ERECTION OF CONSTRUCTIONAL STEELWORK

ILIFFE

ERECTION OF CONSTRUCTIONAL STEELWORK

A TEXTBOOK FOR JUNIOR SITE ENGINEERS AND STUDENTS

STEEL
STRENGTH SECURITY

THOMAS BARRON

Specially prepared for the British Constructional Steelwork Association

This is a revised impression of a practical book on the erection of constructional steelwork specially written for apprentices, students and junior site engineers by an author drawing on his own considerable experience. As with its companion volume, CONSTRUCTIONAL STEELWORK SHOP PRACTICE, its preparation has been supervised by a special committee of the British Constructional Steelwork Association, ensuring that it is authentic in detail yet simple in style.

After describing the general organisation of of a firm specialising in this class of work and the duties of the various personnel, it then discusses various tools and tackle required and how they are employed. The author next deals with the erection of tackle and falsework, and the problems which arise on sites. He then devotes two chapters to the erection of buildings and one to the erection of bridges. The chapter on bolting and riveting has been greatly enlarged to cover the latest methods, including the use of high strength friction grip bolts. Modern methods of welding and flame cutting are then considered. For those aiming at promotion there are important chapters on surveying, estimating and costing, the planning and control of erection work, and the Building Regulations.

All the main points in the text are clearly illustrated by line drawings, photographs and tables. The emphasis throughout is on the practical side of the work and all examples are based on the author's personal experience. Apprentices and students cannot afford to be without this valuable book, for which there is no counterpart in the English language.

247 pages, including 136 text diagrams, plus 20 pages of art plates.

25s net
in UK only

@Seismicisolation

ERECTION OF CONSTRUCTIONAL STEELWORK

A TEXTBOOK FOR
JUNIOR SITE ENGINEERS
AND STUDENTS

THOMAS BARRON
A.M.I. STRUCT.E., A.M.INST.W.

SPECIALLY PREPARED FOR THE BRITISH
CONSTRUCTIONAL STEELWORK ASSOCIATION

LONDON ILIFFE BOOKS LTD

@Seismicisolation

First published 1956
Revised impression 1963

Published for the British Constructional Steelwork Association, Artillery House, Artillery Row, London, S.W.1., by Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1

Printed and bound in England by The Chapel River Press Ltd., Andover, Hants

BKS 4404

CONTENTS

	Preface	7
1	Organisation	1
2	Cranes and Derrick Poles	11
3	Winches, Blocks and Jacks	26
4	Small Tools	38
5	Chains, Ropes and Slings	50
6	Erection of Tackle and False-work	70
7	The Erection of Buildings	87
8	The Erection of Buildings (continued)	101
9	Erection of Bridges	115
10	Bolting and Riveting	136
11	Welding	152
12	Flame-cutting	166
13	Elementary Surveying	176
14	Ancillary Work	196
15	Estimating and Costing	205
16	The Planning and Control of Erection Work	217
17	The Building Regulations	232
	Index	241

@Seismicisolation

PREFACE

THIS book has been written at the request of the British Constructional Steelwork Association and is intended to form a companion volume to their recent publication " Constructional Steelwork Shop Practice ". The aim has been to provide both the young site engineer and the student with a work of reference. With this in mind the subject matter has been kept simple in presentation.

A general description of all tackle, both hand tools and large plant, has been given. Points to watch both in the use and the purchase of these tools have been noted. A study of erection methods for buildings, bridges and other structures follows. Since the previous edition of this book was prepared two important developments have occurred in erection work on site. The use of high strength friction grip bolts has become widespread and the tower crane is now recognised as an important piece of erection tackle. The opportunity has been taken to include material on both these items. Finally there are chapters dealing with subjects associated with erection work such as sheeting, estimating and elementary surveying.

Tabulated information includes such matter as the air consumption of pneumatic tools and the strength of wire ropes and chains. In this respect alone the book should prove useful in the Erection Office. Suggested Tackle Lists for various types of buildings have been prepared and are set out at the end of Chapter 6. Lists for individual operations such as riveting, welding and surveying will be found at the end of the appropriate chapters. Reference to these lists when tackle requirements are being specified should help to prevent the omission of small but none-the-less essential tools.

Foremen and other practical erectors should also find much to interest them. The chapters on surveying, estimating and the costing of erection work will possibly provide much that is new to them. Particular attention should also be given to the final chapter which deals with the safety of erection operations.

Finally I would like to set on record my appreciation of the encouragement and assistance given by the members of the Editing Sub-committee of the B.C.S.A. during the preparation of the work.

MIDDLESBROUGH, 1963 THOMAS BARRON

@Seismicisolation

ACKNOWLEDGEMENTS

The Author is grateful to the following for permission to reproduce illustrations from photographs they have supplied:

A.D.E. Machinery Ltd.

Black & Decker Ltd.

British Oxygen Gases Ltd.

George Cohen & Sons Ltd.

Consolidated Pneumatic Tool Co. Ltd.

Felco Hoists Ltd.

Hadfields Ltd.

Hilger & Watts Ltd.

Holman Bros. Ltd.

Lincoln Electric Co. Ltd.

Murex Welding Processes Ltd.

Herbert Morris Ltd.

North Bar Tool Co. Ltd.

C. Richards & Sons Ltd.

Thomas Smith & Sons Rodley Ltd.

Stringer & Co. (Cradley Heath) Ltd.

Tangyes Ltd.

CHAPTER 1

ORGANIZATION

FIRMS carrying out the erection of steel-framed structures and similar work can be placed roughly under two headings:

(a) Steel fabricators with their own erection staff.
(b) Firms which specialize in steel erection.

The organization necessary to control erection work can conveniently be split into:

(a) Office work.
(b) Supervision of the erection sites.
(c) Operation of the Tackle Stores.

The size of the firm under consideration decides the size of these sections. With a large company the divisions of work between each section will be clear and each unit may operate as a separate entity, but in the smaller firms the Tackle Stores and the Office may be combined and it is possible that the same staff also control the erection work on site.

THE OFFICE

The office of the firm is the nerve centre of the whole organization. From here the entire contract is controlled from the first tentative inquiry to the completion of payment. Estimating, accounting, purchasing of materials, and payment of wages will be the responsibility of staff based at the controlling office, which may also be the headquarters of the erection engineers.

If fabrication work is also undertaken the clerical organization functioning should cover the needs of the Erection Department. When the firm are solely steel erectors then arrangements will have to be made for wages to be paid and the ordering, costing, and invoicing necessary during the course of the contract. The size of the firm and the amount of work carried out will govern the size of each of the departments. In very small firms it is likely that one or two persons will be responsible for the whole of this work.

DRAWING OFFICE

If a drawing office is not already in operation then a small one, possibly with only one draughtsman, will be found very advisable. It will prove invaluable when small additions or alterations have

@Seismicisolation

to be made to existing buildings, and there is often that urgently needed item of tackle that could be drawn out and made economically if the facilities existed.

ESTIMATING DEPARTMENT

In a small firm the Erection Supervisor will himself assess the possible plant and labour costs and add to these an allowance for overheads and profits before handing a rough draft of the tender to an assistant for checking and final typing.

In other cases a separate department will deal with this work. An estimate for erection work cannot always be made by comparison with previous work which may appear to be similar. Thus, in almost every case a complete new estimate has to be drawn up. Many factors will affect the cost of erection. Facilities for the transport of the sections to the site, the availability of adequate plant for the work, and the method of erection of the structure are but a few of the factors that have to be considered. The Erection Supervisor's experience is of great assistance and he should collaborate with the estimators in the preparation of the tender.

ORDER DEPARTMENT

All requirements for the various departments should be purchased through this department. To ensure that the strength, size and performance of the plant is adequate for his needs the Erection Supervisor should be consulted. His approval is necessary as he primarily is responsible for the safety of men, plant and structure.

WAGES DEPARTMENT

It is customary for all men employed to be paid weekly and the money due for any one week is not normally paid until near the end of the week following. This allows time for details of hours worked to be sent in from the sites, for wages to be calculated, and for the appropriate amounts to be despatched. When the sites are scattered over the country considerable time is lost in the course of transmission by post and it is therefore advisable for the foremen to mail all timesheets so that they will reach Head Office not later than by the first post on Monday. The Wages Department should give every priority to the sheets for the distant contracts and, if efficiently organized, there is no reason why the wages calculations on these sheets should not be completed by the Tuesday evening enabling the money to be despatched on the following day.

One of two methods will be employed to send the wages to the sites. Either the wages envelopes will be made up in the office and sent by registered post to the site or else the empty wages

packets will be sent by ordinary post and the total amount due to each site is telegraphed later. This latter method places extra work and responsibility on the foreman as he will have to collect the money in bulk from the Post Office and afterwards split it into the various amounts for each individual packet. This often involves him in handling two or three hundred pounds in ready money on the site and is not recommended for that reason alone.

SUPERVISION OF ERECTION WORK

The whole of the erection work carried out is generally under the control of an Erection Supervisor directly responsible to the management. Through his area engineers and senior foremen this man will control the progress of each individual contract no matter how small or seemingly insignificant.

AREA REPRESENTATIVE

When the firm handles a large amount of work the country is generally split into areas with a representative in charge of the work in each area. Representatives are usually expected to reside in their respective areas and visit each contract at appropriate intervals each week to check that progress is satisfactory and at the same time contact the client or his representatives to ensure that the job is running smoothly. When an inquiry has been received for work within his area the area engineer will often be instructed to visit the site of the proposed works to ascertain the conditions, contact the prospective customer and finally give his idea of the possible erection costs as a guide for the estimator.

SENIOR FOREMEN

Each of these handles one of the larger contracts and is next in rank below the area representatives. Senior foremen must be chosen with great care as they are directly responsible for the running of the contracts and the money involved often amounts to some thousands of pounds.

In addition to being exceedingly capable steel erectors and having the ability to direct labour efficiently, the senior foremen must have a comprehensive knowledge of all the allied processes such as riveting, welding and surveying. Each operation on the erection site must be translated into terms of pounds, shillings and pence so that the money allowed for the site labour costs is carefully budgeted and the size of the squad controlled in relation to the amount of work in hand. The fact that a senior foreman is expected to pay careful attention to the financial aspect does not mean that he should permit shoddy work on a contract he knows

@Seismicisolation

to be running at a loss in an endeavour to make it pay. Incorrect estimating or possibly an unusually long period of inclement weather may be the cause of overspending on the site. Bad workmanship may rescue one contract from financial troubles, but a dissatisfied customer is no advertisement for any firm and the work should never be rushed to the detriment of the finished building.

SITE ENGINEER

On a large contract the site engineer occupies an important rôle. The actual division of control between him and the senior foreman when both are employed on one site is very difficult to define, and therefore they should be picked to work together as a team—one supplementing the other. A rough approximation would be to make the foreman responsible for all lifting arrangements and leave the engineer to deal with the technical work such as lining and levelling of the structure. Thus, with a well-matched engineer and foreman no phase of the work is left without proper supervision. The post of site engineer may provide an opening for a man fresh from the Drawing Office as it offers him an interesting field of practical work which will in time fit him for a higher position in the Erection Department.

JUNIOR FOREMEN

To be certain that his orders are carried out satisfactorily, the senior foreman on a large contract will need the assistance of a number of junior foremen who will each be in charge of a section of the work. These working foremen, as they are sometimes called, will be expected to assist with the actual erection work and not merely act in a supervisory capacity. To assist them in their turn, the junior foremen will have chargehands in control of further smaller sections of the work or individual operations such as bolting-up or scaffolding. On small contracts that do not warrant a senior foreman the junior foreman will be placed in sole charge.

THE TACKLE STORES

SIZE AND LAYOUT

The actual size of the Tackle Stores is, of course, governed by the land available, but when land is being selected for this purpose it should be borne in mind that good road and rail access is essential, even more so than overall size. Many items of tackle handled are of no mean weight or length so that full consideration must be paid to the access roads of the proposed site. Also, as extraordinarily long wagons are required at times, the rail curves should be checked and adjusted if necessary. The subject of layout warrants

more attention than it is usually given, for if the stores are allowed to expand haphazardly in all directions it may eventually be impossible to locate any particular item of tackle at short notice.

Erection tackle is used, and has to be used, in the open and under all weather conditions. This is no reason, though, why all perishable items should not be stored under cover. Greater deterioration is caused to many items of tackle by storage in the open than would occur over a similar period of normal use on the site. With many of the larger pieces of tackle, such as erection masts and the structural parts of cranes, it will be found advantageous to store them so that any particular item can be picked out without disturbing the remainder. This arrangement probably

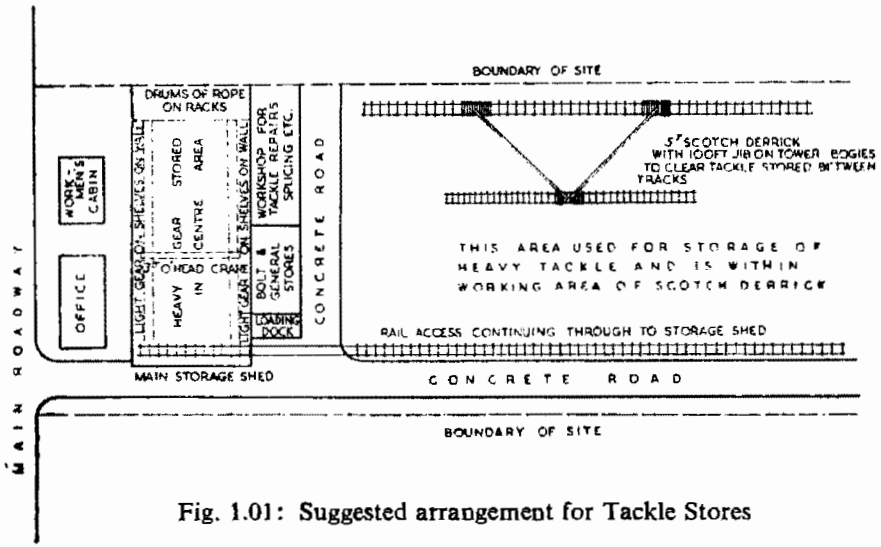


Fig. 1.01: Suggested arrangement for Tackle Stores

means that, even with a moderate amount of heavy tackle, it is not possible to store all the sections within the radius of one stationary crane and therefore a layout with a travelling crane such as suggested in Fig. 1.01 has to be adopted.

A considerable area of under-cover storage space will be required to accommodate wire ropes and chains and it is essential that this area be well served by suitable lifting appliances as these items are often cumbersome and heavy. Wire and rope blocks are best stored by hanging on suitably constructed racks. Light blocks can be stored in the topmost racks and the heavier ones on the lower sections. Other tackle such as jacks, hammers and electric and compressed air machines can be set on shelves around the sides

@Seismicisolation

of this store building. Spanners and drifts can be similarly stored and should be graded into their various sizes and placed in boxes. Hand winches can be stored outside, but again these are best under cover to guard against deterioration. Similar considerations apply to crane machinery and, in particular, to the electrical components.

The arrangement suggested in Fig. 1.01 may be too ambitious for adoption by a small firm but, with careful planning, similar results can be obtained irrespective of the size of the stores concerned. It will be noted that a loading platform has been incorporated with the covered shed to allow bolts and sundry stores to be handled at a comfortable height.

CHOICE OF FOREMAN AND LABOUR

When tackle is being sorted, checked and despatched at the beginning of a large contract, the Tackle Stores will be a very busy place indeed. Between such times there will be numerous quiet periods, and these have to be spent on the fabrication of new plant and the maintenance of that already in stock. Scraping and repainting will occupy a considerable portion of this time but the care of the mechanical items should not be forgotten for they must always be kept in excellent condition so that they can be guaranteed to function if called for at a moment's notice, as is often the case.

The above briefly illustrates the scope of work carried out at the Tackle Stores and the labour force must be chosen accordingly. One or two erectors or slingers will be required to handle in-coming and out-going tackle. These men must be prepared to turn their hands to painting and other odd jobs when their normal work is slack. An experienced plant fitter will be required to overhaul and repair such things as crane machinery, engine-driven winches, compressors, and mechanical tools. A useful asset to the work of the Tackle Stores would be a handyman able to burn and weld. Such a man can always be kept fully employed either repairing and renewing existing tackle or else fabricating new plant from drawings furnished by the erection engineers.

The sites often require at very short notice special sizes and types of wire slings to handle awkward lifts, which constantly arise. Unless the making of these can be contracted out to a firm that can guarantee to complete the work rapidly at a reasonable cost, the work must be done at the Tackle Stores. Often this will prove to be a full-time occupation for one man. An experienced sailor can usually be found to fill this position and he is likely to be able to carry out the work efficiently.

The foreman who is to take charge of the Tackle Stores must be a fully experienced steel erector so that he understands the tackle

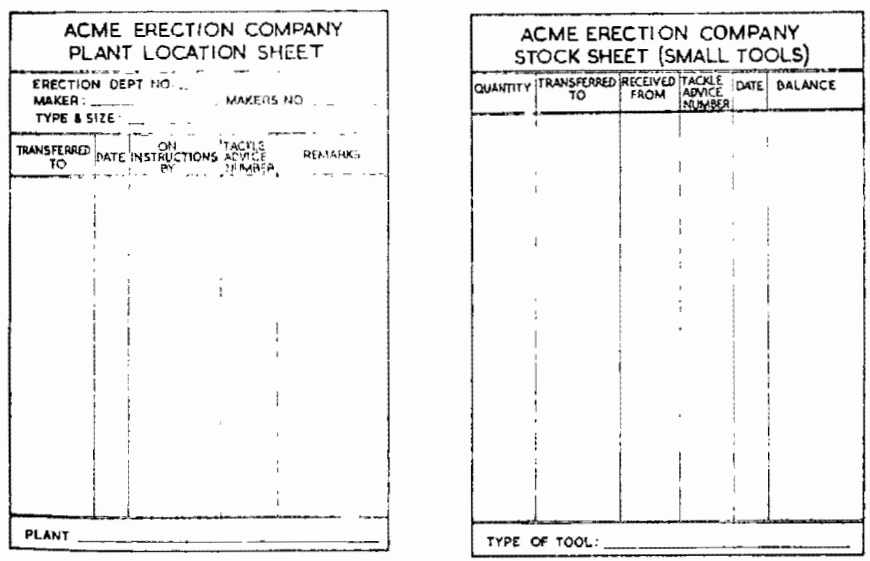
he is handling. He should also have sufficient knowledge of the operations mentioned above to be able to satisfy himself that the standard of work attained is satisfactory.

Each site foreman is in charge of the tackle on his own site but, while not in any way relieving the site foreman of his responsibility, the tackle foreman should be made responsible for the condition of the tackle as a whole. The annual stock-taking is best carried out by the tackle foreman or his assistant, who should visit each site in turn for this purpose. This must not be taken to imply that the site foremen are not to be trusted to do their own stock-taking, but rather that their time is valuable and is better spent supervising the erection work. Throughout the year the tackle foreman should pay periodic visits to the sites to check the condition of the gear on each and order replacements if necessary.

When tackle is returned from a site it should be checked immediately it is received. If it has to be repaired or reconditioned this should be done at once, so that it is available for use when it is next required.

RECORDS TO BE KEPT

Accurate records of all plant, whether large or small, are important for the proper functioning of the Erection Department as a whole.


ACME ERECTION COMPANY
PLANT LOCATION SHEET

ERECTION DEPT NO. ..
MAKER: ..... MAKERS NO. ..
TYPE & SIZE: ..

TRANSFERRED TO	DATE	ON INSTRUCTIONS BY	TACKLE ADVICE NUMBER	REMARKS

PLANT .....

ACME ERECTION COMPANY
STOCK SHEET (SMALL TOOLS)

QUANTITY	TRANSFERRED TO	RECEIVED FROM	TACKLE ADVICE NUMBER	DATE	BALANCE

TYPE OF TOOL: .....

Fig. 1.02 (a): Plant record forms for erection tackle

In addition, the Factories Acts and Building Regulations require that a careful check is kept of the inspection and condition of all lifting

@Seismicisolation

and mechanical equipment. Chapter 17 lists these requirements in more detail.

It is recommended that the method chosen be such that the position of any item of plant can be seen at a glance and that the total plant on each site can be readily found. The forms suitable for a satisfactory system are shown in Fig. 1.02 (a) and (b). This system requires that the main records be kept at the office and not at the Tackle Stores as, owing to the vital importance of accurate records, it is essential that the records be kept up to date

ACME ERECTION COMPANY
ADVICE OF TRANSFER OF TACKLE

DATE. _____ JOB NO. ____
SHEET NO. ____

TO THE ERECTION DEPT.
PLEASE BE ADVISED THAT
THE UNDERMENTIONED TACKLE HAS BEEN
TRANSFERRED FROM _____ SITE
TO _____ SITE
IN LORRY/TRUCK NOS.

QUANTITY	DESCRIPTION	PLANT NO. (IF ANY)
	SIGNED	FOREMAN

ACME ERECTION COMPANY
SITE TACKLE SHEET

SITE _____
JOB _____ SHEET NO. _____

DESCRIPTION	QUAN	RECEIVED FROM	DESPATCHED TO	ADVICE NO	DATE	REMARKS
			CONTINUED ON SHEET NO.			

Fig. 1.02 (b): Record forms for plant at individual sites

by an experienced clerk. Except in the case of large stores, it is unlikely that this record-keeping will be a full-time occupation.

As the forms show, the main items of tackle comprising cranes, crane bogies, lattice derricks, and winches are allocated numbers and their movements are kept up to date on a special form. For the smaller hand-tools the stock sheet illustrated will be sufficient to follow the movements and will also show when stocks are low and reordering becomes necessary. The special Tackle Advice Note is advisable and each note should be in quadruplicate; the copies being distributed as under:

One copy to Head Office.
Two copies to tackle destination.
One copy retained on site.

Different colours should preferably be used for each sheet so that

its use can be easily seen. On receipt of the Tackle Advice Note at Head Office, the new location of the tackle is duly noted. One of the two copies of the advice note sent to the tackle destination has to be signed and sent to Head Office as a check that the movement has been made satisfactorily; any discrepancy between this and the copy originally sent to Head Office should be investigated immediately. A special form is also kept for each site listing the full complement of plant and tools on that site. Movements of tackle to and from the site are noted and the insertion of the number of the Tackle Advice Note enables this to be carefully followed and checked.

To enable tackle to be quickly chosen for any individual job the relevant details of all the larger items of plant should be collected

CRANE DATA SHEET.

TYPE OF CRANE. _____
ERECTION DEPT NO. _____ MAKERS NO. ____

PERFORMANCE
_____ TONS AT _____ RADIUS _____ HEADROOM
_____ TONS AT _____ RADIUS _____ HEADROOM
_____ TONS AT _____ RADIUS _____ HEADROOM
MINIMUM RADIUS _____ FEET

SIZES & WEIGHTS

ITEM	LENGTH	NO. OF PTS	LONGEST PT.	TOTAL WT.
JIBS				
MASTS				
LEGS				
SLEEPERS				

TOTAL WEIGHT OF CRANE: _____

	LENGTH	DIAM.	CONSTRUCTION	ENDS
HOIST ROPE				
DERRICKING ROPE				

POWER UNIT
MOTOR. _____ A.C. OR D.C. _____
MAKER: _____ MAKER'S NO. _____
H.P. _____ VOLTS: _____ PHASE: _____ CYCLES: _____

BALLAST REQUIRED ON EACH LEG: _____

REMARKS.

Fig. 1.03: Plant data sheet

and set out on forms such as shown in Fig. 1.03. Each piece of plant is given a number and the quoting of this number should be sufficient indication of what is required. It will be seen that, as well as showing the performance and mechanical particulars, the

@Seismicisolation

form gives the size and weight of all the main sections, which enables transport to be quickly chosen. As new plant is bought or hired, further sheets will be made out and additional plant numbers allocated accordingly. It is advisable to use the prefix " H " against the plant number of any hired tackle to indicate its origin. Any alterations made to the tackle can be noted on this form and there is space on the back of it where details of the inspections can be entered.

A word on the ordering of spares would be appropriate here. Complete drawings of all plant, together with the maker's handbooks, are necessary and when spares are ordered the maker's plant number and spare part number should always be quoted. Failure to do so gives rise to the possibility of errors occuring during transmission of the order.

CHAPTER 2

CRANES AND DERRICK POLES

VERY little present-day erection work would be possible without the use of some kind of lifting machinery or gearing. The choice of lifting equipment before the modern erector varies from a wooden pole and rope blocks capable of lifting a few hundredweights to the heavy scotch derrick with a capacity of fifty tons. It quite often happens that while one particular type of equipment is ideally suited for the erection of one job, one or more of the others may be used to give the same results. When choosing lifting tackle for any individual job of work, the plant available will therefore have to be considered as well as the type of structure, loads to be lifted and site conditions. Some guidance on the choice of lifting equipment for different jobs is given in Chapters 7, 8, and 9.

It must be clearly understood here that the following descriptions are generalizations only, as each manufacturer builds to his own designs and therefore the details will vary somewhat.

POWER-DRIVEN SCOTCH DERRICKS

(*a*) *Sizes and capacities*

Specially designed scotch derrick cranes can be manufactured to suit any individual requirements, but as the standard models from the various makers range in capacity from 3 to 50 tons, with jib lengths from 60 to 120 ft, it is only occasionally that purpose-made cranes are required. A jib length of 120 ft will be found to be ample for the normal range. The maximum load that can be lifted by any crane of the scotch derrick class can generally be handled at a radius equal to 75 per cent of the jib length, which in the case of the crane with a 120-ft jib gives the very useful working radius of 90 ft. The " jib length " is taken as the distance from the pin at the bottom of the jib to the pin carrying the hoist rope sheave at the jib-head. The sizes of the other main structural components of the crane, such as the mast and legs, will vary in proportion.

(*b*) *Types of power*

Scotch derrick cranes may have either a steam-engine or electric drive. It is only occasionally that work has to be undertaken on sites where electric power is not available and therefore, considering

@Seismicisolation

the general convenience of electricity, it is not surprising that very few steam cranes are now to be seen on erection sites.

The older types of electrically driven derricks were merely adaptions of steam cranes in which an electric motor replaced the steam engine and most of the gearing remained unchanged. Later, designs based on the use of electrical machinery only were developed and the latest patterns are very efficient. Better visibility for the driver is now given the attention it requires and, whereas at one time he was placed behind the gearing and had to sight through it to see the load or his banksman, he is now positioned at the side of the cab, which is provided with large windows to give him an unrestricted view of the hook in all its positions.

(c) *Principal parts*

A typical model of a scotch derrick crane is illustrated in Fig. 2.01, which also gives the names of the principal parts.

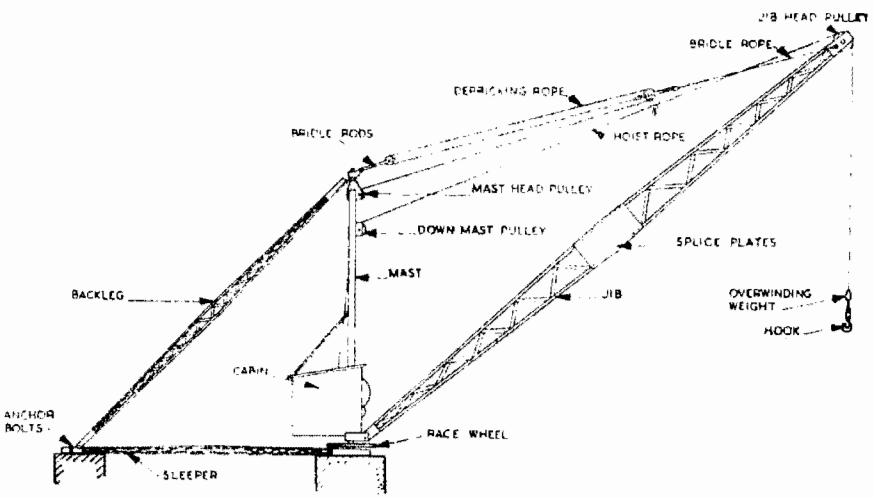


Fig. 2.01: Arrangement drawing of a typical power-driven scotch derrick crane

Different districts sometimes use names other than those shown, but those listed can be taken as the most common.

(d) *Description of gearing*

An electrically driven derrick crane may be powered by one or two motors. In the latter case the additional motor is used to drive the slewing gear direct and is usually fitted to the heavier models or to cranes with exceptionally long jibs. On the single

motor type the slewing is operated by the hoist motor through a cone clutch.

Two hoisting speeds are usually made available—the higher one being intended for light loads only. The lower hoisting ratio is brought into operation by additional gearing and must be used when loads anywhere approaching the maximum are being lifted. The crane makers always furnish particulars of the maximum loads which can be lifted at each hoisting speed.

Derricking of the jib is operated by engaging a sliding clutch which works on one of the shafts of the hoisting gear. When this clutch is engaged, the derricking drum is driven by the hoisting motor and the jib can be raised or lowered as necessary. Operation of the derricking gear is governed by a special interlocking device which prevents any mistakes in its handling by the crane driver. The fitting of this device is compulsory under the Factories Acts.

For perfect operation, when the jib is being raised or lowered the hook should travel in a horizontal line, and on the best cranes the gearing is designed to fulfil this condition. This requirement is necessary to enable loads to be placed accurately and with ease.

It is customary to fit two main brakes. One is foot-operated and controls the hoisting and derricking motions. The other is worked by a hand-wheel and is used on the slewing gear to prevent the crane from slewing round under the force of the wind.

(e) *General*

A description of the types of rope used on cranes will be found in Chapter 5, and details of their sizes and strengths are given in Table 5.01 in the same chapter.

The outer ends of the sleepers of the crane have to be ballasted or anchored, as shown, to prevent the crane from overturning. This can be done with any convenient material and weights of the usual materials employed for this purpose are given in Table 2.01. If there is any doubt about the weight to be used, the makers of the crane should be consulted. An approximate rule is to use as ballast on each leg a weight equivalent to three times the safe working load of the crane.

HAND-OPERATED SCOTCH DERRICK CRANES

Standard sizes of hand-operated derrick cranes are available designed to lift loads of up to 5 tons. Usually the jibs of these cranes do not exceed 60 ft in length. The structural components of a hand-operated crane are known by the same names as those of its powered counterpart, and the hoisting and derricking gear is arranged on the mast in a similar fashion to that of the older types

@Seismicisolation

Table 2.01. WEIGHTS OF COMMONLY USED BALLASTING MATERIALS

Material	Weight in lb/cu ft	
Concrete with gravel aggregate	144	
Granite	165	
Sandstone	140	
Sand	100	
Cast iron	462	
Cast steel	489	
Brickwork	120	
Water	62·5	
Bricks (wirecut)		7 lb each
,, (pressed)		8–9 lb each

of electrically driven cranes described above. Slewing gear operated by a hand-wheel and direct gearing is occasionally fitted to hand cranes. When this is not done, hand-lines will have to be tied to the jib and used to control the slewing.

A number of hand cranes have been fitted with electric motors or other forms of power. These conversions only drive the hoisting and derricking motions and usually the load rating is reduced by 25 per cent. Nevertheless, converted cranes will be found very useful as they are smaller and lighter than the standard powered

Table 2.02. HEADROOM IN FEET WITH STATED JIB LENGTHS AT VARYING RADII*

Length of jib in ft	Radius of lift in ft									
	10	20	30	40	50	60	70	80	90	100
120	119	118	116	113	109	104	98	90	77	66
110	109	108	106	102	98	92	85	75	63	—
100	99	98	95	91	86	80	71	60	—	—
90	89	87	84	80	75	67	56	—	—	—
80	79	77	74	69	62	53	39	—	—	—
70	69	67	63	57	49	36	—	—	—	—
60	59	56	53	44	30	—	—	—	—	—
50	49	45	40	30	—	—	—	—	—	—

* To the above readings *add* height of jib bottom pin above ground level and *subtract* height lost due to hook and/or return block.

cranes and are naturally much faster in operation than the hand crane.

GUY DERRICK CRANES

This is basically a lattice steel derrick fitted with a jib. This lattice derrick section is termed the mast of the crane and is guyed at the head. Seven guys are normally used. For certain classes of work the guy derrick is an extremely useful tool as the mast and jib are so arranged that one can be used to lift the other. No additional tackle is thus necessary to lift the crane to a higher level.

Guy derrick cranes are usually obtained for working loads of 5 tons and above. The standard jib length is 100 ft but both the jib

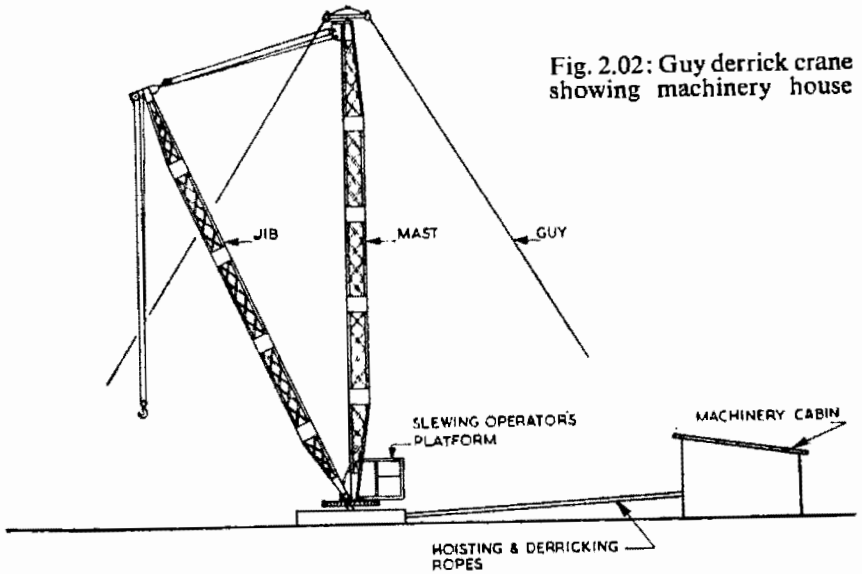


Fig. 2.02: Guy derrick crane showing machinery house

and mast are so constructed that the lengths can be increased or decreased. To slew the jib past the guys, it has to be derricked up until it fits snugly against the mast. The latter is slightly longer than the jib so that the jib passes under the guys. With no back legs to foul, the jib can thus swing a full circle and erect everything within its reach.

The mast and the jib rest on a specially constructed footblock which is an essential part of the crane. The hoisting and derricking ropes run through this footblock and pass over sheaves which direct them to the motor drums. The machinery of the guy derrick is not mounted on the crane structure itself but is carried on a special separate machinery platform. This platform and the footblock will have to be so located that the ropes will run evenly from one to the

@Seismicisolation

other. The motor platform is provided with shackling points at the rear so that it can be tied back to an anchorage.

The rigging of a guy derrick crane can be seen from Fig. 2.02. The hoisting rope does not lift the load direct but passes through a set of blocks hanging from the jib head. The lead line passes along the jib and through the footblock. The derricking of the jib is also controlled through blocks very similar in pattern. These run from jib head to mast head. When the guy derrick is raised, these blocks are used to lift the jib to the higher level.

Slewing of the guy derrick is usually effected by hand-operated gearing at the foot of the mast. When the crane is working, members of the erection squad are stationed here on a small platform to work this slewing gear and also to act as banksmen and give instructions to the crane driver. On some large guy derricks hand-operated gearing is replaced by a " bullring " which is a circular channel, of about 15-ft diameter, suspended from the mast with its axis on the centre line of the mast pivot. An endless wire passes twice round this and returns to a drum on the machinery platform. By working this wire the jib is slewed. A race wheel and pinion driven by a separate motor are also used occasionally.

The guys steadying the mast have to be securely anchored, and anchorages are provided by specially prepared " deadmen " anchor pins in the concrete foundations, or by tying to the completed section of the structure. A quantity of old rails or sleepers buried in the ground is termed a " deadman " anchorage.

THE DERRICK POLE

This is a guyed steel or timber pole with blocks hung from a point as near the top as possible. The lead from these blocks is taken through a snatch at the foot of the pole to a winch situated some distance away. The " reach " of a pole is negligible and it therefore has to be moved to give a vertical lift at each position.

When the pole is used on soft ground, timber has to be placed under it to spread the load otherwise it would tend to sink when loaded. If the pole has only to be moved a short distance this movement can be made with the pole still in a vertical position. A path of timbers will ease the work of moving the foot. The guys must be continually adjusted to keep the pole vertical. Because of the increased loads that can be expected the lattice-steel derrick pole is usually provided with a special footblock.

(*a*) *Timber poles*

These are now rarely used except for light lifts and the rearing of the heavier steel tackle. The guys are tied directly to the head

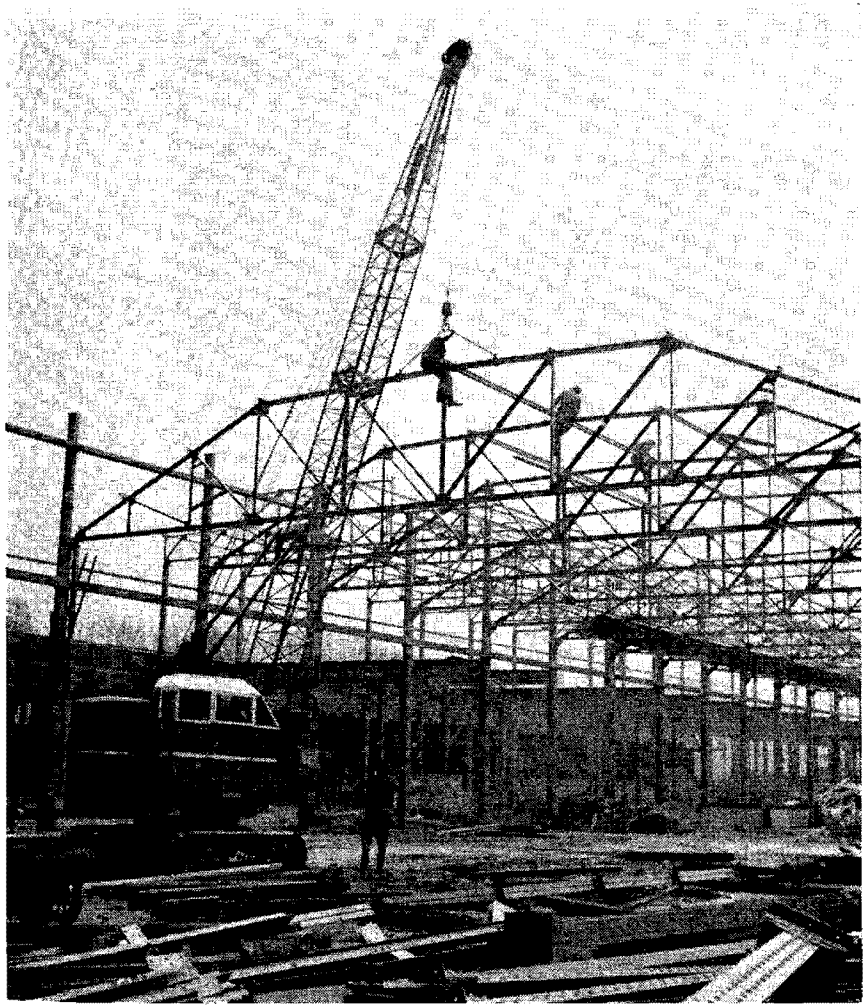


Plate 2.01: Mobile crane equipped with crawler tracks

@Seismicisolation

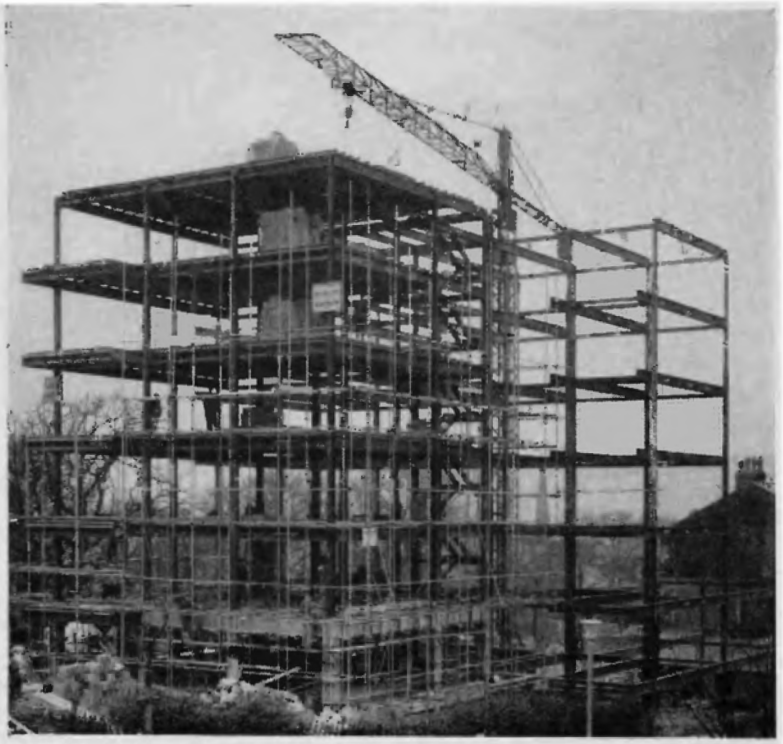


Plate 2.02: Tower crane

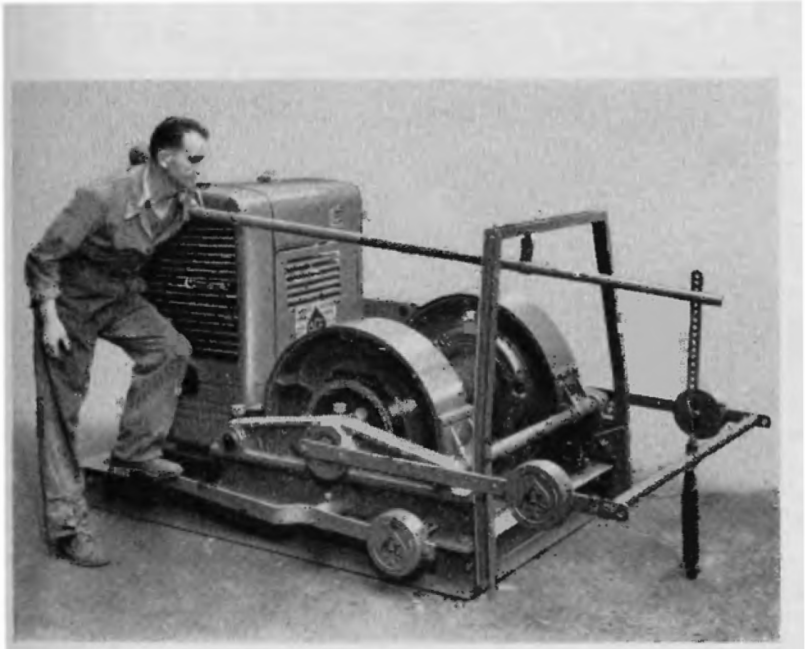


Plate 3.01: Diesel-engined power winch

@Seismicisolation

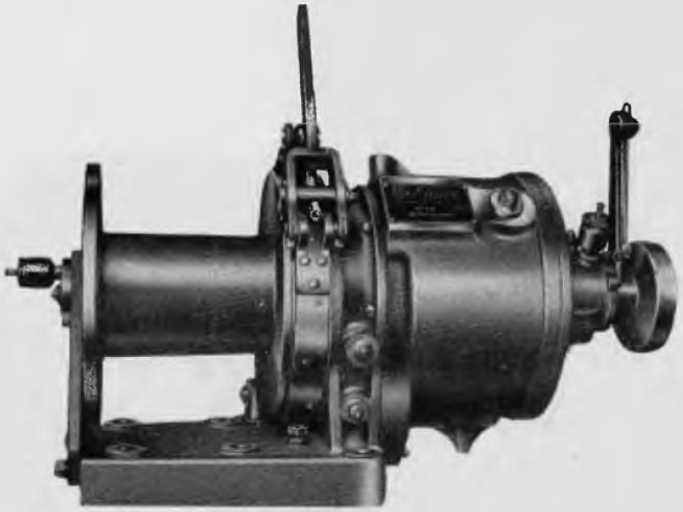


Plate 3.02: Small compressed-air operated winch

Plate 3.03: Ratchet jack showing the two positions for the handle

of the pole and the tackle is suspended in a sling just below this point. As can be seen from the drawing, a piece of timber about four inches square, called a crosshead, is lashed to the pole to hold the blocks clear of the pole itself. This timber can be seen in Fig. 2.03.

All but the largest of timber poles can be reared by hand. The blocks must be slung in position before the pole is lifted and, if

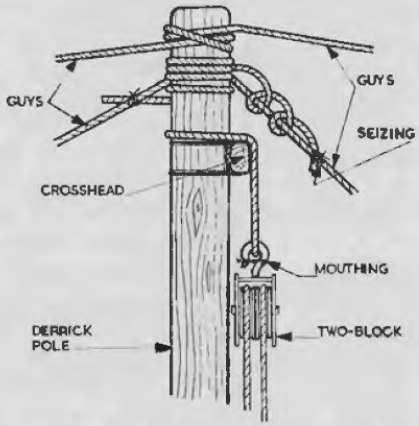


Fig. 2.03: Crosshead on a timber derrick pole

they are not too heavy, they can be fastened in position ready for the first lift. Heavy blocks may make the pole cumbersome to rear and in this case they can be drawn block to block and hauled down after the pole is reared. Do not forget to tie a hand-line to the bottom block so that this can be done—otherwise someone will have to shin up the pole before the blocks can be pulled down.

(*b*) *Steel derrick poles*

The length of these steel derricks may reach 100 ft or more and they can be designed to cope with any lift likely to be met in construction work. The steel derrick is usually fabricated from angle sections or tubes laced together with steel flats or lighter angle sections, although in some cases the whole of one side may be of steel plate construction. The face of the derrick, that is, the side on which the lift is made, should be as free from obstructions as possible and all bolts and rivets should be countersunk, otherwise the load being lifted may lodge against something at a critical moment and cause bad language and hot tempers. Some lattice derricks dismantle into sections of about 15 or 20 ft for convenience in

@Seismicisolation

handling during transit. All the centre sections will be identical, so that derricks can be built up to the required length.

The guys for the steel derrick are fastened by shackles to a circular steel plate, called the " spider plate ", which is fastened to the head of the mast by a steel pin on which it is free to revolve. Thus it is possible to slew the derrick and tackle to suit the lift without

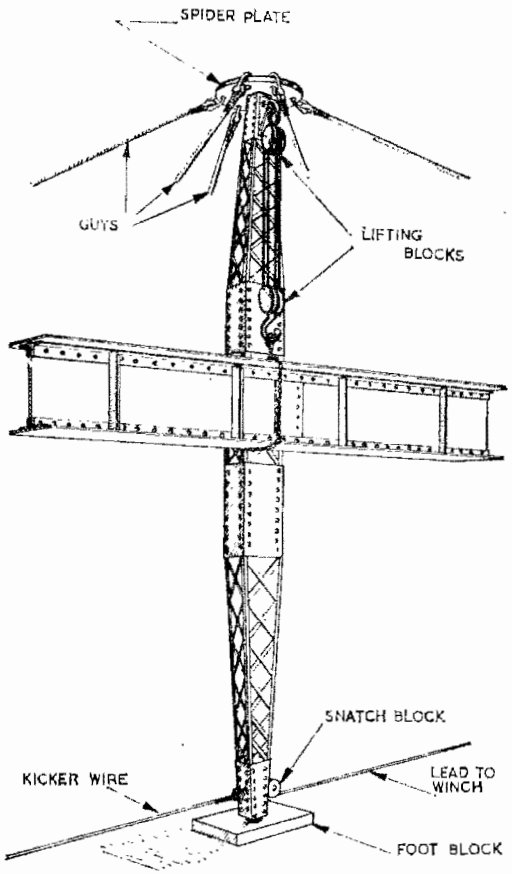


Fig. 2.04: Lattice steel derrick with footblock

the necessity of moving the guys. The spider plate must be inspected frequently to ensure that it is revolving freely and not jammed.

When lifting a load, the derrick should not be moved or sheered more than few degrees out of the vertical as there is a danger of the foot of the derrick kicking out of position. To prevent this, a wire, called a " kicker ", is tied to the foot so that it holds the derrick firm. A similar wire is also used to resist the pull from the lead line. If definite arrangements have to be made to sheer the

derrick before the load can be placed, a winch fitted to the guy which will be carrying the weight will prove advantageous, for the wire can then be slackened as required.

The footblock is shown in Fig. 2.04. It consists of a joist spreader frame with a dished circular plate. A short timber baulk fits into a pocket at the foot of the derrick and is shaped so that it bears evenly on the dished plate.

Each derrick should be clearly marked with its safe working load for the various assemblies that may be made up. Safe working loads decrease rapidly with height, as this increases the slenderness of the derrick. When calculating the loads on a derrick, reference should be made to Table 3.01 in Chapter 3. This shows the need to make allowance for the pull in the lead line from the top block which, in effect, increases the load on the derrick. It will be noticed that, in the case of a derrick lifting a load with a single block at the top, the actual load on the derrick is over 100 per cent more than the weight being lifted.

Thus, when lifting 1 ton 6 cwt with a single block, the load on the slinging point is 1 ton 6 cwt + 1 ton 8 cwt = 2 tons 14 cwt.

The lead line from the top block passes through a snatch to the winch or other hoisting appliance. This tends to pull the foot of the derrick towards the winch, and it is essential that the foot is securely anchored by a " kicker " wire. On no account should the snatch block be fastened to the derrick in any place other than its proper position at the foot. If the snatch block is tied to the derrick above the foot, it throws a severe bending force on the derrick. This force may be sufficient to cripple the mast with a load far less than the safe working load. If it proves impossible to lead the wire from the usual place, then the snatch should be anchored to something other than the derrick mast. The lead line from the blocks on the derrick must always be brought down in line with the mast and not lead off at an angle, as this tends to pull the derrick over.

SHEER LEGS

These can be considered a modification of the derrick pole. Two poles are used and they are lashed together at their tops and the bottoms opened out until they form an angle of about 20°. Side guys are not usually necessary; guys only being placed to the front and rear. The lifting blocks are hung from the point where the poles intersect and the leads, snatches, and winch used as for the ordinary derrick pole.

It is only seldom that sheer legs are specially fabricated for it is more usual to assemble them on the site as required. They will

@Seismicisolation

be found extremely useful when material has to be hoisted through a hole or from an excavation or when bulky items have to be loaded or unloaded from lorries. The arrangement of the poles enables the lorry to run directly under the blocks and, after the load has

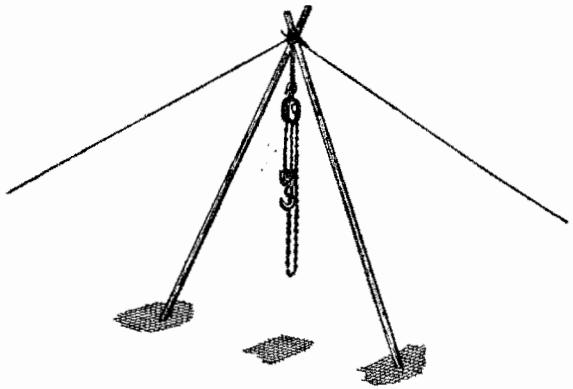


Fig. 2.05: Wooden sheer legs with suspended chain blocks

been lifted clear, the lorry can be driven away and the load lowered to the ground. Chain blocks are useful accessories to a set of sheer legs. Occasionally a single wire to a winch is used for the handling of light loads. In this instance, care must be taken that the snatch block, if fastened to one leg, does not cause overturning.

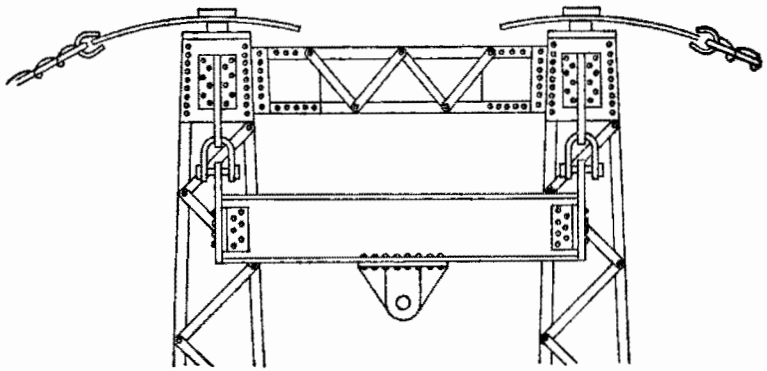


Fig. 2.06: Lattice steel " A-frame "

LATTICE STEEL A-FRAMES

A bulky object lifted with a standard lattice derrick will tend to drag against the face of the derrick. This dragging tendency is more noticeable the higher the object is lifted, and it increases the pull

on the winch, which is dangerous as the load can easily jam. It also increases the bending stress on the derrick.

If such a lift has to be made, it is advisable to use an A-frame constructed from two lattice derricks. Fig. 2.06 shows how modifications have been made to two standard derricks to make them fit this purpose. A latticed strut has been fabricated and bolted between the heads of the two derricks. Existing rivets have been removed, and guys from spider plates on the derricks are led off to the front, back and sides. A lifting beam is used so that the load is spread evenly between the two derricks. It is hung from the permanent lifting shackles of the derricks.

GOLIATH CRANES

Although often used in stocking grounds in factories and works, this crane (Fig. 2.07) is only seldom found on construction sites. On a large contract, or where it is necessary to store a large

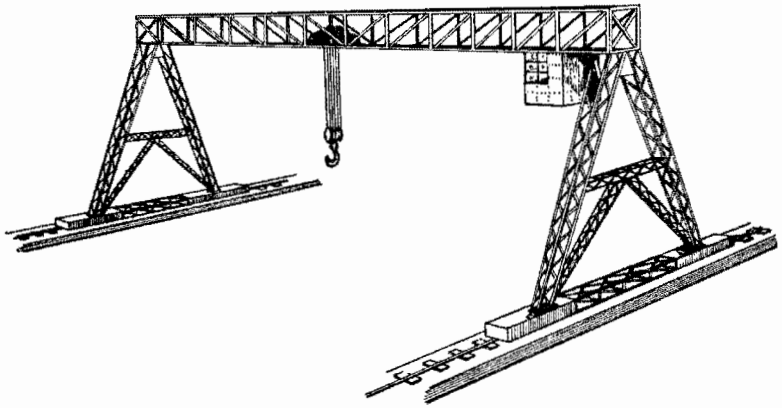


Fig. 2.07: Goliath crane

quantity of steel before erection commences, it would certainly be advisable to consider the use of a goliath crane to span the proposed stockyard. Two or three rail sidings could be covered, depending upon the size of the crane, and as the goliath can move under its own power, the area of the stocking ground would only be governed by the length available. A goliath of special design could be used for the construction of a truss or plate girder span bridge and thus enable every inch of the bridge to be fully covered.

LOCOMOTIVE CRANES

If work is carried out in an existing industrial plant and a locomotive crane is to hand, it could be used to advantage on

@Seismicisolation

certain classes of structures provided that the track is in a suitable position. Under other conditions freight charges and the difficulty of moving the crane to the site will usually outweigh its advantages.

The older locomotive cranes were nearly all of the steam-driven type but modern ones are now available with diesel engines. Lifting capacities range up to 50 tons and the jibs may be 60 ft or longer. In most cases extensions to the jibs can be supplied which will carry a light lifting line and enable small loads to be handled at a larger radius than is possible normally. The jib can be swung in a complete circle and therefore loads can be lifted in any direction.

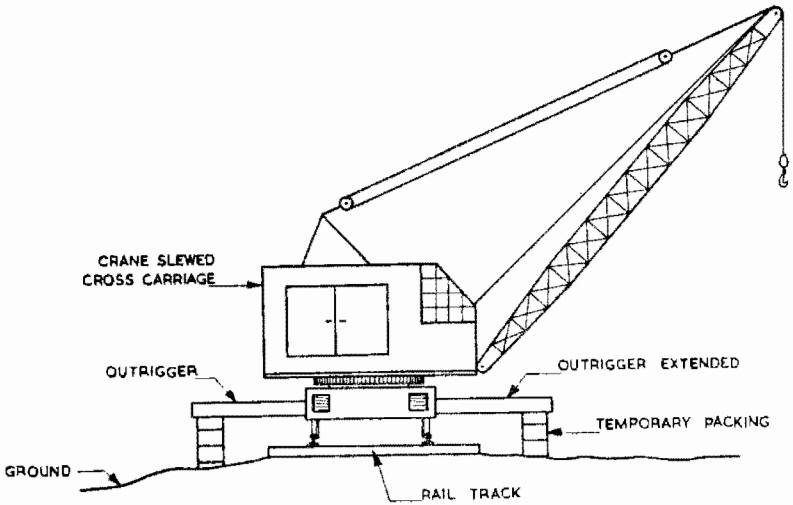


Fig. 2.08: Outriggers of a locomotive crane in use

The weakest lifting point is at right angles to the track, and to prevent the crane from overturning when heavy loads are being lifted from this direction, beams, called outriggers, can be drawn from the side of the crane carriage and packed up from the ground as shown in Fig. 2.08.

MOBILE CRANES

Within recent years the mobile crane has come to be recognized as a very useful piece of erection equipment (Plate 2.01). Development of the present types of mobile crane has been along three lines. There are cranes developed from the dragline or excavator, adaptations from locomotive cranes, and the machine built solely as a mobile crane. Machines such as the mechanical excavator are naturally designed for different usage conditions from the true erecting crane and, generally, conversions of these are not the best all-round cranes for steelwork erection. A machine which is either an

adaptation of the locomotive crane or has been specially designed as a mobile crane should preferably be obtained for erection work.

For almost any work within its reach and capacity the mobile crane will be found to be more than suited. Even if the crane has to be hired, it will sometimes be found that its speed and mobility offsets this additional cost. An erection squad may spend a week or more erecting and ballasting a scotch derrick crane and almost the same length of time dismantling it at the end of the contract. A mobile crane is available for use immediately on arrival at the site and, when its work is completed, no more than an hour or so is expended loading it on to the special carriers which transport it from site to site. This saving of time, more noticeable of course on a small contract than on a large one, reflects beneficially on the cost of the work and gives the client an excellent impression of the efficiency of the erection squad.

Most mobile cranes are available equipped with solid rubber tyres, or pneumatic tyres with restrictor rings, or crawler tracks. Restrictor rings are flanged circular plates bolted to the standard road wheels, so that under excessive loads they come into contact with the ground and relieve the tyres, thus steadying the crane. Pneumatic or solid rubber tyres can be a disadvantage when uneven or very soft ground is encountered, but a crane so equipped is very mobile and can travel from site to site under its own power. Outriggers should be used for heavy lifts.

The mobile crane on crawler tracks has all the advantages of the locomotive crane with the additional one that no track is required for operation. Crawler tracks make the crane very stable and suitable for use on poor ground. Mobile cranes cannot travel very fast and, although this is not a disadvantage on the site, special transporters are needed to move them from site to site.

Two systems of powering these cranes are employed in general practice. The first and most common is the direct use of a single diesel engine with the drives for the various operations taken off through hand- and foot-operated clutches. The directness and simplicity of this method makes a sturdy machine that is easily maintained. The alternative method of operation is to employ a single diesel engine to drive an electric generator. This combination is designed so that the output of the generator varies at the same rate as the motor speed. Separate electric motors for the different crane motions can be coupled to the generator as required, and the speed at which the operation is effected is then governed by the engine speed, which in turn can be adjusted by a throttle control in the driver's cab. When the current is cut off from the motors, electromagnetic brakes are brought into operation.

@Seismicisolation

TOWER CRANES

During recent years an interesting piece of erection plant has been used on many constructional sites. This is the tower crane of which many variations are now available. Designed originally for use on multi-storied constructions the tower crane is now used extensively on all types of construction work.

Basically the tower crane consists of a vertical mast at the head of which rotates a horizontal, or nearly horizontal, jib counterbalanced by ballast slung from a rearward extension of this jib, or alternatively by anchor ropes which pass over a pivot arm at the head of the mast and then down to ballast at ground level. A tower crane at work is shown in Plate 2.02.

The main advantages of this type of crane are that with a mast of sufficient height the jib can swing over the full structure under erection and, as the jib slews through a full 360°, material can be handled to and from any position within the working radius of the crane. Generally the driver's cab is mounted high on the mast so that he has an excellent view of all operations and a banksman is seldom necessary. To give equivalent operational service the traditional scotch derrick crane would have to be mounted on high trestles, which are both expensive and slow to be built, and in use the working area is restricted to approximately 270°.

The capacities of tower cranes as at present available compare favourably with those of scotch derrick cranes. Lifting capacities range from a few hundredweights to over 15 tons and jib reaches extend up to 164 ft. The safe working load of course decreases as the radius of the lift is increased but, even so, some models can lift over 2 tons at 164-ft radius. The height of the mast can be as great as 400 ft although cranes of such size are not free-standing but have to be tied in at intervals to the structure under construction.

There are three basic types of tower crane—static, rail-mounted and climbing. The static tower crane is set up in a selected position from which it can sweep the full required working area. For the larger cranes careful preparation of the ground may be necessary but frequently it is possible to select a suitable part of the permanent foundation work. The rail-mounted crane, as the name implies, can be arranged to travel and is thus advantageous where the work would be beyond the reach of a stationary crane. Each manufacturer has his own specifications but generally these rail-mounted cranes are designed to run on a track of about 10-ft gauge and can negotiate comparatively tight curves so that they are very versatile and take up the minimum of space. Often the wheel mountings are designed so that the crane can readily be transferred to other track running at right angles to the original.

@Seismicisolation

All tower cranes are virtually self erecting and the climbing crane can increase its height by hauling itself up the completed structure of the building (for example up the lift shaft), or by assembling further sections round its mast and then hauling itself to the top of this addition. By this means cranes can be extended up to any required height although, as noted above, it may be necessary to tie the mast to the structure at intervals. The manufacturer will be able to give advice on this procedure but any additional stresses on the building should be carefully studied and due precautions taken if necessary.

Erection times for all types of tower crane are very comparable with those for scotch derrick cranes and, if it would be necessary to erect the scotch derrick crane on trestles, then the erection of the tower crane should be both a quicker and cheaper operation. The tower crane is frequently positioned in the centre of the structure as it takes up such a comparatively small area and, when its work on site is complete, it is easily dismantled into small sections which can be lowered down and removed without much difficulty.

CHAPTER 3

WINCHES, BLOCKS AND JACKS

WINCHES

HAND WINCHES

STANDARD sizes of hand winches range from 1-ton to 5-ton direct pull. This listed capacity is the safe working load for a direct pull by the wire from the drum and will be stamped on the maker's name plate which is usually attached to the main side plates. The effect of the direct pull from the winch can, of course, be increased by reeving the lead through a set of blocks.

It is safe to say that the uses of the hand winch are many and varied and no site should be without one. In the absence of other forms of power, they are used in conjunction with derrick poles for lifting and can also be employed for hauling heavy loads along the ground. The lead from a winch should always be taken off horizontally as it is not usually possible to anchor a winch satisfactorily to withstand a pull in any but a horizontal direction. If it is necessary to change the direction of the pull, a suitably sized snatch block will have to be used.

The normal pattern of hand winch consists basically of two steel side plates bolted to channel bearers, with the barrel and gears contained between the side plates, and the shafts for the handles projecting from them. Hand winches may be classed as either single- or double-geared depending upon the arrangement of the gearing. Triple-gearing is occasionally fitted to the larger size of winches. On the double-geared winch a layshaft with additional gears is utilized to give an alternative and lower gear so that heavier loads can be hauled with greater ease. The gears are changed by sliding the layshaft along until the required pinions are engaged; and gears should be fitted with guards.

To enable the wire to be paid out rapidly, most winches can be thrown out of gear leaving the barrel free to revolve. A pawl, which can be released if necessary, is fitted and works on a ratchet on the barrel preventing the latter from running backwards under load. Each winch is fitted with a hand brake, operated by either a lever or a wheel, which must be capable of sustaining the full working load of the winch. Heavy loads should never be lowered by applying only the brake but the wire should be paid out by manual operation of the handles in the appropriate direction. The use of

the hand brake is not recommended because it is very difficult to apply the braking action gradually and, unless this is done, the wire which always has a certain amount of slack even under heavy load is tightened rapidly, resulting often in serious damage to the wire and/or tackle. A standard make of hand winch is shown in Fig. 3.01.

Time spent in correctly setting and ballasting a winch will always pay dividends. The winch should be securely anchored to a stake or other suitable object and the backs of the bearers must be well loaded with ballast, preferably pig iron. Take great care to check

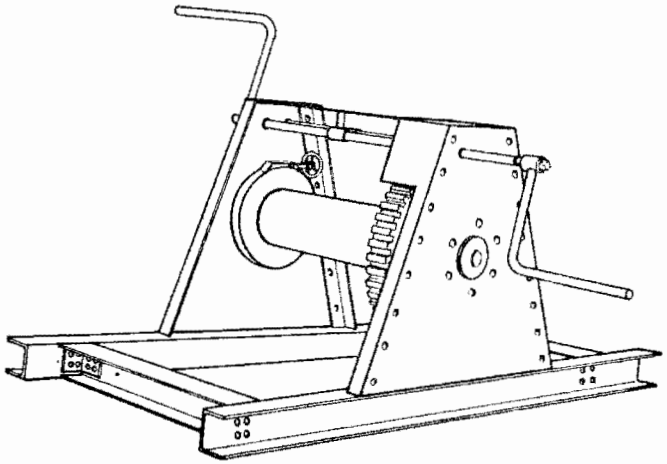


Fig. 3.01: Hand winch

that the lead is run squarely on to the barrel, as it can be very annoying to find that, when lifting an important load, the wire continually builds up on one side of the barrel. Besides being extremely dangerous, this increases the effort required to turn the handles of the winch. Note that there must be a minimum of four full anchorage turns on the barrel before the load is lifted as the wire may slip otherwise.

POWER WINCHES

Various patterns of power winches are available to supplement the hand-operated models. These power winches are useful and, of course, economical with labour as they usually require only one man—the driver—for their operation. The larger models with direct pulling capacities of one ton and over can be coupled with blocks and used to lift heavier loads. The smaller varieties are very light and are easily handled about the site by one or two men.

@Seismicisolation

When crane lifting facilities are not available, these small powered winches will prove ideal for hoisting small members such as gutters, sheeting bars, and purlins.

The power winch consists basically of a prime mover, drive, rope barrel, and a suitable bedplate which serves to locate and hold the various components in their respective positions. The prime mover may be petrol, diesel, electric, steam, or compressed air and is chosen to suit the particular requirements of the work in hand. The diesel engine is to be recommended for most erection work, as it is very reliable and will deliver most of its power at comparatively low running speeds (Plate 3.01). The fact that special arrangements may have to be made to install electric power on some sites limits the versatility of the electrically driven model.

The construction and operation of the power winch is very simple. Usually a friction drive is adopted to rotate the barrel and the operation of an eccentric moves the barrel in or out of drive. The braking arrangements are such that immediately the drive is released the brakes come into operation. Because of the basic simplicity of the power winch, there is a risk that maintenance may be neglected and a strict check should always be kept on this point. The driver should also be carefully selected so that a fully competent man is employed.

With extensions or repairs to an existing factory a supply of compressed air may be available which can be utilized for lifting. Unless this is the case, it is seldom economical to install a temporary supply merely to operate a winch. When such a supply is available, however, it does suggest a method of lifting which is well worth considering carefully. Air consumption of a pneumatic winch may be reckoned at 3 to 3½ cu ft of free air per ft ton of lift with a working pressure of 80 to 100 lb/sq in.

Pneumatic winches can be obtained with either a rotary blade type engine or a reciprocating engine. The latter type of engine is more economical on air consumption and also gives a higher starting torque. The model illustrated in Plate 3.02 has a rotary piston engine and can be readily bolted to a suitable base. A safety brake is fitted which ensures that the load is held should the air supply be interrupted. The barrel of this winch can be disengaged from the engine to enable the rope to be hauled off quickly.

BLOCKS

The erector uses blocks for various purposes in the normal course of his work. Sometimes the blocks are hung from the derrick pole or slung from a safe and convenient position and are used for lifting; at other times they are used to tighten guy ropes or haul

heavy machinery along the ground. In fact, blocks are employed in all cases where the hauling or lifting capacity is to be increased.

Blocks are available as one-, two-, three-, or four-sheave blocks, the classification depending upon the number of pulleys fitted. In use the blocks are paired off generally as "three- and two-block" or "four- and three-block". The "three- and two-block" combination is possibly the most widely used. The single sheave is used only for light heaving purposes. It is important to note here that when selecting a point of suspension for the blocks it must not be forgotten that this point will have to withstand the load from the lead line as well as the load to be lifted. This lead line load will vary, depending on the combination of blocks and, as shown later in the chapter, may be increased by as much as 20 per cent by friction in the blocks.

ROPE BLOCKS

As shown in Fig. 3.02, the shape of the groove in the sheave of the rope block is quite different from that of the wire rope block. This is because of the different manner in which the manila or hemp rope strains under load compared with the steel wire rope.

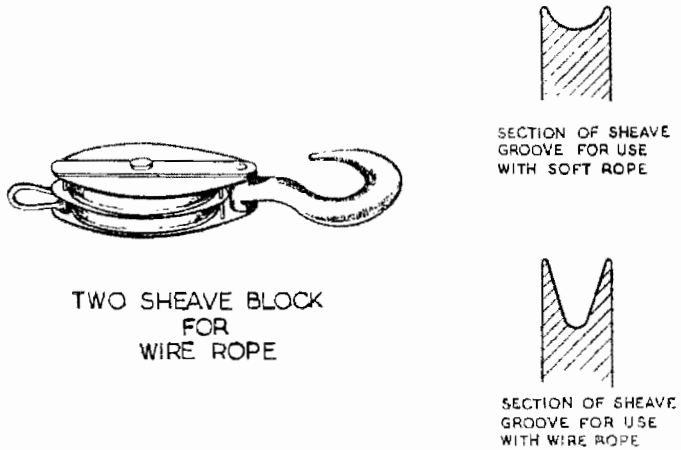


Fig. 3.02: Two-sheave wire rope block

If blocks intended for soft rope are used for wire rope, then the load tends to flatten the rope and strain it severely. Rope blocks should never be used with wire rope for this reason, as well as for the fact that a higher load than they are designed to withstand might be placed on them in that case.

Rope blocks are not costly and an ample number should be made available on every site as their uses are many and varied. When

@Seismicisolation

the pull in the lead line exceeds 5 cwt, rope blocks will not be suitable for hand hoisting and a light winch will have to be used. For convenience in transport about the site, the blocks should be drawn together and the lead line looped round the falls. This practice will keep the falls in their correct order and, if the surplus rope is coiled neatly, no difficulty will be experienced when the blocks have to be used again. Unless this practice is followed, the rope will become tangled.

WIRE ROPE BLOCKS

The sheaves of these are of larger diameter and the groove is narrower with steeper sides than is the case with rope blocks. The groove of wire rope blocks is specially designed to hold the wire rope in shape under the application of the load, which will tend to flatten the wire rope as it passes over the top of the sheave. Due to the shape of the flanges, the sheaves of wire rope blocks are more liable to damage than those of ordinary rope blocks and they should, therefore, be treated with care. Blocks having sheaves with broken flanges must not be used for any length of time as the rope will wear very rapidly.

SNATCH BLOCKS

A snatch block is simply a single sheave block with an arrangement for unlocking one side plate so that the rope can be quickly lifted out or into position. A section of the side plate is hinged

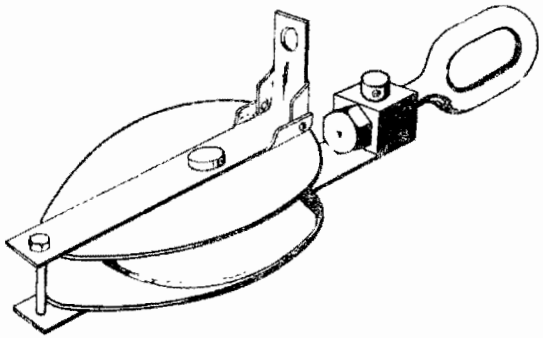


Fig. 3.03: Snatch block

and is locked in the closed position by a pin which prevents accidental release. This can be clearly seen from Fig. 3.03.

The snatch block is employed to alter the direction of the lead from the winch and in this case seldom carries an excessive load. The most common use for the snatch block is at the foot of a derrick where it transfers the horizontal lead from the winch into a vertical

direction to run to the blocks at the head of the pole. Dependent upon the line of the ropes, the load on a snatch block may be a maximum of twice the load on the rope.

HINTS ON REEVING TACKLE

This can prove a difficult operation for the beginner unless dealt with methodically. An example of the procedure adopted to

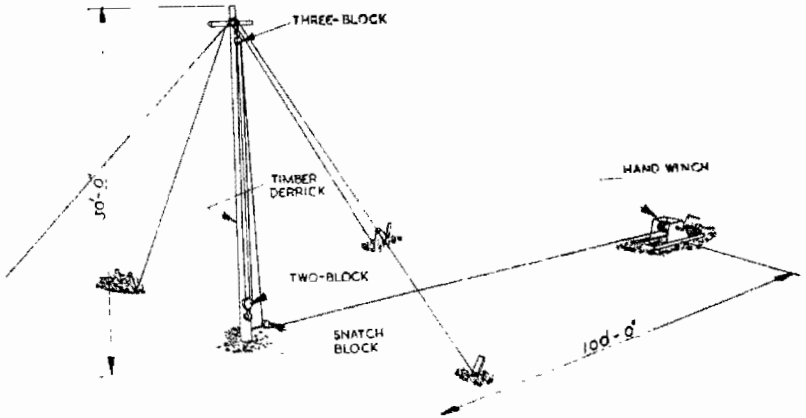


Fig. 3.04: Length of rope in tackle

reeve a set of three- and two-blocks will be given as an illustration.

Place the blocks on the ground about 3 to 4 ft apart and lash them securely in this position. Take one end of the rope and run it over one of the outside sheaves of the three-block and then down to the sheave on the same side of the two-block. Note that the rope should be taken round the sheaves on each block in the same direction; that is, if the rope is carried round the three-block in a clockwise direction then it should also be taken round the two-block in the same direction. Now take the rope over the centre sheave of the three-block and back down to the remaining sheave of the two-block. The reeving is now completed by running the rope over the remaining and outside sheave of the three-block and then bringing it back and anchoring it to the eye on the two-block. To fasten the rope to this becket, tie it back on itself with two half hitches and lash the end with a piece of whipping. Take care to occupy as little room as possible with this lashing as the extra headroom made available by a small and neat lashing is always useful.

A three-sheave block may be used in place of the two-block if the latter is not available. In this case only the two outside sheaves must be used. Unless this is done, the load will be thrown on

@Seismicisolation

one side of the block which may easily strain it. In any case, the work of heaving will be made harder.

LENGTH OF ROPE FOR SETS OF BLOCKS

Two variables must be known before the length of rope for a given set of blocks can be calculated. First, the combination of blocks it is proposed to employ and second, the maximum distance between the blocks before the load is lifted. It will be noted that the latter figure bears no relation to the height that the load is to be lifted except that, if the height of lift exceeds the distance the blocks can be moved apart, the lift must be made in two or more separate stages with the blocks moved higher for each lift. The calculation is made as follows:

1. Add together the number of sheaves in the selected blocks.
2. Multiply by the maximum distance apart, centre to centre, of the blocks before lifting is commenced.
3. To this result add the length of the rope from the top block to the winch or other lifting appliance used, making due allowance for any snatching of this lead line.
4. Add sufficient rope to allow for four or five turns on the winch barrel before hoisting is commenced.
5. Add 10 to 15 ft of rope to allow for that encircling the blocks.

This should suffice for all normal sizes of blocks.

For the example shown in Fig. 3.04 the calculation is made thus:

Combination of blocks used is a three- and two-set.	
Therefore the number of sheaves is	5
Distance apart of the blocks before lifting	30 ft
Thus length of rope required is 5 × 30 ft	150 ft
plus lead to winch	130 ft
five turns on winch barrel	40 ft
and allowance for rope on blocks	15 ft
	335 ft

The length of rope chosen would probably be 350 ft to allow for some variation in the position of the winch and derrick pole.

EFFICIENCY OF BLOCK TACKLE

Every foreman should know from experience how to select a combination of blocks suitable for any particular lift. The mechanics of lifting by block tackle are, quite possibly, a closed book to him and therefore it is proposed to explain simply in the next few paragraphs how the loads that can be lifted by a set of blocks are calculated.

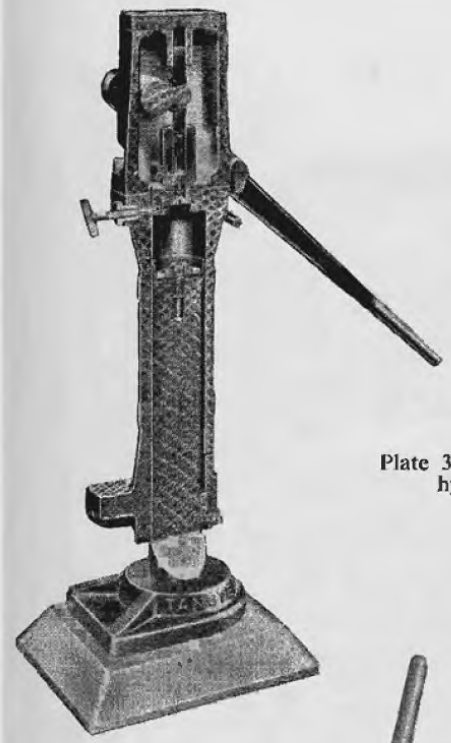
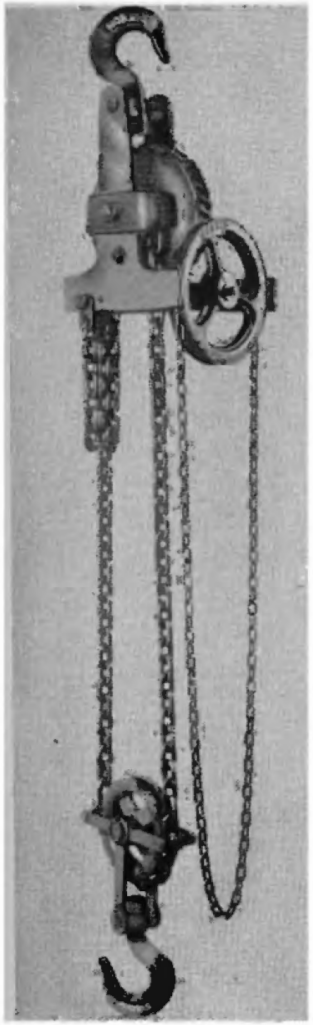


Plate 3.04: Sectional view of hydraulic toe-jack

Plate 3.05: Ship jack with separate pump chamber

@Seismicisolation

Plate 3.06: Hauling a girder with a sylvester



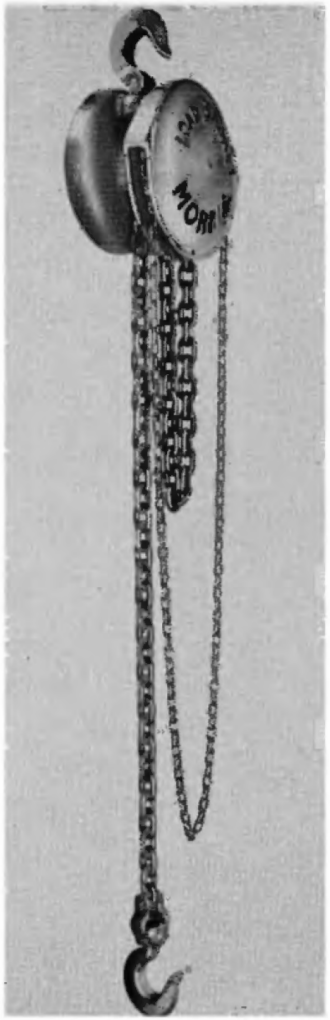


Plate 3.07: Worm gear and triple gear chain blocks

@Seismicisolation

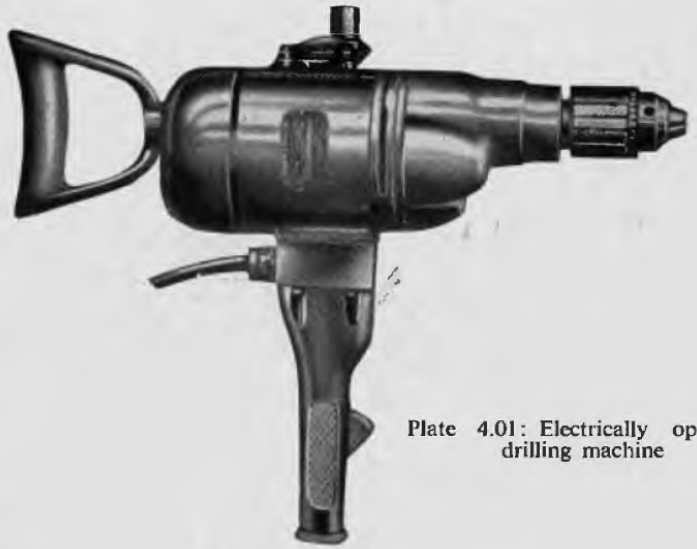


Plate 4.01: Electrically operated drilling machine

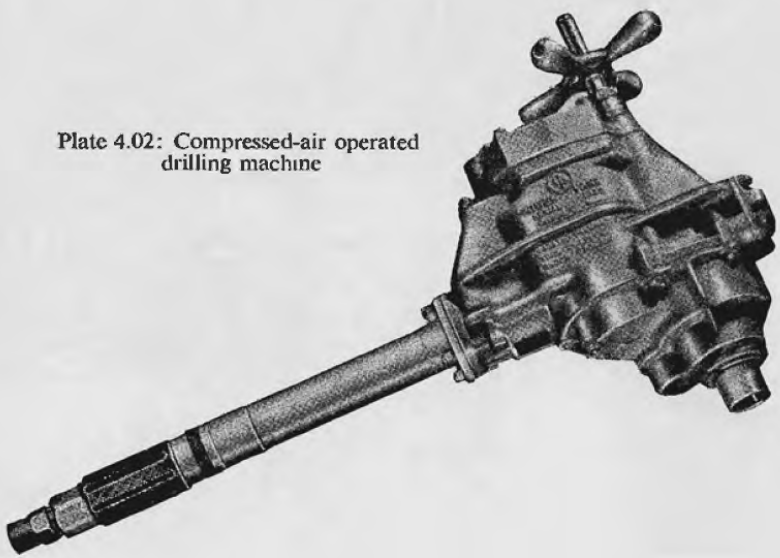


Plate 4.02: Compressed-air operated drilling machine

The very simple case of a combination of a one- and a one-block, as shown in Fig. 3.05 (a), will be considered first. To understand how these blocks operate, imagine that the lead line is hauled in by 40 in., for instance. The action of the sheaves in the two blocks would distribute this between the two falls, the net result being that the two blocks would move 20 in. closer together. The top block is hung from a lifting point or similar connection and can therefore be considered as fixed, so that the bottom block will rise 20 in.

Consider next a set of three- and two-blocks, as shown in Fig. 3.05 (b). In this case the lead line is again hauled in 40 in.

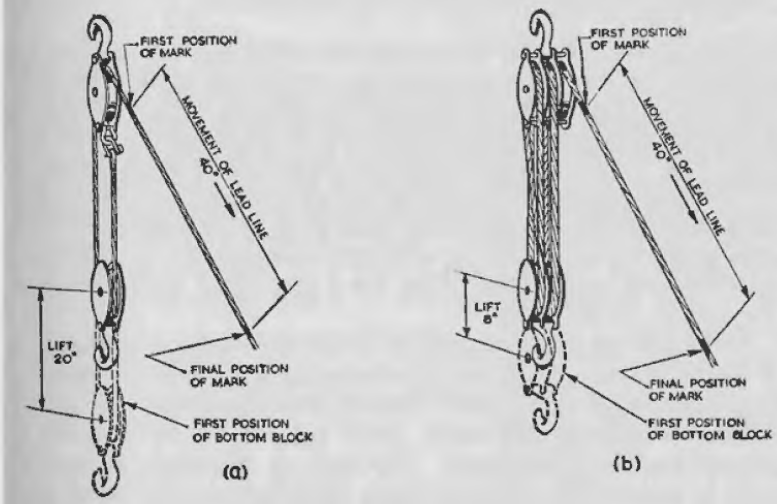


Fig. 3.05: Efficiency of block tackle

and once again the sheaves will distribute this between the falls. There are five falls in this instance, and the bottom block will therefore rise one-fifth of 40 in., or 8 in., in relation to the top block.

By using elementary mechanics it can be shown that, theoretically, the pull in the lead line of a set of blocks multiplied by the distance the line is hauled in is equal to the load carried by the blocks multiplied by the distance these move. Referring to Fig. 3.05 this gives the formula:

$$\text{Pull in lead line} \times 40\text{in.} = \text{Load on blocks} \times \text{lift}$$

This formula readily gives a method of calculating the permissible loads for the two combinations of blocks considered above. In the first case the load that could be lifted by the blocks would be

@Seismicisolation

Table 3.01. SAFE LOAD ON VARIOUS COMBINATIONS OF BLOCKS

Diameter of lead line in inches	Safe load on lead line		Arrangement of blocks													
			Single		1 and 1		2 and 1		2 and 2		3 and 2		3 and 3		4 and 3	
	ton	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*
½	1	8	1	6	2	11	3	12	4	13	5	12	6	9	7	6
⅝	2	4	2	1	3	18	5	13	7	5	8	16	10	8	11	9
¾	3	0	2	15	5	7	7	15	9	19	12	0	13	18	15	12
⅞	4	2	3	16	7	6	10	12	13	12	16	8	19	0	21	8
1	5	8	5	0	18	12	13	18	17	18	21	12	25	0	28	2

* (i) Rope to be of 6 × 37 construction best plough steel.
(ii) For each snatch block used on lead line the safe load on the blocks should be multiplied by 0·925.
(iii) For load on slinging point add lead line load to load on blocks.

twice the load on the lead line, and in the second case the multiplying factor would be five. Theoretically, therefore, a hoisting unit consisting of a 2-ton winch and suitable wire rope could lift 4 tons with the one-and-one set and 10 tons with the three-and-two combination. The multiplying factor in any other case is easily obtained by counting the number of falls in the set of blocks, the lead from the top block being neglected in this as it has no effect. These calculations do not, however, take into consideration the effect of the friction of the sheaves which, for a given load, would increase the load on the lead line.

Table 3.01 has been prepared to cover the various combinations of blocks in common use and allowance has been made for friction. Inspection of the table shows that the winch pulls required to lift different loads are well above those that would be required if friction were not considered. The load on the block suspension point is greater than the load being lifted because this point also has to withstand the pull of the down lead from the top block. This fact must not be disregarded when selecting a point for the hanging of the blocks.

Considering the load in a snatch block, in which the lead line is returned in the same direction in which it is led in, it will be seen that the load on the snatch block is more than double the lead line load. Selection of the snatch block and also of the anchorage point should be made with this in mind.

JACKS

The jack in one of its many forms is one of the most useful pieces of tackle that can be included in an erector's toolbox and at least two should always be provided on every job-site to cope with any emergency that may arise. Lifting jacks may be classed as screw,

ratchet or hydraulic, depending upon their method of operation. Certain patterns are available mounted on a special carriage and base which permits the load to be lifted and moved some distance horizontally before being lowered.

When selecting jacks for erection purposes particular attention should be paid to the base area which must always be large enough to prevent accidental overturning, as it is not always possible to use the jacks under ideal conditions. A good erector, when lifting against steel or cast iron, would be sure to insert a thin piece of timber or sacking to lessen the risk of slipping. In the case of hydraulic jacks, either a type with a screw collar, or some form of packing, should be used as a safety precaution against failure of the jack.

SCREW JACKS

These are possibly the simplest and handiest type of jack that can be bought and are very suitable for all classes of light work. As the name implies, the lift is made by the screwing action of the ram which thrusts against the threaded portion of the jack base. Screw jacks are offered in standard sizes from 5 tons to about 30 tons

Fig. 3.06: Screw jack

and Fig. 3.06 illustrates a typical model. Ball-bearing heads are available on some models.

RATCHET JACKS

The ratchet type of jack is usually manufactured as a combined head and toe jack, and the toe will be found a great advantage as the jack can thus be inserted into gaps as small as 3 in. Most makers, however, do not recommend that the toe be used to lift more than 50 per cent of the permissible head load and in some cases this figure may be as low as 25 per cent.

Trip ratchet jacks are obtainable which drop the load immediately the mechanism is released, but this can prove very dangerous and

@Seismicisolation

their use is definitely not recommended. The type of jack that has to be ratcheted both up and down should always be selected as the lowering can be accurately controlled. The movement of the jack head can be reversed by adjusting a locking device on the body of the jack.

A disadvantage of the ratchet jack is the space required to work the operating lever which has to be moved in a vertical direction. This is remedied somewhat on models with a double socket for the lever which can then be used in the most convenient position. Plate 3.03 shows a ratchet jack of this type and the double socket can be plainly seen.

HYDRAULIC JACKS

For heavy lifts the hydraulic jack is the most suitable and standard models are on the market which will lift loads of up to 200 tons. The fluid used in these jacks may be either water or a special oil. Two patterns of hydraulic jack are shown in Plates 3.04 and 3.05—the toe jack and the ship jack. The latter is obtainable either with the pump unit attached as shown, or separate, which makes this jack very adaptable in confined spaces. In the latter case the two units will be connected by flexible piping. The hydraulic toe jack is less stable and therefore less easy to position. Once correctly set, however, it can be relied upon to function with ease.

The ship jack can be obtained in larger capacities than the toe jack. Care must be taken to ensure that only the base of the ram chamber is carrying the load. The pump chamber must not be allowed to carry any load as it is a casting, not designed for this purpose, which might possibly fracture under an unexpected load.

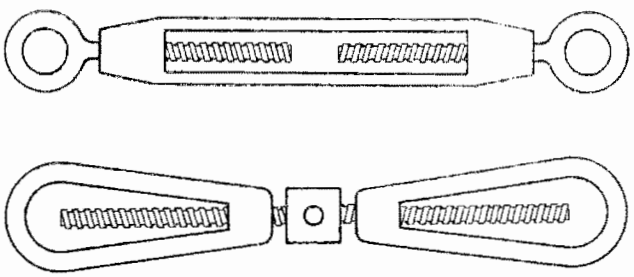


Fig. 3.07: Union screws

UNION SCREWS

Fig. 3.07 shows the construction of typical models. As can be seen, they consist basically of two steel links which screw on to a

@Seismicisolation

threaded connecting bar. This bar can be rotated by inserting a suitable toggle into the centre hole and, as the threads are opposite-handed, the links can be moved closer together or wider apart as required. Union screws are used for a wide variety of purposes. A typical use is to strain wires and pull portions of a building plumb.

THE SYLVESTER

This tool originated as a pit prop remover and is not seen as often on the construction site as might be expected, possibly because some erectors are not fully aware of its possibilities. Compared with the loads it can shift, the sylvester is very light, easily handled, and quickly adjusted. It is ideal for moving heavy loads along the ground.

Its construction and method of operation are very simple, as can be seen from Plate 3.06. One chain is permanently attached to a steel bar with a rack on one edge. The most convenient link of the other chain is slipped quickly into the slot on the body of the tool and the two chains are drawn together by working the lever. This moves the body of the tool along the bar, while slipping is prevented by the pawl which can be released when the tool has to be reset.

CHAIN BLOCKS

The three main types of chain blocks are the Weston, worm gear and triple gear patterns. The Weston type is very simple to use and light to handle, and its operating chain also acts as the hoisting chain. It can, thus, become oily and greasy in use. Worm gear and triple gear blocks should be used for loads of 1½ tons and over.

Triple gear blocks take up less headroom than the worm gear type. For example, with a 5-ton pattern they may only require 75 per cent of the headroom required by worm gear blocks. They are to be recommended not only for this reason but also for their lighter weight and cleaner lines, which make for easier handling. Chain blocks must be carefully used on the site and not allowed to lie around, but should be brought back to the site store cabin and given regular attention. Plate 3.07 illustrates triple gear and worm gear type chain blocks.

CHAPTER 4

SMALL TOOLS

DRILLING EQUIPMENT

MODIFICATIONS to steelwork have often to be made at the site and drilling gear should therefore be included in the tackle for all but the smallest of contracts. Whether hand, electric, or compressed-air equipment is selected will, of course, depend not only on the type of power available on the site but also on the amount of drilling work anticipated.

On a large contract a special drilling bench can be constructed from scrap angles and this can be fitted with a permanent drilling stand. Many small jobs, such as the fabrication of extra cleats and small beams, can then be handled entirely on the site.

HAND-DRILLING GEAR

Although it may be felt that hand-drilling is old-fashioned and slow, it nevertheless has many advantages when the work is awkwardly placed. Fig. 4.01 shows a typical ratchet brace. The socket into which the drill shanks are fitted can be seen below the

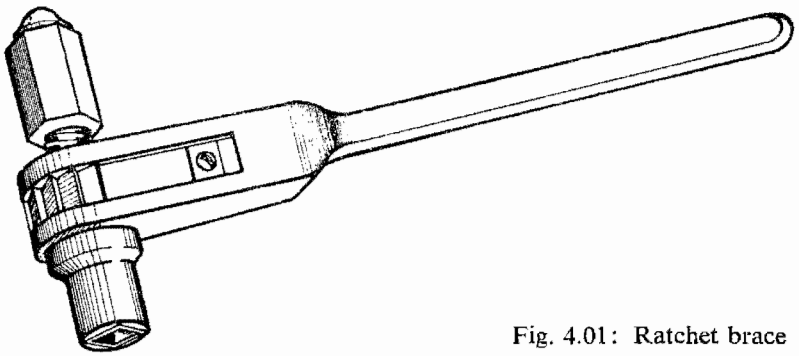


Fig. 4.01: Ratchet brace

ratchet. Square shank drills are used with hand-drilling equipment. A reciprocating motion applied to the lever rotates the body of the drill through a ratchet mechanism, and a screw on this body is used to exert drilling pressure by thrusting against the special stand. Hand-drilling is slow work at the best of times and, if much drilling is expected, suitable power-operated machines would be advisable.

DRILLING STANDS

A drill stand is essential except for drilling very light gauge steel. The usual pattern is depicted in Fig. 4.02. This consists basically of a vertical post with a sliding arm which can be locked in any desired position by a set screw or key. The foot of the stand is clamped or bolted to the member which is to be drilled, and the arm takes the thrust of the gear when in operation. Other types

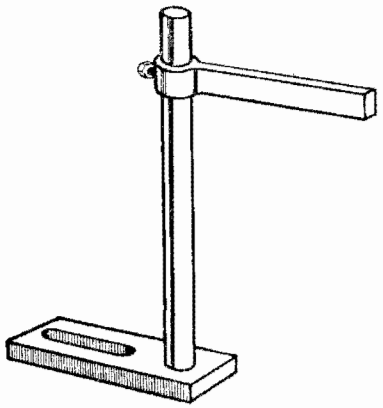


Fig. 4.02: Usual pattern of drill stand

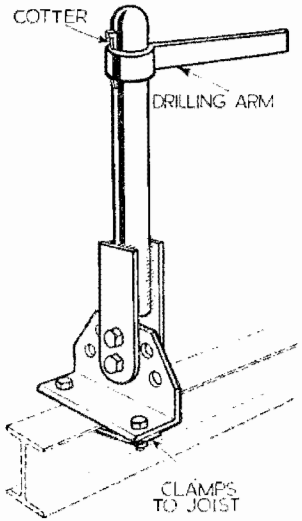


Fig. 4.03: Drill stand giving a variety of drilling angles

of drilling stands are to be obtained. Fig. 4.03 illustrates a particularly useful model which can be clamped quickly to a joist. As shown, the post can assume a number of different angles and the stand will also fit varying sizes of joist.

POWER DRILLS

Machines are available so that either electricity or compressed air can be utilized for the rapid drilling of holes (Plates 4.01 and 4.02). The sizes and capabilities of each type of machine are roughly the same, except for the manner of operation, and there is little to choose between them. Electricity is more often readily available on the site than compressed air, so that the electrically driven machine is possibly more adaptable.

The speed of the motor of the electric drill is reduced by taking the drive through a train of gears. It is always advisable to check the running speed from the maker's catalogue when choosing a machine. The majority of electric drills are equipped with "Universal"

@Seismicisolation

Table 4.01. AIR CONSUMPTION OF PNEUMATIC TOOLS

Machine		cu ft free air per minute at 80 lb/sq in.
Drilling machine	$\frac{1}{2}$–$\frac{3}{4}$ in. holes	25/30
,, ,,	$\frac{7}{8}$–1 in. holes	35/40
,, ,,	$1\frac{1}{4}$ in. holes	45/50
Corner drills	*as above*	*as above*
Grinders	6 in. dia. wheel	35
,,	8 in. dia. wheel	45

motors which will operate on either a.c. or d.c. current and at voltages of 105–115, 200–230, and 235–250. Note that all machines should be wired so that the body of the machine is earthed as a safeguard against accident. Machines from the standard range are capable of drilling holes of up to $1\frac{1}{4}$-in. diameter.

It is customary to provide only two sizes of machine, one capable of drilling up to $\frac{3}{4}$-in. diameter holes and a larger model to drill up to 1-in. or $1\frac{1}{4}$-in. diameter holes. "Close quarter" drills are available and will be found very useful when it becomes necessary to drill holes adjacent to another part of the structure. The driving shaft in these machines is offset from the spindle of the motor and positioned very close to the side of the casing.

Clean, dry air is the first essential for any pneumatic tool and great attention must therefore be paid to the air supply. The supply hose should always be blown clean with the compressed air to dislodge any dirt or dust before the drill is coupled to it. Apart from filters on the air line itself, a fine gauze filter is fitted to the inlet of each tool. This latter filter must be handled very carefully. If it is broken, it should be replaced at once as it is the last line of protection against dirt entering the machine from the hose. Only the lubricating oil recommended by the makers should be used on compressed air machines, which should be oiled at least once a day when they are in use.

MORSE TAPER ARBORS, SOCKETS AND REDUCING SLEEVES

Drills intended for use with power-operated drilling machines have a Morse taper arbor, as shown in Fig. 4.04. It can be seen clearly that the drill shank is specially shaped and has a tang at the end entering the machine. Contrary to general opinion, this

tang does not transmit the driving force but is only intended to locate the drilling bit. The driving torque is passed to the drill by friction on the sides of the Morse taper shank. These sides are set at a specially designed angle. Care must be taken, therefore, not to damage the tapers as otherwise the full grip will not be obtained. In this case, the load may be thrown on the tang which, as it is not designed to carry this load, may easily snap.

Reducing sleeves are available, and one is shown in Fig. 4.04. These enable smaller drill bits to be used in a large machine. For

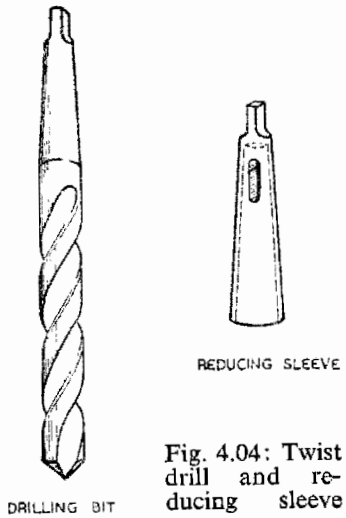


Fig. 4.04: Twist drill and reducing sleeve

instance, a large machine with a normal drilling capacity of $\frac{7}{8}$ in. to $1\frac{1}{4}$ in. can be adapted with a 3–2 size reducing sleeve to give a drilling capacity ranging down to $\frac{1}{2}$ in.

OTHER MECHANICAL TOOLS

Nut runners and impact wrenches will prove profitable tools to operate when large numbers of bolts have to be tightened. They are invaluable for the bolting of bunker plates or deck plates. With the aid of one of these machines, three to four times the work possible by hand methods can be achieved. A special die fitted to the shaft of the machine grips the nut and, when the control is operated, runs the nut down until it becomes tight. In the case of an impact wrench, the machine then delivers a series of blows to the nut until it is fully home. The action of the machine can be reversed so that nuts can also be removed.

Grinding machines are needed on the site for cleaning welding work or plate edges cut by the oxy-acetylene torch. Machines

@Seismicisolation

capable of taking either a 6-in. or 8-in. abrasive wheel will be required. Models with the straight handle will be found easier to operate than the pistol-grip pattern. Operators should be instructed to wear goggles on every occasion these machines are used so as to prevent injury to the eye from flying pieces of metal. Circular wire brushes can also be used in these machines. The wire brush is fastened to the circumference of the wheel. The overall diameter is usually the same as that of the abrasive wheel. Under the action of centrifugal force the wires fly out and form a very hard brushing surface.

MISCELLANEOUS SMALL TOOLS

SPANNERS AND WRENCHES

The podger spanner is the constant companion of the erector. Straight and cranked podger spanners are illustrated in Fig. 4.05. They are available in two types of steel. Those manufactured from the harder steel are ideally suited for steel erection work, but care should be taken that they are not mislaid on the site as their initial cost is higher. Reference to British Standard 2583 : 1955 is recommended when purchasing podger spanners. Other types of podger spanner are available but should be purchased with care, as it may be found that the shank is too thick for insertion in holes intended to take bolts which the jaws of the spanner fit.

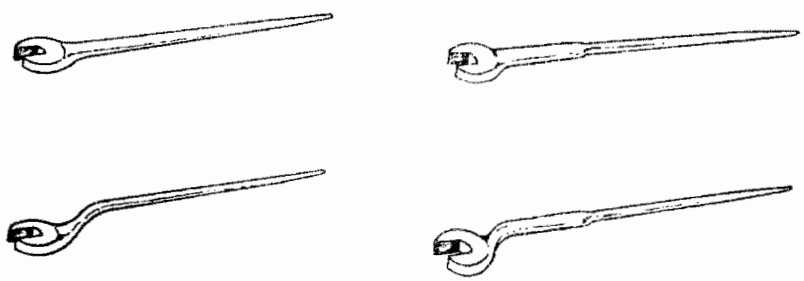


Fig. 4.05: Types of podger spanner

This prevents the erector from using the spanner to line the holes in a connection before he inserts the bolts. It is a serious handicap when working aloft.

A range of various sizes of double-ended spanners to fit the unusual sizes of nuts occasionally encountered should always be included in every kit of tools. Large holding-down bolts are often met with, and a suitable spanner to fit the nuts may not be available on the site. In such an emergency a flat spanner could be cut on

site from a scrap piece of steel with the oxy-acetylene cutting torch. While not ideal, a spanner made in this fashion will fulfil its purpose.

When handrailing with screwed connections has to be fixed, the stillson wrench, shown in Fig. 4.06, is a necessity. Two pairs, one to hold the tubing and one to screw the connection, are required.

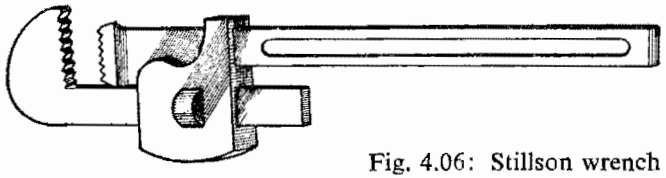


Fig. 4.06: Stillson wrench

The larger sizes of stillson wrench will be found useful for tightening holding-down bolts. Chain tongs are similarly useful.

DRIFTS

When rivets or bolts are being inserted into multi-plate connections, drifts must be used to hold the plates in line. When riveting, service bolts are inserted first and the plates drawn tight before the rivets are driven.

The usual patterns of drifts are shown in Fig. 4.07 and are available to suit all sizes of holes. Taper drifts are used to line the holes. When there are a number of plates in the connection, barrel drifts are inserted to maintain the plates in line. The taper drift, by reason of its shape, will not perform this function satisfactorily.

Drifts are very liable to roll off the working platform and are difficult to locate and retrieve because of their size. They should always be kept in a box to prevent them from rolling off the platform and hurting people in their fall. More drifts are lost on a contract than any other tool and, for this reason, a good number should always be sent to the site in the first case.

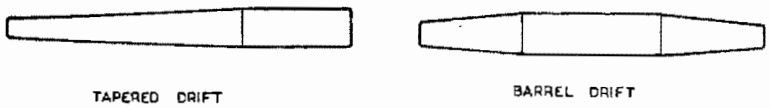


Fig. 4.07: Types of drifts

HAMMERS

When selecting hammers for steel erection work, particular attention should be given to the shafts. These should be of the best quality as they will have to stand much punishment in the normal course of events. Spare shafts should always be provided

@Seismicisolation

with the tools so that reshafting can be carried out on the site, if necessary. Ball pein hammers of 2-lb weight, 7-lb flogging hammers, and 14-lb sledge hammers are the sizes to include in the tool kit.

After a heavy hammer has been used aloft, it is sometimes thrown to the ground. This practice should be discouraged as, besides being dangerous to other workmen, the shaft is almost certain to be damaged. A hand-line should always be used for lowering the hammer.

SHACKLES

Dee and bow shackles are the usual patterns chosen for erection work. Both types are available with either large or small jaws and are selected to suit the particular use to which they will be put. Reference to British Standard 825 : 1949 will give much useful

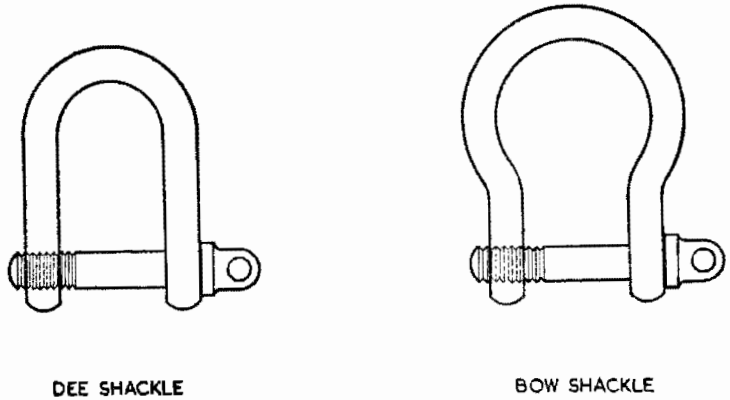


Fig. 4.08: Dee and bow shackles

information on sizes and types. Fig. 4.08 illustrates the different patterns of shackle. Each is designed to carry a certain safe working load, and this information must be clearly stamped on the shackle, together with an identification mark.

Shackle pins may be of various patterns, the most common being screwed at one end and having an eye at the other so that it may be tightened or slackened with the toggle spanner. Other types of pin have either countersunk heads, requiring the use of a screwdriver, or they may be locked with a split pin or forelock. As these latter are easily mislaid, such pins are not advisable.

BULLDOG GRIPS

Bulldog grips, illustrated in Fig. 4.09, are available to fit wire ranging from $\frac{1}{4}$-in. to 2-in. diameter. Their grip on the wire is quite

reliable and they will always prove to be of great use on the construction site. Three at least should be fitted, and the U-bolt part of the grip should always be positioned over the tail end of the rope, with the bridge on the working part.

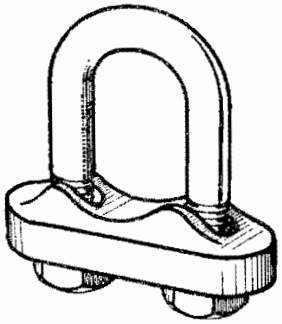


Fig. 4.09: Bulldog grip

STAKES

Stakes suitable for anchoring winches and guys can be cut from scrap angle section steel. The best sections to use are 3-in. or 4-in. equal angles, and they should be cut into lengths of approximately 5 ft. To enable the stake to be easily driven into the ground, the

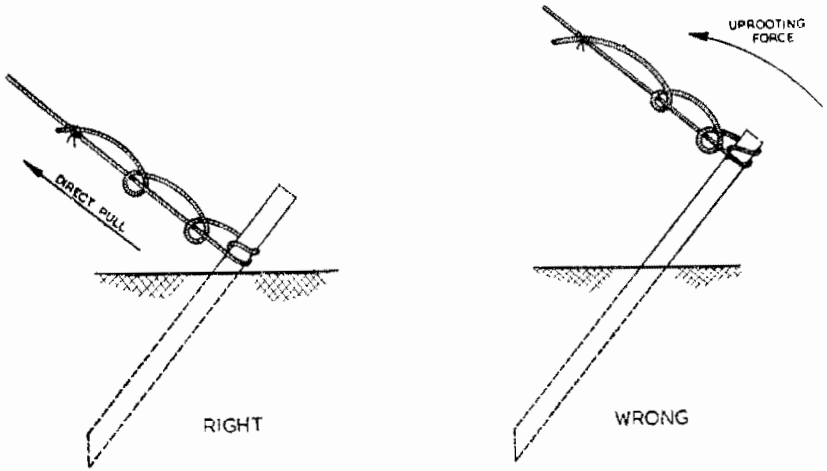


Fig. 4.10: Staking—correct (left) and incorrect method (right)

end which is to be entered should be cut to a taper point with the oxy-acetylene cutting torch.

This is an appropriate place to mention one vital point about staking which does not appear to be understood by some erectors.

@Seismicisolation

Guys or lashings must always be fastened to the stake as close to the ground as possible, otherwise a powerful uprooting force is exerted on the stake. Fig. 4.10 clearly illustrates this point.

TIMBER FASTENERS

It is very unlikely that any elaborate timber structures will have to be made on the site. Temporary trestling and the like is usually of steel, and the erection engineer will endeavour to have this work

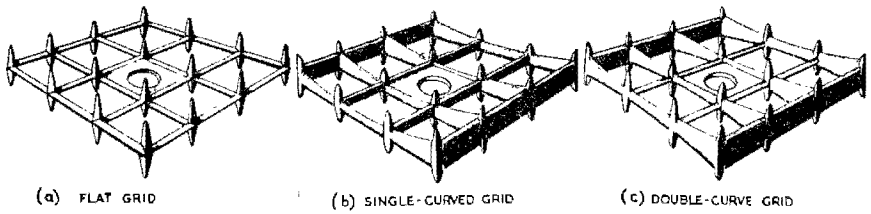
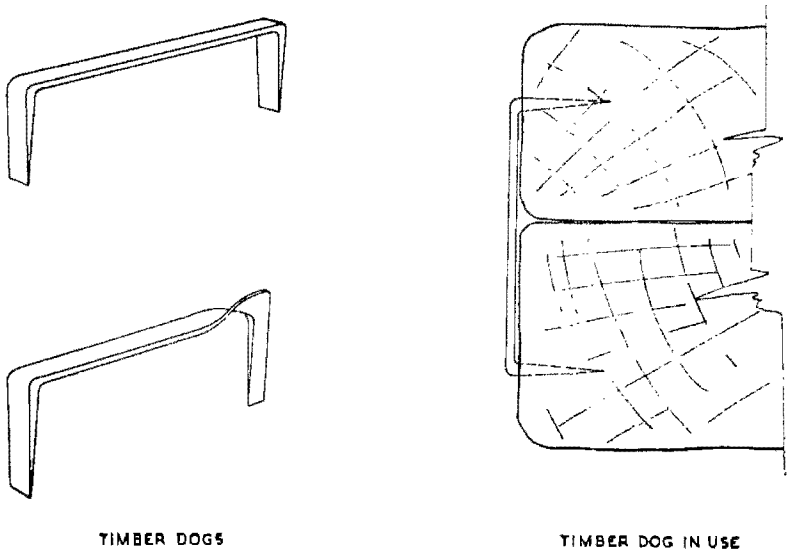


Fig. 4.11 (above): Timber fasteners. Fig. 4.12 (below): Timber dogs



fabricated in the construction shops. However, if timber does have to be used for structures likely to carry considerable loads, the design should be approached carefully, and full advantage should be taken of the special timber connectors now available. Fig. 4.11 shows a spiked grid connector. The clamping bolts force the teeth on the rings into the wood surface and the joint formed is much stronger than that possible with the use of bolts alone. Plate washers should be used under bolt heads and nuts.

Packings of baulks and sleepers are frequently used. When it is necessary to clamp the component timbers of these together,

timber dogs, such as are shown in Fig. 4.12, can be used. These are knocked into the timbers and the wedge shape of the spikes draws the timbers together and holds them firmly.

ROLLERS

It is good practice always to include four or five timber or steel rollers, about 5 ft long, among the tackle for a contract. Heavy objects can be rolled over soft ground by first laying down a path of battens, which will increase the loaded area of the ground. They should prove ample for all but the softest ground.

Steel rollers are usually cut from lengths of scrap pipe. Pipes 2 in. to 4 in. in diameter are the most suitable sizes. Smaller diameters are not recommended, unless the surface on which they are to be used is very smooth, as their rolling action can be halted by quite small pieces of metal or stone. Larger sizes of pipes than 4-in. diameter tend to make the rolling action too sudden, which is not advisable.

WEDGES

Wedges of both timber and steel will always find a use on the erection site. Timber wedges are used to " scotch " crane wheels, etc., thus preventing movement, and also for wedging up light loads. If a prop is to be lifted, folding wedges should be used as shown in Fig. 4.13. Driving one from each side in this manner ensures that

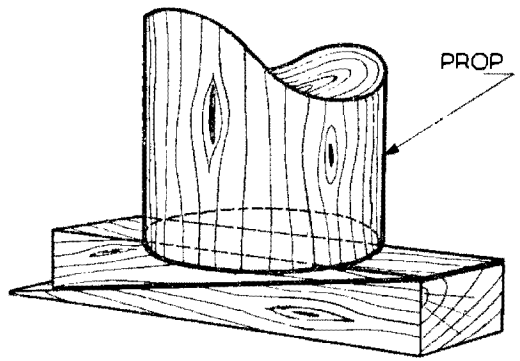


Fig. 4.13: Using wedges to obtain a straight lift

the foot of the prop rests on a horizontal surface and will not kick out. When the requisite height has been reached, a nail driven through the two wedges will hold them securely in position.

Stanchions and other heavy objects call for the use of steel wedges. The shape of these should be such that the taper runs

@Seismicisolation

from 3 in. to nothing, and the length should be about 16 in. Too steep a slope is not advisable as it will make the wedge liable to spring out if driven hard. A heel on the wedge, as in Fig. 4.14, is of great assistance when the wedge has to be withdrawn.

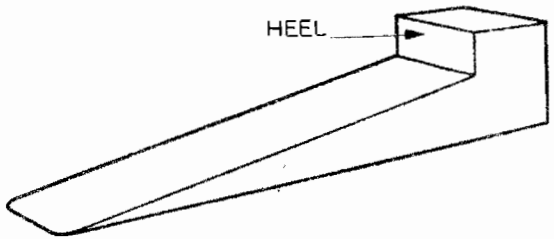


Fig. 4.14: Steel wedge with heel to aid withdrawing

CLAMPS

The term "clamp" is usually taken to mean the C-clamp illustrated in Fig. 4.15 (a). This clamp can be used to hold a drill stand in position when holes are not available for bolts. It can also be used to hold material together preparatory to welding. A toggle through the hole in the head of the screw will give the necessary action. Another type of clamp is shown in Fig. 4.15 (b). Correctly

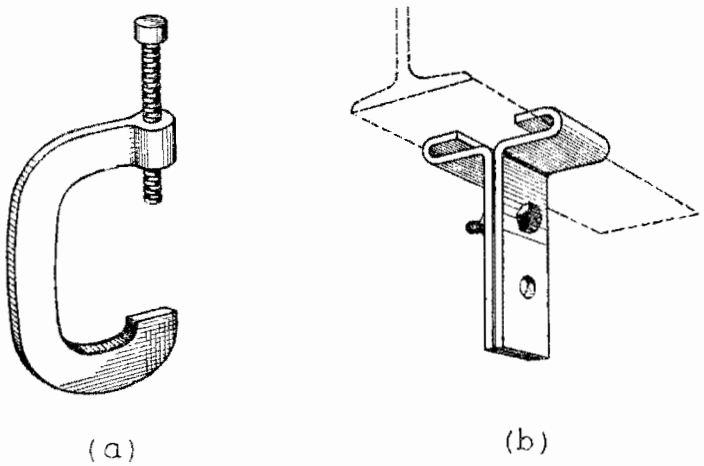


Fig. 4.15: "C" clamp (*a*) and beam clamp (*b*)

positioned and tightened, this is ideal for slinging blocks from a beam when the headroom available is limited. A further advantage is that the top flange of the beam does not need to be uncovered as would be necessary if a strop were to be used. A good blacksmith will readily fashion a clamp or clip of this pattern to suit any particular shape of beam.

PINCH BARS

The most convenient pattern of pinch bar is about 4 ft long. One end of the bar is drawn out to a point, while the other and heavier end is shaped into a heel and toe. The length of the toe should not be too great in proportion to the overall length of the bar, otherwise the leverage that can be obtained is lessened considerably. Fig. 4.16 illustrates a typical pinch bar.

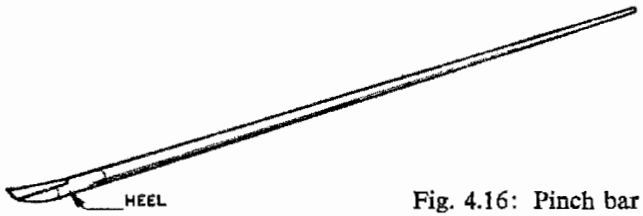


Fig. 4.16: Pinch bar

TWO-WHEELED BOGIE

A useful piece of equipment to be included with the tackle is the two-wheeled bogie. This will have a platform measuring about 3 ft × 2 ft, set over a short axle, with two wheels of approximately 9-in. diameter. Sections of steelwork can be lifted on to the bogie and can be readily trundled about the site.

@Seismicisolation

CHAPTER 5

CHAINS, ROPES AND SLINGS

SOFT ROPES

HEMP ropes have been largely replaced by steel wire ropes, but they are still used for the falls of rope tackle up to a capacity of about 3 tons and also for hand-lines and lashings. These ropes are commonly made from hemp or sisal, although coir and nylon have their uses in exceptional cases.

Makers supply tables of safe working loads for tarred and untarred rope but a rope will deteriorate if improperly used and allowed to get dirty or wet. Ropes should be stored in a dry and well-ventilated shed. It is essential that wet ropes are dried out carefully and not thrown on the ground and left to dry on their own accord.

WIRE ROPES

These are almost indispensable to the erection engineer because of their large selection of size, their good wearing and handling capacities, and their strength. The use of these ropes with the correct combinations of blocks enables loads ranging from a few hundredweights to hundreds of tons to be lifted with comparative ease. An understanding of the construction and maintenance of wire ropes is, however, essential if a particular rope is to be selected and used with an appreciation of its limits as well as its capabilities It is hoped to indicate in this chapter some of the more important points that must be given attention to if the rope is to be employed and treated correctly.

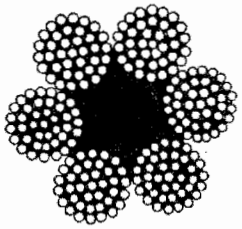


Fig. 5.01: Section through a wire rope of 6 x 37 construction

DESCRIPTION OF ROPE

Wire ropes can be obtained in many constructions and sizes. Each rope is composed of a large number of steel wires wound together in different fashions. Generally speaking, the greater the

number of wires the more flexible will be the finished rope. The type of construction mostly used for erection purposes is that known as "6 × 37 construction", and a section of this type of rope is shown in Fig. 5.01. As can be seen, this rope consists of six strands arranged over a central fibre core. Each strand in turn is composed of 37 separate wires. This large number of wires imparts to the finished rope the flexibility and wearing qualities that are essential in erection work.

Various types of steel are suitable for manufacturing the ordinary engineering type of rope, and the trade description together with the ultimate tensile strength of various steels are given below:

Best patent steel	80–90 tons per sq in.
Special improved patent steel	90–100 ,, ,,
Best plough steel	100–110 ,, ,,
Special improved plough steel	110–120 ,, ,,

The type known as "Best plough steel" can be selected as the most suitable for the work we are considering in this book.

Examination of a wire rope will show that the wires are twisted to form the strands, and that the strands are twisted in their turn to form the rope. The form of this twisting is known as the "lay" of the rope, and when no lay is specified it can be assumed that the rope will be made with right-hand ordinary lay (i.e., the lay of the wire in the strand is anticlockwise and the lay of the strands

Table 5.01. SAFE WORKING LOADS FOR 6 x 37 CONSTRUCTION WIRE ROPES OF BEST PLOUGH STEEL*

Approx. dia. in inches	Circumference in inches	Weight in lb per 100 ft	Breaking load in tons	Safe working load in tons
$\frac{5}{16}$	1	18	3·5	0·6
$\frac{3}{8}$	$1\frac{1}{8}$	21	4·2	0·7
$\frac{1}{2}$	$1\frac{5}{8}$	43	8·4	1·4
$\frac{5}{8}$	2	66	13·2	2·2
$\frac{3}{4}$	$2\frac{3}{8}$	92	18·0	3·0
$\frac{7}{8}$	$2\frac{3}{4}$	123	24·7	4·1
1	$3\frac{1}{8}$	159	32·4	5·4
$1\frac{1}{8}$	$3\frac{1}{2}$	198	39·7	6·6
$1\frac{1}{4}$	$3\frac{7}{8}$	242	49·4	8·2
$1\frac{3}{8}$	$4\frac{3}{8}$	311	62·0	10·3
$1\frac{1}{2}$	$4\frac{3}{4}$	369	74·1	12·4

* A factor of safety of 6 has been used to calculate the above.

@Seismicisolation

in the rope is clockwise). The other types of lay are as follows: left-hand ordinary lay, which is the opposite to the above; and right-hand Lang's lay and left-hand Lang's lay, in which the strand and wire lays are both clockwise or anticlockwise respectively. Non-spinning wire rope is also available and will be found particularly useful as hoist rope on scotch derrick cranes equipped with return blocks. Its use will prevent the return block from spinning under varying load conditions.

HOW TO MEASURE WIRE ROPES

The circumference of a wire rope is the correct method of specifying its size. The length of the circumference is taken as that of the smallest circle which completely encloses the wire. This is found by measuring at three points which must be at least 5 ft apart from

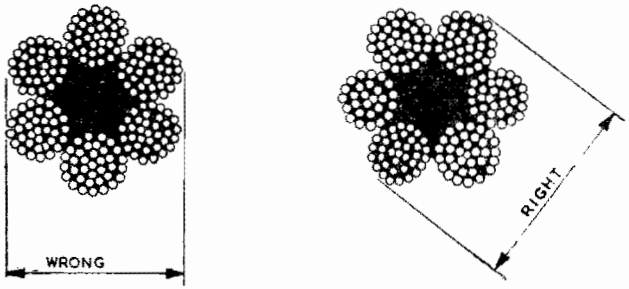


Fig. 5.02: Right and wrong way to measure the diameter of a rope

each other. Callipers used as in Fig. 5.02 enable the diameter to be ascertained and the corresponding circumference is given in Table 5.01, page 49.

MINIMUM SIZES OF DRUMS AND PULLEYS

The continual bending and straightening of a wire rope as it passes over pulleys or winch drums is one of the main causes of wear. When a rope is bent, the wires farthest from the centre of curvature undergo a tensile stress. If the rope is already loaded, this increases the load. At the same time, the side of the rope nearest the centre of curvature has its tension decreased. If the rope is *not* loaded, this side, however, is placed in compression. The smaller the diameter of the pulley sheave, the more the rope will be bent in passing over it, and this will put a greater strain on the rope. If a rope passes over a series of pulleys which bend it first one way and then the other this effect is magnified.

British Standard 302 : 1938 recommends certain minimum sizes of pulleys and drums to use with each size of rope. For 6 × 37

construction rope, the minimum pulley diameter is given as six times the circumference of the rope it is intended to use. Pulleys and drums in everyday use may not meet this requirement, and it is therefore essential that ropes used over such pulleys are frequently examined for signs of wear.

When using wire rope on drums it should be noted that wear can also be caused by the rope not being led squarely on to the drum. Constant rubbing of the sides of the ropes readily causes wear. For cranes the angle of lead of a wire rope on to a drum should not exceed 1 in 12.

CAUSES OF WEAR OF WIRE ROPE

The shape of the groove of the pulley sheaves is as important as the diameter. When the groove of the pulley sheave is too wide for the particular rope in use, the rope tends to flatten as it passes over the sheave and this causes a strain on the individual strands. Conversely, if the groove is too narrow, the rope will be damaged by being gripped too tightly. Reference to British Standard 302 : 1938 will give details of the correct shaping of the groove for use with various sizes of rope.

Blocks are usually discarded when the flanges of the sheaves are broken, but the fact that wear in the bottom of the sheave is liable to cause much greater damage is not widely known and is often overlooked. Loads carried by the ropes are transmitted to the pulleys as the ropes pass over this part of the sheave, and pulleys in constant use should frequently be inspected for signs of wear here. Under careful examination, the jib head pulley on a scotch derrick or a guy derrick crane often shows wear in this manner.

On erection work, wire ropes are used out of doors for the greater part of their working lives and the constant exposure to dampness soon causes wear due to corrosion. Frequent examination and oiling must be adopted to counteract this. Particular attention should be paid to wire ropes when they are used in chemical factories where the air may be heavily laden with acid fumes which will greatly accelerate any corrosive action.

Corrosion inside the rope may be recognized by a rusty-looking liquid that its squeezed out when the rope is in tension, or when the wires in the strands are found to be slack. Constant cleaning of the rope will help to prevent corrosion, but paraffin or petrol should never be used as they will only make matters worse. After cleaning, greasing with a lubricant recommended by the rope manufacturers will help to prevent further attacks of corrosion.

If a crane or similar piece of hoisting machinery has been idle for long, then the ropes must be examined to ascertain that their

@Seismicisolation

condition is satisfactory before the appliance is brought back into use. Special attention should be given to the points at which the wire ropes come into contact with the sheaves and drums, as it is at these points that corrosion is most likely to begin.

HANDLING OF WIRE ROPES

Serious damage can be done to a rope before it is even put into commission by inexperienced handling when it is uncoiled on receipt from the makers. A wire rope should never be uncoiled by pulling the rope straight off the top of the coil. When this is done, kinks are quickly formed which will prove difficult to remove. Loads should never be put on a twisted rope, otherwise an unnatural permanent twist is made and the rope is seriously damaged. This damage can never be corrected as the lay of the rope is disturbed and the rope strained. Quite often the full damage cannot be seen, nevertheless the life of the rope is seriously shortened.

Damage caused in this fashion can be prevented by the use of a suitably constructed turntable, such as is shown in Fig. 5.03. This could be quickly and cheaply made. To uncoil the newly received rope, it is placed on the turntable and the upright bars positioned to suit. The ties of the coil are now cut and the rope taken off the coil by walking away with the outer end of the rope while allowing the turntable to revolve. The same procedure should be adopted when uncoiling manila rope and the same apparatus can be used. Besides having a turntable permanently installed in the Tackle Stores, it would be advisable to provide one on each large site.

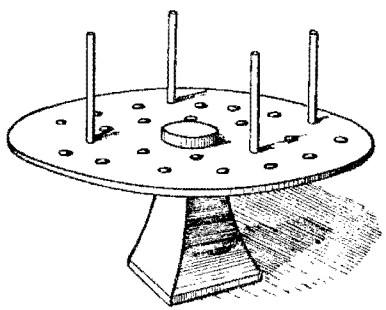


Fig. 5.03: Turntable for coiling rope

When a turntable is not available, an alternative method for uncoiling a rope is to upend the coil so that its axis is horizontal and then roll it along the ground, leaving the rope in a straight line on the ground behind it.

Similar care must be paid to the reverse procedure of re-coiling the rope. The rope is first laid out on the ground in a straight

line and then the turntable is used to wind it back into coil form again. When a turntable is not available for re-winding, an old drum can doubtlessly be found and used instead; but care must be taken to see that the drum is turned and that the wire is not merely passed over the top of the drum. Three or four pieces of wood should be placed against the drum, as shown in Fig. 5.04, before

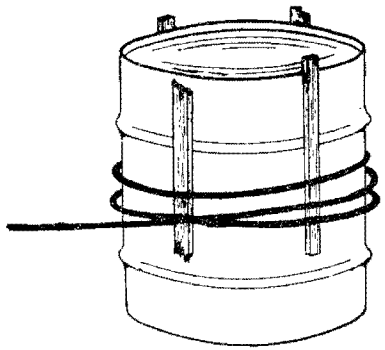


Fig. 5.04: An easily made substitute for a turntable

starting the coiling operation so that the wire can be easily lifted off the drum when it has been fully coiled. Whether a turntable or a drum is used for coiling the rope, the coil should always be lashed before being removed from the formers as otherwise it will immediately tend to uncoil again.

STORAGE OF WIRE ROPES

Ropes should always be stored in a dry shed and be so arranged that they are clear of the ground. If sufficient space is available, it is recommended that one section of the Tackle Stores should be set aside for this purpose. The tackle foreman should make regular inspections of all ropes in his care to ensure that they remain satisfactory.

WIRE ROPES FOR CRANES

Because of their high working speeds wire ropes used for all types of mechanically driven cranes are liable to have a short working life. Inspections, required by law in the Building Regulations, must therefore be made at frequent intervals. All remarks made about wire ropes generally apply also to ropes intended for use on cranes and other mechanical hoisting equipment.

TYPES OF ENDS FOR WIRE ROPES

The most commonly used ends for wire ropes required for erection purposes are: Bulldog connectors; thimbles; whippings. Bulldog

@Seismicisolation

connectors are described in Chapter 4 and the reader is advised to note carefully the instructions about fitting them.

Thimbles are used to terminate a wire rope, such as a hoist rope of a crane or the ends of certain types of slings. Some of the slings described later are fitted with thimbles and, as can be seen, reeving thimbles are of the same type—almost heart-shaped but somewhat larger to enable an ordinary thimble to be threaded through.

When a wire rope has to be cut on the site it should be securely bound each side of the proposed cut so that the strands do not fly apart on cutting. This binding is termed a "whipping". An alternative method, if the gear is available, is to use the oxy-acetylene cutting torch to melt through the wire, using the heating flame only, so that the strands weld together and do not fly apart. Preformed wire ropes have a set put in the individual wires during manufacture and there is consequently no tendency to fly apart.

ORDERING OF WIRE ROPES

When wire rope is ordered the manufacturers should always be given the following details:

- Length
- Size (circumference)
- Construction
- Quality
- Lay of rope
- Details of any splicings or special fittings.

KNOTS AND SPLICES

Where ropes are used, a knowledge of joining and fastening them is essential. All erectors should be able to make the various knots and lashings, and a man who cannot do so may be a danger to himself and others.

All guys and bracing wires used for erection work must be correctly tied, for otherwise trouble is bound to occur.

Brief descriptions of the uses of the most widely known knots are set out below and the drawings illustrate the finished knots. It is not recommended that a novice should attempt to make an important splice from the notes given but rather that he uses them as a guide for practice purposes only. An experienced splicer should then inspect his splices and give him valuable guidance.

BOWLINE

The bowline gives a perfectly non-slip loop which can be readily untied as can be seen from Fig. 5.05 (a).

@Seismicisolation

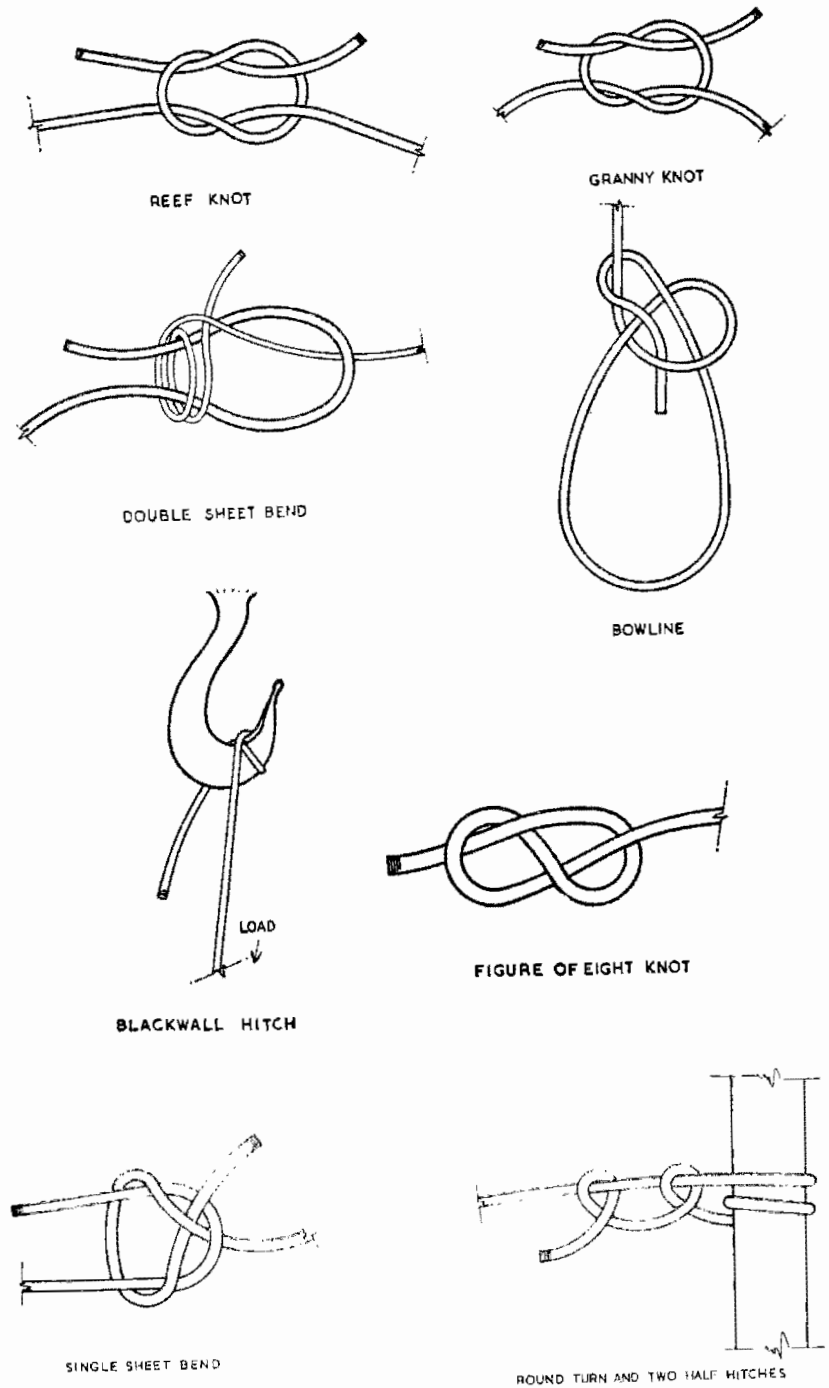


Fig. 5.05 (a): A selection of useful knots in common use

FIGURE OF EIGHT KNOT

This can be tied at the end of a rope to prevent the rope from running out through a set of blocks.

SINGLE SHEET BEND

This knot is used for joining ropes of equal or unequal thicknesses and can also be used for attaching a wire to a loop in another rope. The arrangement of the knot can be seen from the illustration. The bight is made with one rope (the thicker, if ropes of two different thicknesses are being joined). The other rope is passed through this loop and taken round the loop and under itself, as shown.

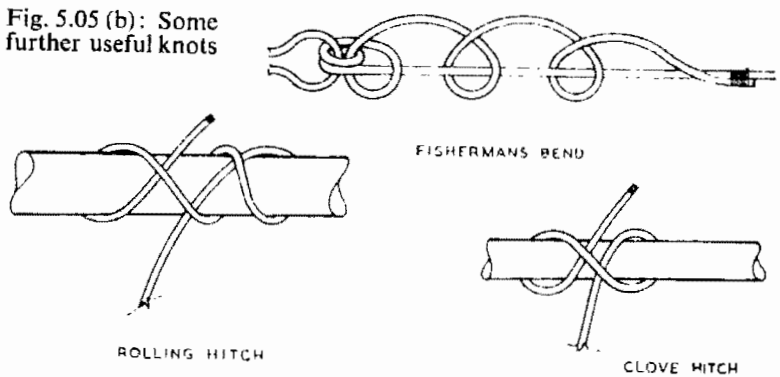
DOUBLE SHEET BEND

This knot is made in a similar manner to the single sheet bend but the second rope is passed twice round the loop and under itself each time.

ROUND TURN AND TWO HALF HITCHES

The knot is used to make a rope fast to a post or stake. As its name implies, the rope is taken completely round the anchorage. If a heavy load has to be taken by the rope, more than one round turn may be employed.

Fig. 5.05 (b): Some further useful knots



FISHERMANS BEND

This is an alternative to the round turn and two half hitches and is particularly useful where there is likely to be alternating slacking-off. The rope is double at the point of most strain.

BLACKWALL HITCH

The rope is crossed over the hook as shown. The loaded part of the rope bears on the tail and holds it firmly. The tail must

be held in position so that it does not move if the tension on the other part is temporarily released. This hitch is frequently made round the hook of the lower of a set of blocks so that it can be hauled down.

The hitch can also be used on a crane hook and the live part can be led away through a snatch block, from where it can either be taken to a set of blocks to haul the crane into a new position or used for other hauling purposes. The blackwall hitch must never be used for lifting.

CLOVE HITCH

The hitch is used to fasten a rope to a pole or similar object. It is also used to fasten the guys to the head of a wooden derrick pole. The clove hitch can easily be made in the centre of a length of rope by folding the loops over each other, and is often made thus when guying a derrick pole. In this case the two ends form separate guys.

ROLLING HITCH

This has an extra turn and is really a double clove hitch giving a much firmer hold.

STOPPER HITCH

The stopper hitch will be used when it becomes necessary to transfer the anchorage of a guy or other wire while it is still under load. With a steel wire guy a short sling chain will be used as a stopper. The chain is wrapped round the wire in the opposite direction to the lay of the rope and the end brought back and through the ring. The load can now be transferred to this chain and the anchorage changed. A short length of fibre rope is used to put a stopper on a fibre rope guy. This rope is taken round the loaded rope and a half hitch is made against the lay. The tail of the stopper is then wrapped several times round the loaded rope in the direction of the lay. The load can then be transferred to the stopper.

Knots in fibre ropes are easy to make and fibre ropes should therefore be used for practice until the movements are perfected. Wire rope, particularly in the larger sizes, is very stiff and considerable force is required to make the knots.

Until the full load is brought on to the knot in a wire rope the parts are liable to spring open and slide over each other, and so become loose. To prevent this each loose end should be taken round the loaded part in two half hitches and the ends seized to the loaded part as indicated in the sketch of the fisherman's bend.

@Seismicisolation

WHIPPING A ROPE

The whipping is laid along the rope and about eight or nine turns are made round both the whipping and the rope, as shown in the first illustration of Fig. 5.06. A loop is then formed with end A and a further eight or nine turns are made at which point the end is

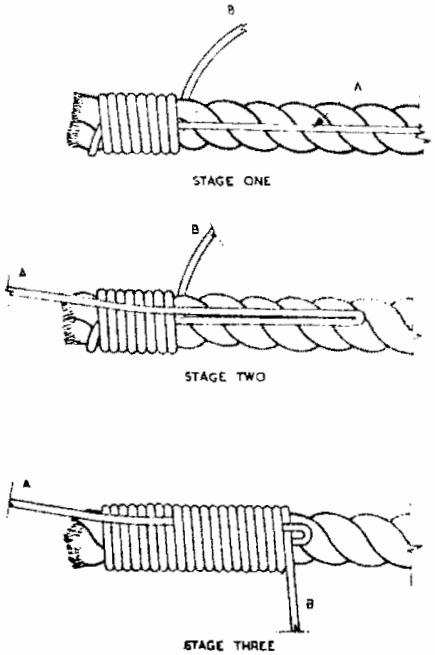


Fig. 5.06: Whipping a rope

threaded through the loop. Pulling on end A will pull end B under the whipping and thus secure it. The ends of the whipping are trimmed flush to complete the work.

LASHING BLOCKS AND POLES

A short wire sling or sling chain is often used to suspend the top block from a wooden derrick pole. The sling is taken round the head of the pole, slipped through one eye or ring of the sling and hung over the crosshead as indicated in Fig. 2.03.

Occasionally a suitable sling is not available and the block has to be lashed to the pole. A clove hitch is made round the pole and the lashing wire taken round the hook and the pole alternatively in a figure of eight.

Two half hitches round the lashing complete the work—the end of the wire being seized in the usual fashion. A similar

lashing will bind two poles together when they are to be used as sheer legs. Fig. 5.07 illustrates both these lashings.

SPLICING

Splicing is the joining of two ropes without a knot and it gives a considerably stronger connection than is possible with a knot.

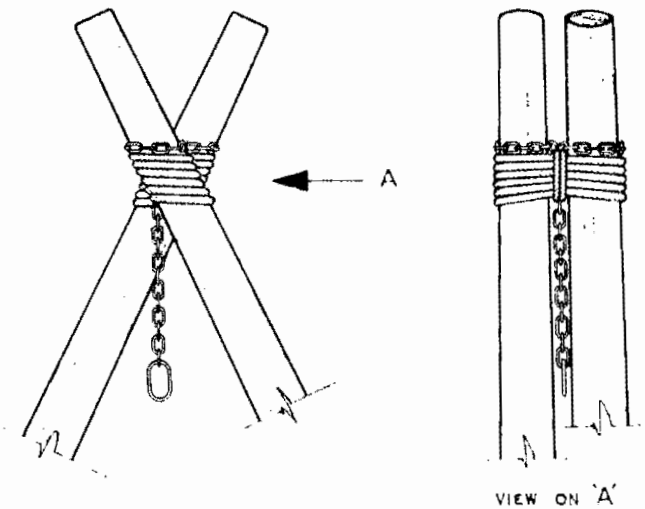


Fig. 5.07: Lashing sheer legs

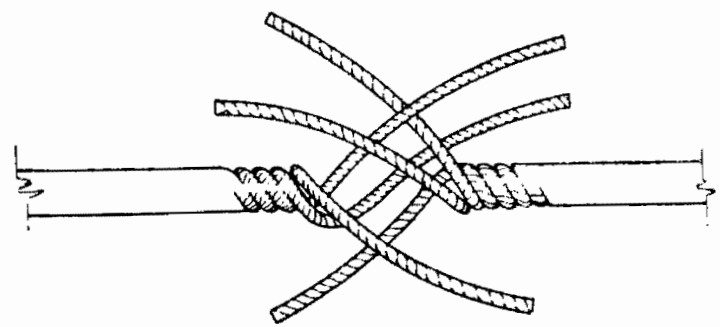


Fig. 5.08: Short splice

SHORT SPLICE

The strands of each rope are unlaid for a distance of about three times the circumference of the rope and the ropes are fitted together as shown in the sketch in Fig. 5.08. Next, each strand of the left-hand rope is passed against the lay over one strand on the right-hand rope and under the next strand. This is repeated with the

@Seismicisolation

strands of the right-hand rope. The strands are now halved and the whole operation repeated. Trimming completes the splice.

EYE SPLICE

The strands are unlaid for a distance of about three times the circumference of the rope. Making the size of eye required, strand

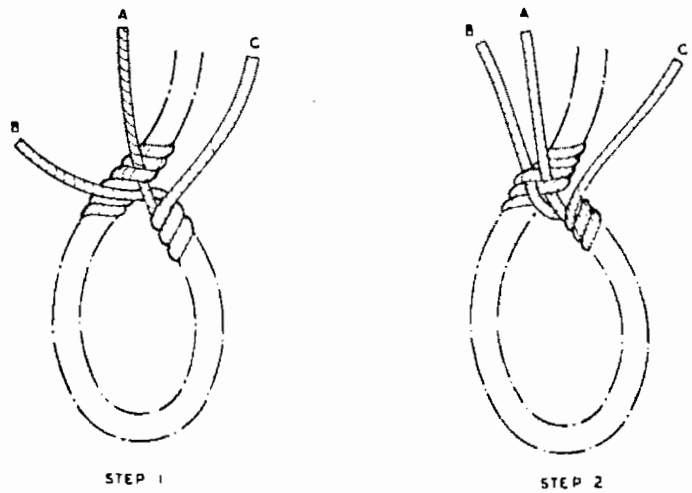


Fig. 5.09: Eye splice

A (Fig. 5.09) is passed under one strand of the standing part of the rope as shown; strand B is now passed under the next strand of the standing part as in the right-hand sketch; strand C is taken round the back and under the next strand of the standing part of the rope. Continue and finish as with the short splice.

LONG SPLICE

The length of a long splice is usually taken to be 7 ft for each $\frac{1}{8}$ in. of the diameter; i.e., for a $\frac{5}{8}$-in. rope the length of rope would be 35ft. A long splice will pass through a set of blocks, which a short splice will not do.

At half the length of the splice back from each end of the rope a temporary binding is made. At this point each alternate strand on both ropes is cut short and the two ropes forced together as in Fig. 5. 10 (a). The inner fibre core is cut away in both cases. With the rope married in this fashion the temporary bindings are removed.

One of the short strands on the right-hand side is unlaid and, as it is wound back, the long strand from the other side is laid in its place. This continues until nearly the full length of the long strand

has been laid. This is now repeated with one of the short strands of the left-hand side.

Repeat this operation again with one short strand from each side but only unlay for a distance equal to two-thirds of that which the first strand was unlaid. Repeat again with the remaining short strands but only for one-third of the distance. The remainder of the strands is trimmed off and the rope will be as in Fig. 5.10 (b).

At each point these short ends are pulled apart and the fibre core of the rope is cut through. The ends are then crossed again and tucked into the centre of the rope. A spike is forced through the wire and twisted and the strand laid in place of the fibre core which is removed as far as necessary. This is done in each case.

The splice is finished neatly (and the user is protected from injury from projecting ends of wire) by " parcelling " and "serving".

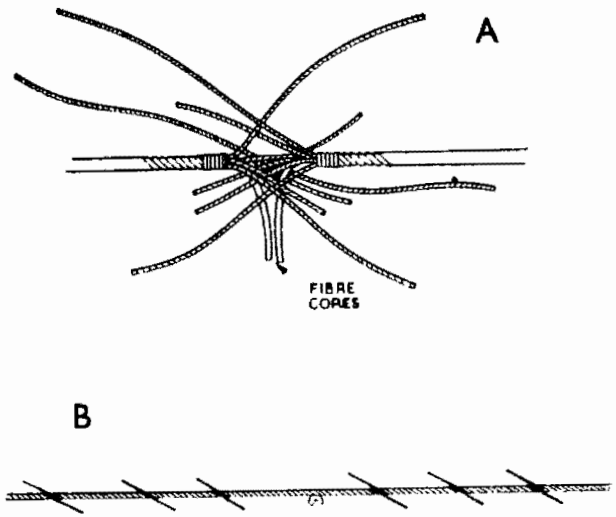


Fig. 5.10: Long splice

Parcelling is effected by wrapping strips of hessian or strong tarred paper the length of the splice to provide a good foundation for the serving. Occasionally a splice is " wormed " before parcelling. This means the filling of the strands of the wire with fine yarn to present a round surface to receive the parcelling. Both the parcelling and the worming are wrapped in the direction of the lay of the rope.

To complete the splice, spun yarn is lapped tightly round the parcelling. This binding is usually placed in position with a specially shaped serving mallet with a grooved head. The serving is wrapped

@Seismicisolation

Table 5.02. SAFE WORKING LOADS FOR WIRE ROPE SINGLE PART SPLICED SLINGS*

Permissible working load in tons	Minimum rope circumference in inches	Approximate diameter in inches	Minimum overall length in inches
1	1½	15/32	37½
1½	1¾	9/16	45
2	2	⅝	50
2½	2¼	¾	60
3	2½	13/16	65
4	3	15/16	75
5	3⅛	1	80
6	3⅜	1 1/16	85
8	4	1 5/16	105
10	4⅜	1⅜	110
12½	5	1 9/16	125
15	5½	1¾	140

* A minimum length is specified to ensure sufficient flexibility.

Table 5.03. SAFE WORKING LOADS FOR DOUBLE PART WIRE SLINGS*

Permissible working load in tons	Minimum single part rope circumference in inches	Approximate diameter in inches	Minimum overall length	
			Spliced endless in inches	Endless grommet in inches
1	1⅛	⅜	30	9½
1½	1½	15/32	37½	11½
2	1⅝	½	40	12½
2½	2	⅝	50	15½
3	2	⅝	50	15½
4	2⅜	¾	60	19
5	2½	13/16	65	20
6	3	15/16	75	23½
8	3¼	1 1/32	82½	26
10	3¾	1 9/16	95	29½
12½	4	1 5/16	105	33
15	4⅜	1⅜	110	34½

* A minimum length is specified to ensure sufficient flexibility.

in the opposite direction to the lay of the rope. Sometimes soft galvanized steel wire is used for serving instead of spun yarn.

SEIZING A ROPE

"Seizing" is the name for a type of whipping used to secure two ropes side by side. An eye is first formed in one end of the seizing. The two ropes are then held in position and the seizing taken round them—the plain end of the seizing being threaded through the eye at the other end and pulled tight. A series of turns is now made with the seizing, pulling it tight at each turn. The end is passed back under the seizing and through the eye. After pulling tight it is secured with a clove hitch and is tucked away.

WIRE ROPE SLINGS

Wire rope slings are much more in favour than chain slings. They are lighter and, in the longer sizes, are more flexible and handled more easily than a chain sling of comparable strength. The rope used for them is constructed to a similar standard to that for crane

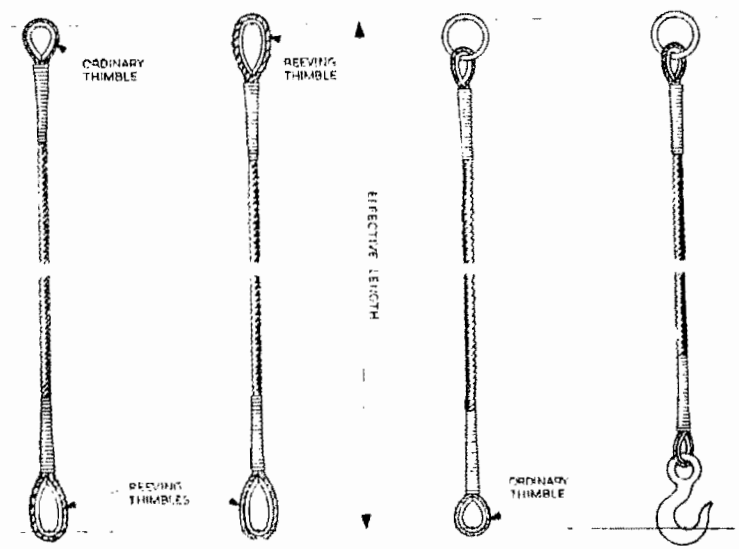


Fig. 5.11: Types of wire rope slings

work. The further advantage of wire slings is that they do not require the constant annealing that a chain must be given. A certain minimum length of rope is, however, necessary to allow sufficient room for the splice to be made satisfactorily.

The various forms of the one-leg sling are illustrated in Fig. 5.11. That shown at the right is handy for slinging small beams and the

@Seismicisolation

Table 5.04. SAFE WORKING LOADS FOR TWO-LEGGED WIRE SLINGS*

Permissible working load of one leg in tons	Permissible working load of two-legged wire sling if included angle of legs is as follows:									
	0°		30°		60°		90°		120°	
	ton	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*
1	2	0	1	18½	1	14½	1	8¼	1	0
1½	3	0	2	18	2	12	2	2½	1	10
2	4	0	3	17¼	3	9¼	2	16½	2	0
2½	5	0	4	16½	4	6½	3	10½	2	10
3	6	0	5	16	5	4	4	4¾	3	0
4	8	0	7	14½	6	18½	5	13	4	0
5	10	0	9	13	8	13	7	1	5	0
6	12	0	11	11¾	10	7¾	8	10	6	0
7½	15	0	14	9¾	13	0	10	12	7	10

* Note the rapid decrease in safe working loads as the angle between the legs of the sling is increased.

like. The safe working loads for these slings are given in Table 5.02. Figure 5.12 illustrates a double part spliced endless sling and also a double part endless grommet sling and their carrying capacities are set out in Table 5.03. As there is no splice as such in the endless grommet, this type of sling can be made to a very small overall length.

Two-leg slings, more commonly known as brother slings, are very handy for slinging beams and other sections which have to be placed horizontally. When using brother slings it must not be forgotten that the safe working load decreases very rapidly as the angle between the legs is increased. This is indicated very forcibly in Table 5.04, in which the safe working loads are given for various sizes of brother slings used with the legs at different angles to each other. Consider, for example, a brother sling composed of two legs each of 1-in. diameter wire rope. Each leg has a permissible working load of 5 tons. When the angle between the legs is zero, the safe working load of the complete sling is twice this or 10 tons; but when the angle is increased to 90°, the safe working load is only 7 tons 1 cwt, or about seven-tenths of the original! It is essential, therefore, that this included angle between the legs of the brother sling be kept to the minimum possible and that the reason for this be explained to all who may use these slings.

A chart prepared from Table 5.04 should be posted in a prominent position in all site cabins.

ARE OF WIRE ROPE SLINGS

All the points made earlier in this chapter regarding the care of ire rope apply equally well to the care of wire rope slings. Treated ith care, a wire sling will give a long period of satisfactory use. amage frequently occurs when objects with sharp edges are lifted. ften, due either to forgetfulness or to ignorance, such loads are ung without packing the wire off the sharp edges—a very angerous practice. A slight movement of the object while it is fted, or even merely its weight, can part the sling without warning. imber packings and sacking should therefore always be used.

RDERING OF SLINGS

The full requirements of the purchaser should be clearly stated hen the order is being made out. The main information needed is:

(a) Type of steel and construction of rope.
(b) Details of the ends required.
(c) Effective length of the sling (see Figs. 5.11, 5.12 and 5.13).
(d) Size of rope or safe working load required.

he sling will be received together with a certificate stating the ermissible working loads. This information should be entered n the plant card for the sling. If the sling has not been marked ith its capacity, this should be done at once—preferably with a etal tag.

SCAFFOLD WIRES

These consist of small-diameter wires, usually ¼ in., 5/16 in. or ⅜ in., tted with a thimble at one end and a ferrule at the other. The

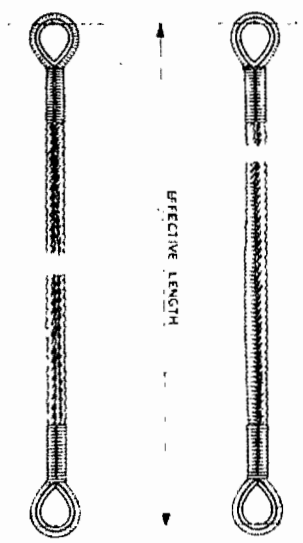


Fig. 5.12: Endless grommet and endless spliced wire rope slings

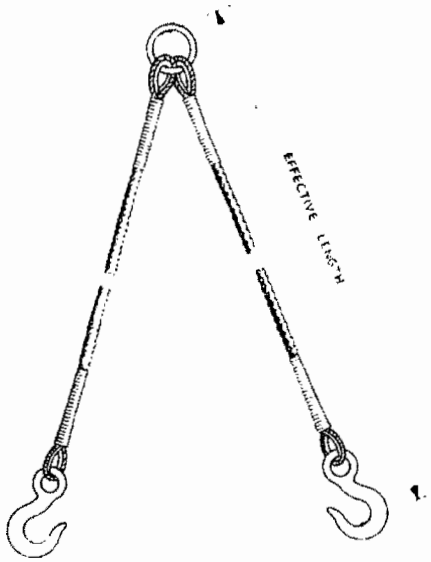


Fig. 5.13: Wire rope brother slings

@Seismicisolation

Table 5.05. SAFE WORKING LOADS FOR TWO-LEGGED CHAIN SLINGS*

Nominal diameter of chain in inches	Permissible working load of two-legged chain sling if included angle of legs is as follows:									
	0°		30°		60°		90°		120°	
	ton	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*	*ton*	*cwt*
$\frac{1}{2}$	3	0	2	18	2	12	2	2	1	10
$\frac{9}{16}$	3	15	3	12	3	5	2	13	1	17
$\frac{5}{8}$	4	12	4	9	4	0	3	5	2	6
$\frac{11}{16}$	5	12	5	9	4	17	4	0	2	16
$\frac{3}{4}$	6	15	6	10	5	17	4	15	3	7
$\frac{13}{16}$	8	0	7	14	6	18	5	13	4	0
$\frac{7}{8}$	9	2	8	16	7	18	6	9	4	11
$\frac{15}{16}$	10	10	10	3	9	2	7	8	5	5
1	12	0	11	12	10	8	8	10	6	0
$1\frac{1}{16}$	13	10	13	1	11	14	9	11	6	15
$1\frac{1}{8}$	15	2	14	12	13	2	10	14	7	11
$1\frac{3}{16}$	17	0	16	8	14	14	12	0	8	10

* Note the rapid decrease in the safe working loads as the angle between the legs of the sling is increased.

Table 5.06. SAFE WORKING LOADS FOR SINGLE-LEG CHAIN SLINGS

Nominal diameter of chain in inches	Permissible working load	
	ton	*cwt*
$\frac{1}{2}$	1	10
$\frac{9}{16}$	1	17
$\frac{5}{8}$	2	6
$\frac{11}{16}$	2	16
$\frac{3}{4}$	3	7
$\frac{13}{16}$	4	0
$\frac{7}{8}$	4	11
$\frac{15}{16}$	5	5
1	6	0
$1\frac{1}{16}$	6	15
$1\frac{1}{8}$	7	11
$1\frac{3}{16}$	8	10

length will vary but is generally about 15 ft. As their name implies, one of the main uses of these wires is to lash scaffolding into position but many other uses will always be found.

CHAIN SLINGS

Chain slings are a part of the tackle on almost every job and are widely used. Either standard or special grades of wrought iron are used in their manufacture, and the strength of the chain is measured from the diameter of the individual links. The effective length of the chain sling is measured similarly to that of wire rope slings.

USE OF CHAIN SLINGS

Care should be taken during the use of a chain to see that it is not damaged by bearing on sharp objects while under load. Particularly when it is used to lift a load with sharp corners, the chain must be properly packed with timber so that it is not strained. Note that when using two-leg slings the hooks must be turned so that they point outwards, i.e., away from each other.

Sling chains are made with the ring of a larger diameter than necessary so that it can be used over a hook intended for a larger safe working load. For instance, it is often necessary to use a 1-ton sling chain on the hook of a 5-ton crane. Chains with a ring too small for the hook must never be used, otherwise the ring may be permanently damaged even if it does not break at the time.

The safe working load of two-leg brother chains decreases rapidly as the included angle between the legs is increased. The dangers of this have already been shown in the case of wire rope brother slings but the subject is important and cannot be given too much attention. Another table, Table 5.05, has been prepared and should always be consulted before any important lift is made.

Sling chains must never be thrown to the ground after use as this can cause damage. All too often this damage is not seen at the time but is sufficient to cause serious trouble when the chain is used next. Frost in the chain can make the iron very brittle and, when commencing work on a frosty morning all chains should be carefully warmed to drive out the frost. Knots must never be tied in a chain.

ANNEALING OF CHAINS

Periodically all wrought iron chains must be annealed. The exact stipulations are detailed fully in Chapter 17, and the reader would be well advised to make himself fully acquainted with these requirements. In the case of chains this annealing process must be carried out every 14 months except when the links of the chains are constructed from bar of $\frac{1}{2}$-in. diameter or less. In this case the period between annealings is six months.

@Seismicisolation

CHAPTER 6

ERECTION OF TACKLE AND FALSE-WORK

THE correct tackle must be provided and used so that work on any contract can proceed smoothly and quickly. Erection of the steelwork can be seriously hampered unless this tackle is carefully erected and maintained in good order throughout the duration of the contract. Steel erection proper will not be able to commence immediately steel is delivered to the site unless the cranes or other plant are in position and in full working order. The foreman who is to have charge of the contract must therefore be sent to the site in advance, together with a small number of erectors so that all this preliminary work can be carried out without undue haste. Adequate time should be allowed for the erection of the tackle and it will usually be found that any additional expense incurred by this policy is well repaid by later results.

Plenty of work will await the preparation squad. All the temporary buildings, such as the site office, men's cabin, and store cabins will have to be erected, as well as the tackle. It is advisable to select a position where all these buildings can be grouped together. When this is done, a check can be easily kept on the items in the store. The client's site representative should be consulted before any of these buildings are erected so that he can suggest a suitable site where there will be no necessity for moving later to make way for any of the permanent structure.

TIMBER AND STEEL DERRICKS

A derrick, whether it is of timber or lattice steel construction, is almost certain to be required for even the simplest of erection work. Much work can be carried out using only the derrick. Although progress will be slow because the derrick has to be moved into position, usually by hand, before a lift can be made, there are occasions when derricks are worth their weight in gold. If other facilities are not available, a derrick will have to be used for the erection of the scotch derrick crane. Even when the crane is in commission, suitable derricks may still be required to reach distant corners of the work, or to help with the lift when it is beyond the capacity of the crane alone. When the derrick can be lifted about by mechanical means, placing and rigging occupies little time.

The method of erection will depend upon whether or not suitable lifting facilities are available. A crane or another derrick may be to hand, or possibly a set of blocks can be slung off an adjacent

structure. In these cases the erection will be a fairly simple matter. The derrick is assembled complete on the ground and fitted with the guys and blocks and lifted straight into the position required. Even when facilities for lifting the complete derrick are some distance away from the final position it is to occupy, it will usually be advisable to take advantage of them and erect the derrick as near as possible, afterwards "walking" it to its final position. Before attempting to lift the derrick the guying points will have to be prepared. Theoretically, only three guys are necessary to hold a derrick in the vertical position but at least one additional guy is always used for erection work. Six is the usual number. These extra guys share the load in certain positions and are a great help when the derrick is moved and the guys are changed.

The simplest kind of derrick consists merely of a timber pole which can readily be reared by hand. The lifting blocks should be reeved and slung at the top of the pole before rearing is attempted. They can be set block to block to keep their weight to a minimum, but do not forget to fasten a rope to the bottom block so that it can be hauled down when the pole is reared, otherwise someone will have to shin up the pole. Once this first pole has been reared, other and larger derricks can be lifted until the derrick required for the lift is in position.

Because of limited space, it is not always possible to erect a lattice steel derrick complete. In such a case the derrick must be assembled in its final vertical position. This is accomplished in a series of operations. First, the top section of the derrick is assembled on the ground and hauled vertical. This section is then lifted sufficiently for another section to be fitted underneath. The processes are repeated until the derrick is of the required height. When a derrick is lifted in this manner, it must be guyed both at the top and the bottom to hold it vertical. This method of assembly must also be used when the height of the derrick is such that it cannot be lifted in the normal way because it might bend or collapse.

GUY AND WINCH ANCHORAGES

It is essential that anchorages of any description should be selected and prepared with care. The failure of an anchorage under load can have serious consequences and it is therefore important that the strength is adequate. This applies to anchoring points for snatch blocks as well as for guys and winches. If it is possible to test an anchorage before it is put into use, this should be done. Inspections should also be made during use.

Either tee or angle section stakes are the most commonly used anchorages for light work. These can be quickly cut from scrap

@Seismicisolation

steel with the oxy-acetylene cutter. Lengths of about 5 ft are the most suitable for the usual run of work, and the end which is to be driven into the ground should be shaped to a point. After the stake has been driven to the desired depth, the guy wire is tied to it.

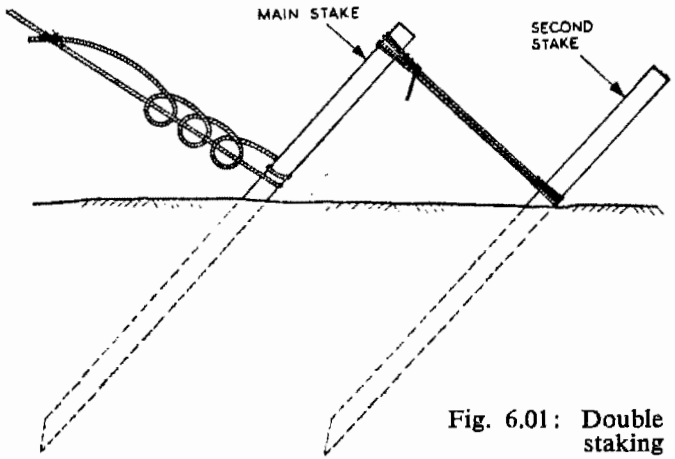


Fig. 6.01: Double staking

This fastening must be made as near the ground as possible, otherwise a very strong uprooting force will be exerted on the stake. If the ground or the loads on the guy are such that a single stake would not suffice, resort will have to be made to " double staking ".

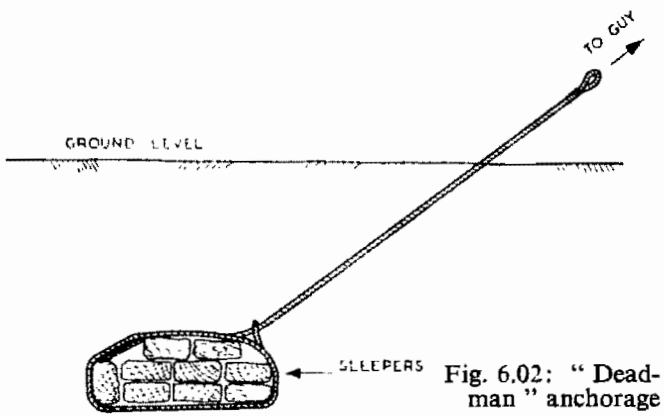


Fig. 6.02: " Deadman " anchorage

The second stake will be driven in the ground 2 or 3 ft behind the first, as shown in Fig. 6.01. Note from the illustration that the top of the front stake is tied to the back stake and, as in the case of the guy on the front stake, this fastening is made to the rear stake as near the ground surface as feasible.

If a very heavy load is expected from the guys, stakes may not provide sufficient anchoring force and the guys will be fastened

instead to " deadmen ". A deadman anchorage is illustrated in Fig. 6.02. It consists merely of steel rails, sleepers, or the like, buried in the ground and provided with some means of securing the guys. Concrete bases in adjacent sections of the building offer other facilities for anchoring, and a piece of angle or similar material is bolted to the holding down bolts and the guy is fastened to this with a shackle.

SCOTCH DERRICK CRANE ERECTION

On important work it is worth while to make a careful drawing showing the reach and headroom available to ensure that the crane is properly sited to cover the successive erection operations, including finishing the structure. Scotch derrick cranes may have to be erected and dismantled a number of times during a contract.

Table 6.01. SAFE SOIL PRESSURES

Type of soil	Safe pressure in ton/sq ft
Ordinary earth	½
Back-filling	⅓
Muddy clay	¼
Soft clay	1
Hard clay	3
Gravel	4
Soft chalk	1
Hard chalk	3–4

Precious days will be saved on these operations if all men employed are fully familiar with the work. With experienced men, this work will prove to be just a routine job and no difficulty need be expected.

Naturally the first step is to decide on the position of the crane and the decision will be governed by the room available on the site as well as by headroom considerations for the particular job in hand. The crane may be set up in a fixed position on the ground or building, or it may be carried on bogies and hauled along tracks as required.

Assuming that the crane is to be erected on the ground, the position of the bearings for the kingpost and sleeper-ends must be marked out and the ground at these points must be carefully brought to the same level. The loads from the crane will be concentrated and arrangements must be made to spread them to give a safe

@Seismicisolation

pressure on the ground. The crane makers will be only too pleased to give the maximum loads which occur at these points and, with the information on safe soil pressures given in Table 6.01, the size of foundation required can be readily calculated. If there is any doubt as to the safe bearing pressure of the soil in question, a low figure should be adopted so as to increase the foundation area. Specially prepared concrete foundations are advisable if the crane is to be erected in a fairly permanent position. If these foundations are made of suitable size, the leg of the crane can be anchored to them instead of using ballast. It must be fully understood that all these foundations are to be carefully levelled or difficulty can be experienced with the running of the crane.

Once this preparatory work has been completed, the erection of the crane can begin. The soleplate and racewheel are lowered on to a thin wood packing on the centre foundation and levelled in. The sleepers, or lie-legs as they are sometimes called, are now fitted

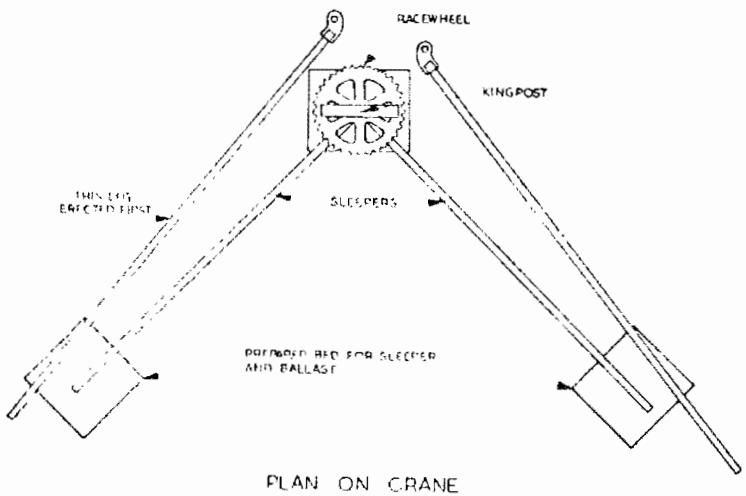


Fig. 6.03: Order of erection of a scotch derrick crane

to the soleplate and the levels of the whole checked. The mast is erected over the gudgeon pin washer with its sides packed up off the soleplate and, as it will not stand on its own, it must be either guyed or staked back to the sleepers with suitable poles. If poles are to be used in this manner, sufficient ballast must be placed on the sleeper-ends to prevent overturning of the partly erected crane.

The next operation is the fitting of the raker legs. On most makes of cranes these fit over a pin at the head of the kingpost, and the lower leg must therefore be fitted first. If this type of crane is being erected, the erector should stand between the sleepers of the crane facing the mast. The leg on his left-hand side should be

erected first. This instruction will be understood readily from Fig. 6.03. One or two makes of cranes have different connections at this point but examination will readily show the procedure to be adopted.

When the two raker legs and the mast-head nut and pin are in position, the assembly of the machinery on the mast can be put in

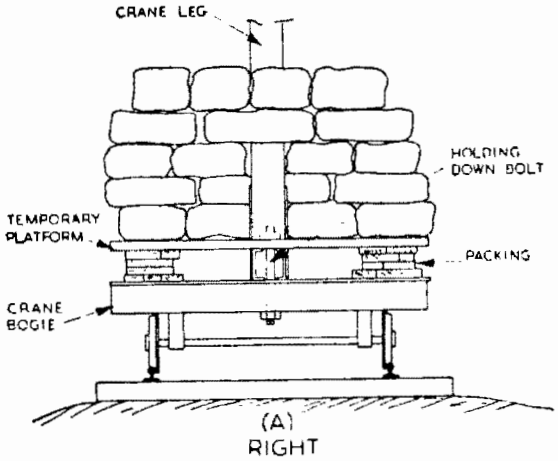


Fig. 6.04 (a): Correct stacking of ballast

hand. On most cranes this machinery has to be completely built up, and great care has to be taken to see that all bearings are correctly fitted and that the shafts revolve freely. Cranes with the gearing in one unit are easy to assemble, although the weight of the unit may prove a hindrance unless suitable lifting equipment is to hand.

While the machinery is being fitted, the remainder of the erection squad will have laid out the jib in front of the mast. The foot of the jib is then lifted into position and the jib pin inserted, after which the reeving of the wires can continue. When the wires are in position and the machinery is working, sufficient ballast should be placed on the sleeper-ends to enable the jib to be lifted. A severe strain may be put on the crane parts if the jib is lifted carelessly from the near-horizontal position in which it has been assembled. This strain can be considerably lessened if the jib-head can be raised somewhat before the weight is taken by the derricking wire. If another crane is to hand, it should be used to help with this operation.

It would seem appropriate here to say a few words on the ballasting of the sleeper-ends of a scotch derrick crane. Occasionally time is spent carefully ballasting the crane with the correct weight of material but, through ignorance of the real function of the

@Seismicisolation

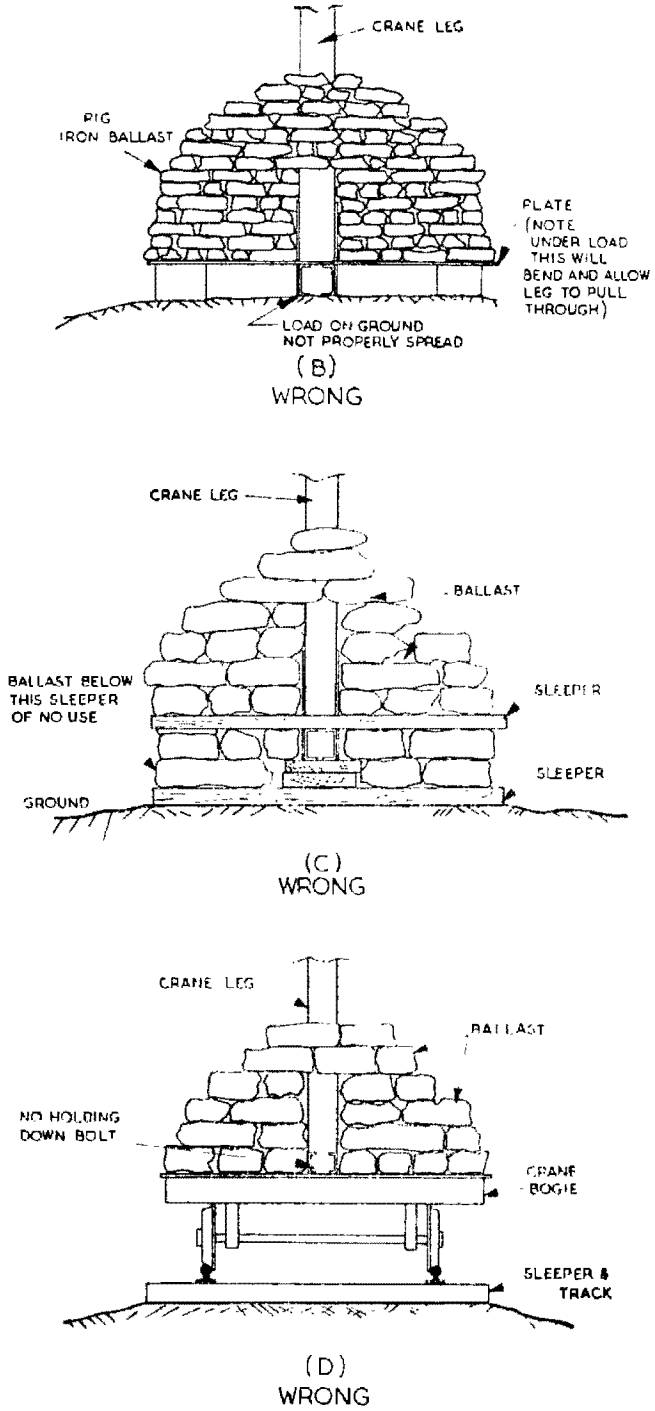


Fig. 6.04 (b, c, d): Incorrect methods of stacking ballast.

ballast, it is stacked in such a fashion as to be of little or no use. Correct and incorrect methods of stacking ballast are shown in Figs. 6.04 (a), page 73; and 6.04 (b, c, d,), page 74.

Examination of cases (c) and (d) shows that in the first instance only part of the weight of the blocks is fulfilling its purpose, and in the second case the weight of some of the ballast is carried on the bogie which is not fastened in any way to the sleeper leg.

If, during the erection of a building, a scotch derrick must be placed on the steel frame itself and the crane is only of light capacity, then it may be permissible to anchor it direct to the structural framework. When the crane is to be used to its full capacity, an uplift of about three times the load lifted can be expected at the ends of the legs. This will exert an upward force on the members to which the legs are attached. Therefore, when a heavy crane is used, the whole section of the building involved must be checked to see that it will withstand this load. If this check shows that there is no danger, then it will be in order to proceed but, of course, all connections should be inspected to ascertain that they are fully bolted or riveted, as the case may be.

SCOTCH DERRICK CRANES ON PREPARED TRACK

Any tracks that are used to move the cranes to different sections of the building must be carefully laid, otherwise movement of the crane is seriously hampered and valuable time lost. Errors in the preliminary laying of the track have a habit of increasing as the cranes are travelled and, in bad cases, the cranes may have to be partially dismantled before the track can be corrected. The centre line of each track should first be marked with a row of pegs accurately set by a theodolite and care should be taken to ensure that all the bogies are parallel, so that the crane will run to the given line.

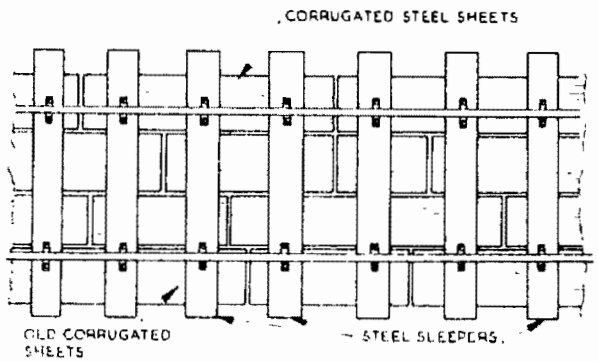
Flat-bottomed rail is always used and the sleepers may be either steel or timber. These sleepers will be spaced about 30 in. apart, depending upon the nature of the ground and, if the track is well laid, the rail need only be fastened to alternate sleepers. Steel sleepers last better than the timber variety and should be obtained if at all possible. The rails are fastened to the timber sleepers by dogs, and to the steel sleepers by clips and bolts. When lifting facilities are available, whole sections of track can easily be moved about the site without having to be stripped down.

If the track is well packed against possible subsidence, no trouble need occur. When soft ground is encountered, however, other provisions will have to be made to prevent the ground from sinking. Fig. 6.05 shows two useful measures that can be adopted. Either old corrugated sheets are laid under the tracks, or timbers are laid

@Seismicisolation

longitudinally. It is surprising how very effective these elementary provisions can be.

At times it becomes necessary for the track of a scotch derrick crane to span ducts or ground irregularities. Small spans will be covered by merely laying the beams across underneath the rails but something more elaborate will be necessary with larger spans.



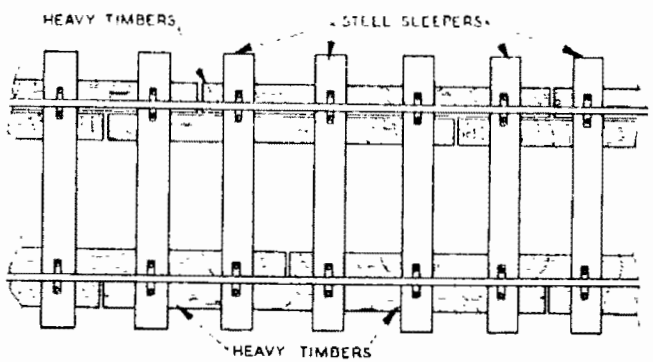


Fig. 6.05: The prevention of ground subsidence

The beams required for this purpose will be selected from Table 6.02 by considering the load from the crane bogie as being concentrated at the span centre.

If these beams are to be provided merely for moving the crane across the opening (i.e., the crane is not required to work with the bogies stood on the beams), the weight to be allowed for is only that of the crane and ballast. When the crane is operating, additional loads are thrown on the bogies and, if this condition is likely to apply, allowance should be made when calculating the size of the beams.

Inspection of Table 6.02 shows that, over the same span, the beams suitable for carrying the heavier loads are of a greater depth than beams which would be suitable for lighter loads. This increase in depth will make the beams more liable to be unsteady, and the deep beams will require some form of cross-bracing. This bracing should be spaced about 5 or 6 ft apart, depending upon the beams selected and the span, and bolts should be used so that the whole can be dismantled when the bridging is complete. If drilling of the

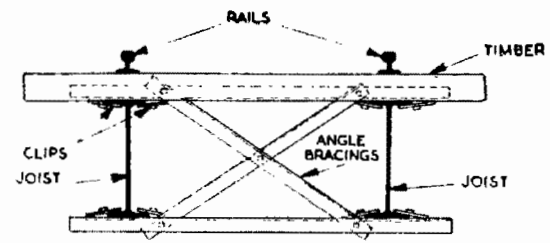


Fig. 6.06: Temporary bracing for deep beams

beams has to be avoided, some form of clamping, such as that suggested in Fig. 6.06, should be adopted.

Table 6.02. CARRYING CAPACITIES OF ROLLED STEEL JOISTS*

Section of joist in inches	Safe point loads in tons at span centre with spans of following lengths:										
	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft	24 ft	28 ft	32 ft	36 ft	40 ft
8 × 5	9·4	6·2	4·8	3·7	2·9	2·3					
8 × 6	9·5	7·9	6·2	4·7	3·7	3·0					
10 × 5	9·7	8·1	6·9	6·0	4·8	3·9					
10 × 6	13·6	11·3	9·7	8·5	6·7	5·4					
12 × 5	12·2	10·2	8·7	7·6	6·8	5·8	4·0				
12 × 6L	17·5	14·6	12·5	10·9	9·7	8·4	5·8				
14 × 6L	21·0	17·5	15·0	13·1	11·7	10·5	8·1	6·0			
15 × 6	21·8	18·2	15·6	13·6	12·1	10·9	9·1	6·6	5·1		
16 × 6L	25·7	21·4	18·3	16·0	14·3	12·8	10·7	8·4	6·4		
18 × 6	31·1	25·9	22·2	19·4	17·3	15·5	12·9	11·1	8·7	6·9	5·6
20 × 6½	40·8	34·0	29·1	25·5	22·7	20·4	17·0	14·5	12·7	10·0	8·1
22 × 7	50·5	42·3	36·2	31·7	28·2	25·4	21·1	18·1	15·8	13·8	11·1
24 × 7½	70·0	58·5	50·0	43·9	39·0	35·1	29·3	25·1	21·9	19·5	16·8

* The loads to the *left* of the heavy zig-zag line exceed the bearing capacity of the web of the plain joist without allowance for dispersion of load to the top flange or actual length of bearing.

@Seismicisolation

GUY DERRICK CRANE ERECTION

The question of the bases and the guy anchorages for the guy derrick crane will have been discussed with the building contractor at an early stage of the contract. This will have enabled the anchorages to be cast at the same time as the main concrete foundation work. A prepared base will be required for the foot of the mast and the motor platform, as well as anchorages for the guys.

The maximum load from the mast is the total of the weights of the mast, jib, and a proportion of the weights of the guys, as well as the maximum load that may be lifted. A side thrust is also present when the jib is picking a load out at a radius. The designer will be able to state whether the floor slab will be able to carry these loads at the point selected. If not, it may be possible to strengthen it.

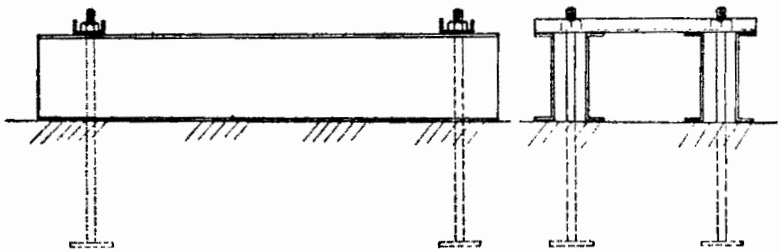


Fig. 6.07: Anchoring the foot block of a guy derrick

The footblock of the guy derrick is usually constructed as illustrated in Fig. 6.07 and, when the details are known in advance, locating bolts can be set in the concrete slab. These will hold the footblock against any side thrust from the jib and also counteract the pull on the wires to the motor. The bolts are burnt off flush with the concrete after use.

A steel reinforcing rod, bent to the shape shown in Table 6.03, is suitable for the construction of a guy anchorage. The minimum length anchored in the concrete must be maintained so that the rod will not pull out. The block holding the pin must also be heavy enough to make a suitable anchorage. Table 6.03 will assist with the design of the anchorage pins. The machinery frame can be anchored with similar, but smaller, rods.

Care must be taken that the footblock is truly level and that the machinery platform is in its correct position. The wires should lead evenly on to the barrel. The machinery platform must not be too close to the foot of the mast so that there is some " give " in the wires. About 30 ft is satisfactory. Unless provision is already made, the machinery and driver's position will have to be protected from the elements. This will restrict the field of vision of the

driver and he will take all signals from the man who operates the slewing of the mast.

The mast will be erected by crane or by another and smaller steel derrick. It will then be securely guyed off in all directions. The jib can next be assembled and lifted. In this case the lifting blocks will be slung from the mast. Care must be given to the reeving of the hoisting and derricking wires which must be run on evenly, otherwise the blocks will be twisting continually as they run up and down. The mast should now be rotated and checked for being truly vertical with the jib opposite each guy in turn. Plumbing of the mast can be effected by the turnbuckles which are used at the ends of each of the guys. The " jumping " of the guy derrick crane to a higher level is described in the next chapter.

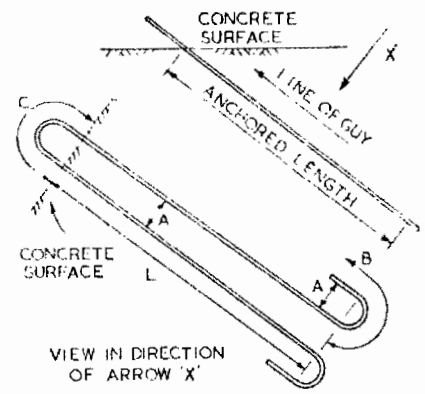
TRESTLING AND FALSE-WORK

Almost every contract of any size will require some kind of trestling or false-work, whether it is to lift the cranes well above ground level so that a high section of the building can be erected, or to support a member that is being assembled in its final position. Trestles used to carry a crane can be mounted on bogies, if required, and the whole structure, including the crane, can be moved along the building as erection proceeds. The crane will be fastened to the trestle and the ballast can be placed at the foot of the trestle, providing that the connections between the crane and trestle are strong enough to carry the uplift.

It should be noted here that, when towers and trestling are being

Table 6.03. THE DESIGN OF ANCHORAGE PINS*

Diameter of guy in inches	Permissible load on guy in tons	Diameter d in inches	Minimum anchored length L in inches	A in inches	B in inches	C in inches	Total minimum length in inches
½	1·4	½	20	2	10	16	56
⅝	2·2	½	24	2	10	16	60
¾	3·0	⅝	26	2½	11	17	65
⅞	4·1	¾	32	3	12	18	74
1	5·4	⅞	36	3½	13	19	81



* (i) Concrete to be best quality 1 : 2 : 4 mix.
(ii) Guys to be steel wire ropes, 6 × 37 construction, of best plough steel.
(iii) Anchorage rods to be inclined in plane of pull on guy.

@Seismicisolation

designed to carry cranes and similar lifting appliances, due allowance must be made for the slewing loads which will occur when the crane is in use. On high structures, and especially those on exposed ground, the pressure exerted by the wind will be appreciable and must be considered. Table 6.04 gives approximate wind pressures at various heights.

The carrying capacities of the common sizes of rolled steel joist are set out in Table 6.02. The figures given are for point loads at the centre of the span and can be doubled if the load is uniformly distributed over the full length of the span. When selecting beams from the table, and also in the design of all erection tackle and false-

Table 6.04. WIND PRESSURES*

Height above ground in feet	Pressure in lb/sq ft
0–50	20
50–100	30
100–150	35
150–200	40

work, due allowance must be made for the unforseen loads which must often be borne. Loads from erection gear can never be predicted with the same certainty as those in the design of other steel structures, and allowance should also be made for the rough handling which erection gear may receive on the job site.

The foundation for any trestle must be perfectly level and firm, so that the expected load from the trestle can be carried safely. Unless the foot of the trestle rests on rock or concrete, it is useless to support it merely at the corners. Instead a "raft", as it is called, should be used. This covers the whole area of the trestle and extends beyond so that the load on the ground is less than the safe bearing pressure of the ground. Fig. 6.08 shows a raft under a trestle.

When designing trestling for a particular requirement, it is always advisable to have it fabricated on a unit basis so that all sections will be interchangeable. Nothing is more annoying when trestling is urgently required for a contract than to find that the trestling available will not fit. Cutting it to suit will perhaps only make it useless

* In very exposed locations local guidance should be sought and local records checked.

for a future job. If possible, the trestling should be so designed that the height can be varied in steps of as little as 6 in. This will prove to be sufficient variation for any work as smaller variations of heights can be obtained by using packings.

Because of the scarcity of suitable timber and its high price, this material is not commonly used for the construction of trestling or

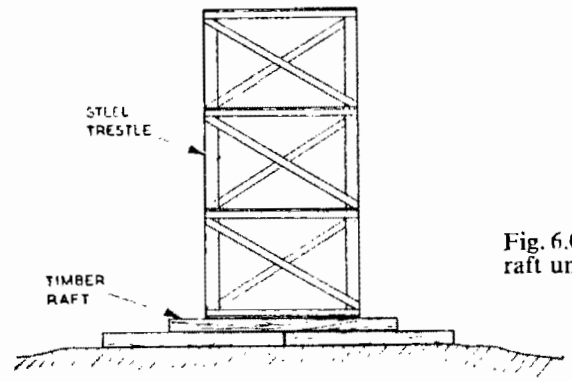


Fig. 6.08: Timber raft under a trestle

false-work in this country. In some parts of the world, however, timber is found in abundance. In such places it will be used almost exclusively as it can be quickly cut to size on the site so that all varieties of false-work can be made. When appreciable loads are to be carried by the timber structure, its design is a matter for an engineer whose advice should always be sought. Special connectors are available for timber joints, and the use of these is always advisable in place of bolts alone.

TACKLE LISTS

The following lists are set out to indicate the tackle required to undertake the erection of certain buildings. They are intended as a guide only and must be modified to suit individual requirements.

1. Basic necessities for each job:
   - Time books
   - Note books
   - First Aid Box
   - Fire extinguisher with refills
   - Building Regulations and Factories Acts posters (for display)
   - Cabin with table and seats
   - Stove
   - Bucket
   - Kettle
   - Wash basin
   - Soap
   - Tackle requisition book
   - Tackle advice books

@Seismicisolation

2. Tackle for the erection of 40-ft span Truss Building. Height to eaves 20 ft, and to apex 30 ft.

1	Timber derrick pole, 35 ft long—6-in. diam. at top
4	Rope guys, 80 ft long—2⅜-in. circum.
6	Angle stakes, 5 ft long
1	1-ton Winch with 250-ft wire bond ½-in. diam.
2	1½-ton Wire slings × 4 ft
1	1½-ton Sling chain
1 set	Luff tackle—20-ft drift
6	Scaffold poles
2	60-ft Tail lines
1	25-ft Ladder
4	2-ton D-shackles
6	9 in. × 3 in. Timbers
1	Timber cabin with padlock
1	Large toolbox with padlock
1	14-lb Hammer with spare shaft
2	Hand hammers with spare shafts
2	Pinch bars
2	Heel wedges
12	Podger spanners 4—⅞, 4—¾, 4—⅝
12	Taper drifts 4—⅞, 4—¾, 4—⅝
12	¼-in. Wire lashings
12	⅜-in. Wire lashings
2	Union screws

Also basic necessities as listed above

3. Tackle for the erection of 80-ft span building with crane girders maximum lift 5 tons.

1	5-ton Scotch derrick crane with all mechanical and electrical gear, 100-ft jib, 42-ft pin centres
3	Bogies to suit, with crane holding-down bolts
30 tons	Ballast
12	20-ft Lengths F.B rail, 6 in. deep.
2	10-ft Lengths F.B rail, 6 in. deep.
50	Steel sleepers
200	Rail clips with bolts
20	Steel fishplates with bolts
1	3-ton Scotch derrick crane, 60-ft jib, 25-ft pin centres
1	400-ft Coil cable with switch and switch box
1	Cabin (for office) with tables, chairs and drawing racks
1	Large cabin for men with tables and benches
1	5-ton Brother chains with 20-ft legs
1	5-ton Sling chain × 15 ft long
2	3-ton Wire slings × 8 ft long
1	3-ton Sling chain × 10 ft long
2 sets	Luff tackle with 20-ft drift
1	Two-wheeled bogie
4	150 ft × ⅝ in. Wires.
1	200-ft Coil soft rope, 2-in. circum.
36	¼-in. Wire lashings
36	⅜-in. Wire lashings

12	9 in. × 3 in. × 15 ft Battens
24	Timber sleepers for packings
2	5-ton Screw jacks
6	25-ft Scaffold poles
1	25-ft Ladder
1	Large toolbox
2	5-ton Shackles
2	3-ton Shackles
2	14-lb Hammers with spare shafts
6	2-lb Hand hammers with spare shafts
24	Podger spanners 8—⅞, 8—¾, 8—⅝
24	Tapered drifts 8—⅞, 8—¾, 8—⅝
2	Side sets
2	Cold chisels
4	Heel wedges
4	Union screws 3 tons SWL
4	Steel rollers
1	Hand-drilling gear stand
1	Ratchet
1	Clamp
12	Square shank drills 4—$\frac{15}{16}$ in., 4—$\frac{13}{16}$ in., 4—$\frac{11}{16}$ in.
1	Paint pot
2	Paint brushes (4 in.)
1	2-ton Winch with 400 ft × ½ in. wire bonds
2	1-ton Snatch blocks
2	Shovels
1	Jim Crow

Burning Gear as set out in Chapter 12
Surveying Gear as set out in Chapter 13
Riveting or Welding gear if required
Also basic necessities as listed above

4. Tackle for the erection of Garage building with 100-ft span lattice girders, weight 20 tons each, overall height of building 30 ft.

1	Mobile crane to lift 2 tons with 40-ft jib with toolbox and other gear
2	Lattice steel derricks to lift 12 tons at 40 ft
2	Footblocks to suit
2	Head shackles
2 sets	10-ton Three- and two-blocks
2	10-ton Shackles
2	10-ton Wire slings × 8 ft
4	2-ton Snatch blocks
10	Wire guys 100 ft × ¾-in. diam.
24	Bulldog grips to fit ¾-in. wire
2	3-ton Winches with 350 ft wire bond ¾-in. diam.
24	Timber packs 6 ft × 12 in. × 12 in.
12	Timber sleepers
1	Cabin for office with tables, chairs and drawing racks
1	Large cabin for men with tables and benches
1	2-ton Brother chains with 20-ft legs
2	2-ton Wire slings × 8 ft
2	2-ton Sling chains × 10 ft
4	35-ft Timber poles with 6-in. tops

@Seismicisolation

12	Angle stakes × 5 ft
2 sets	Luff tackle 20-ft drift
1	Two-wheeled bogie
4	150 ft × $\frac{5}{8}$ in. Wire
1	200-ft Coil soft rope 2-in. circum.
4	Heel wedges
36	$\frac{1}{4}$-in. Wire lashings
36	$\frac{3}{8}$-in. Wire lashings
12	9 in. × 3 in. × 15ft Battens
2	25-ft Ladders
1	Large toolbox
2	14-lb Hammers with spare shafts
6	2-lb Hand hammers with spare shafts
24	Podger spanners to suit
24	Tapered drifts to suit
2	Side sets
2	Cold chisels
4	Steel rollers
1	Hand-drilling gear stand
1	Ratchet
1	Clamp
12	Drills 4—$\frac{13}{16}$ in, 4—$\frac{13}{16}$ in, 4—$\frac{11}{16}$ in.
1	Paint pot
2	Paint brushes (4 in.)
4	Union screws
2	Shovels
1	Jim Crow

Burning Gear as set out in Chapter 12
Surveying Gear as set out in Chapter 13
Riveting or Welding Gear if required
Also basic necessities as set out above

POINTS TO NOTE

1. Erection gear and trestling is erected and dismantled throughout its life. Take care it is not damaged in handling.
2. Erection derricks and cranes should not be used when any of the structural members are damaged.
3. All splice material must be inserted and all bolts tightened.
4. Electrical gear must be protected from the weather. Similar protection should be given to the remainder if possible.
5. Select the correct plant for the work. Never overload the gear.
6. With derricks and guy derricks, check that the anchorages are adequate.
7. With scotch derrick cranes, be sure that the correct amount of ballast is used and that it is correctly stacked.
8. When using track for a scotch derrick crane, be certain that it is correctly set and soundly packed.
9. Be sure that all timber used, whether for derrick poles or packing, is perfectly sound.

@Seismicisolation

CHAPTER 7

THE ERECTION OF BUILDINGS

STEEL framing is often selected as the basis for a particular building because of the speed with which the site erection can progress, enabling the other trades engaged to follow very closely behind. This is made possible by the amount of prefabrication which can be undertaken before work actually starts on the site. Reinforced concrete and other forms of construction, with the exception of some precast work, do not possess this advantage. Where the client is paying high charges for his land, the time taken for construction of the proposed building is a very important consideration, for, until the building is in commission, he is gaining no benefit. The erection supervisor's responsibility is to ensure that no time is lost when the erection does commence and he will have to plan his work carefully and well in advance.

ERECTION METHODS

The erection of some type of steel-framed building will be the erection engineer's most frequent assignment. It is difficult to describe every conceivable mode of erection likely to be met on building construction work for the simple reason that the majority of buildings are purpose-made and are therefore rarely identical. Even when identical buildings have to be erected, the chances are that site conditions will vary to such an extent that different erection procedures have to be adopted. For instance, on one site it may be possible to deliver lattice girders completely assembled while on another site, because access is difficult, lattice girders forming part of an identical structure have to be delivered piece-small. In addition to these restrictions the client's requirements often demand alterations to what would be the most suitable programme for the erector.

Methods of erection are changing constantly. Different firms and erection engineers will always have different methods of undertaking the same work. No hard and fast rules can be laid down, and the method of erection selected will depend upon the tackle that is available at the time the work has to be commenced as well as upon the capabilities of the men in charge of work on the site.

A general survey of buildings would show that, for describing erection procedures, two general classifications could be made.

Multi-storied structures, where the greater part of the construction is composed of beams and stanchions, will be called "office" buildings, and one-storied structures with a trussed or portal-framed roof, usually of large span, could be placed in the second classification of "shed-type" buildings. It will be impossible to classify every structure into one or the other of these groups as many buildings do not consist of purely one type of construction. A garage with a trussed span of, say, 40ft supported on steel stanchions would be a typical shed-type building, yet in the same structure there may be an office block at one end representing a considerable percentage of the total tonnage. This office section is likely to be of beam and stanchion construction. In cases where the tonnages involved are only small, the same tackle would be used for both sections. On larger structures the erection procedure would vary according to the work on hand.

OFFICE BUILDINGS

The space available to the erector will largely govern the selection of the procedure to be used. For example, if the site is in a heavily built-up area and is closely bordered by existing buildings, the method adopted may differ from that which would be chosen if the building were on an open site. In the first case the crane, or whatever tackle is to be used, would have to be situated within the area of the building itself and would have to be lifted to higher floors as the erection progressed. On an open site, where sufficient room is available, the cranes could be mounted on tracks on the ground, possibly outside the area of the structure, and could be moved the length of the building if required.

Where the storage space is severely limited, it is imperative that the steel for each section of the structure be carefully scheduled so that only the amount immediately required for the work in hand is sent to the site. It is also essential that the steel arrives at the correct rate for economical erection.

The main points to consider when selecting tackle for any particular construction work will be:

(a) Proposed method of erection
(b) Speed of erection required
(c) Height of the structure
(d) Reach required of the tackle
(e) Weights and number of the maximum lifts.

The tackle for work on an office building of normal construction will generally be a mobile crane, or a scotch derrick crane, or a guy derrick crane. In isolated instances a steel or timber derrick pole

may be used but this is now very uncommon due to the inherent slowness of work with this type of tackle.

ERECTION BY MOBILE CRANE

Provided that conditions permit its use, the mobile crane is ideally suited for almost any type of erection work. It can commence work immediately it is delivered to the site and when it has completed the work it can be despatched to another site within a matter of hours. Its main disadvantage, when used for office building construction, is that it cannot pick loads approaching its maximum capacity unless it is standing close to the point of lift. In other words, its reach is very small and compares unfavourably with that of a scotch derrick crane of similar lifting capacity. Therefore, if the foundation work on the building is such that the crane cannot move into a suitable position for every lift its use may not be advisable.

Often the office type of building has a basement extending over the whole of the area, with the ground-level floor supported on the steel frame. When this is the case, the use of a mobile crane is unlikely to be practical unless there is some convenient method of moving the crane onto the basement slab or working it either off the structure or off temporary trestling.

A mobile crane can seldom be obtained with a jib length of over 80ft, and this jib length naturally governs the height of the building that can be erected with the crane at ground level. For buildings that are only slightly higher than the reach of the crane at ground level it is often worth while to consider the cost of erecting as much as possible with such a crane and erecting the remainder of the structure with a small scotch derrick crane mounted on top of the completed portion. All the necessary steel could then be placed within reach of the scotch derrick crane by the mobile crane. When a few feet of extra headroom are required for an individual lift, it is a simple matter to construct a suitably sized packing at the point of lift and run the crane on to this before hoisting the load.

When a mobile crane is employed for the erection of an office building each tier of the structure should be completed from ground level to roof before the next tier is commenced, as illustrated in Fig. 7.01. Bearing this in mind, deliveries of steelwork will have to be scheduled accordingly. A continual site check on all steel deliveries is necessary as the omission of one single piece would seriously hinder the erection work or could even halt it completely.

Crawler tracks are advisable as standard equipment on all mobile cranes used for steel erection purposes. The rate of movement of the crane is lessened when it is equipped with these tracks but

@Seismicisolation

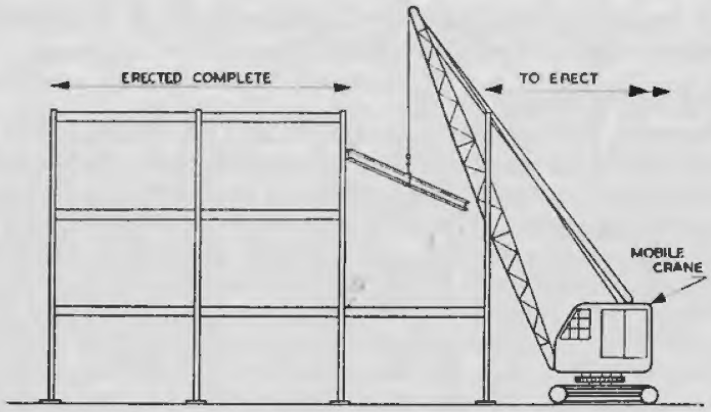


Fig. 7.01: Office building construction using a mobile crane

increased stability results. Crawler tracks are indispensable when the crane has to be worked over the hard-cored ground surface which is usual on building sites. Even when mobile cranes have to be used on a concrete floor, these tracks will not mark the surface unduly and the crane's weight will be spread more satisfactorily. If, as occasionally happens, the finished surface has been applied to the concrete before the erection commences, precautions must be taken to prevent damage. In such cases a rubber-tyred model could be used, but should such a model not be to hand a tracked model could be run over a carpet of timber sleepers, as shown in Fig. 7.02.

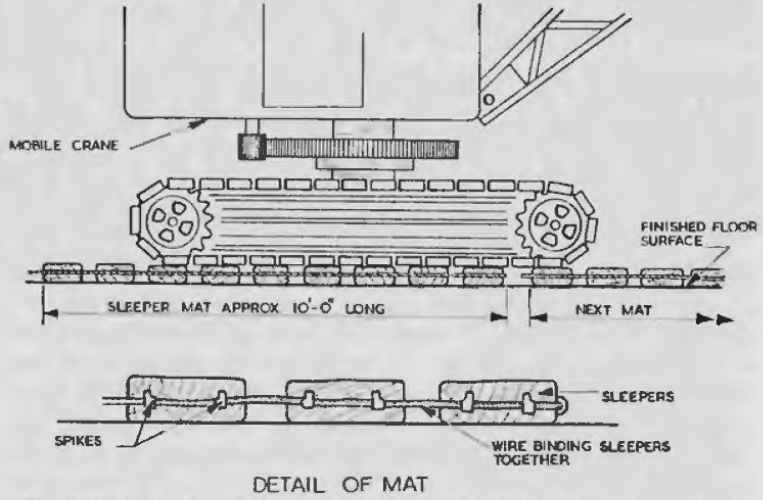


Fig. 7.02: Sleeper mats to prevent damage to a finished concrete surface

ERECTION BY GUY DERRICK CRANE

Whether the erection is to be carried out by guy derrick or scotch derrick crane, the first consideration will be the assembly of the necessary tackle on the site. If the stanchion bases are at ground level and a suitable finish (hardcore or concrete) has been laid there will be no problem. If, on the other hand, the building has a basement extending over its whole area the erector is immediately faced with a problem. If the site is in a congested area, this problem is further complicated. Off-loading of plant and material has often to be undertaken inside the building area in such cases.

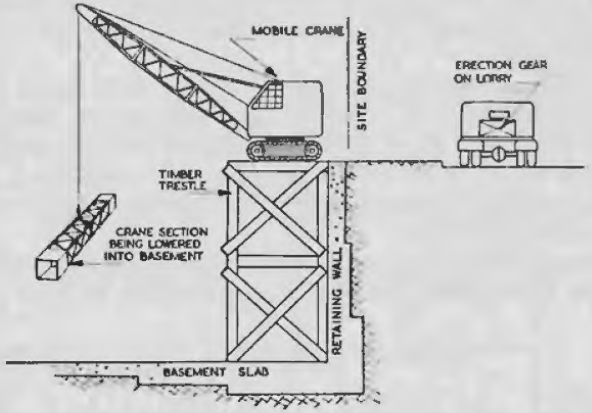


Fig. 7.03: Mobile crane on a trestle for offloading into a basement

If space permits a small crane, either a hand-operated derrick crane or a mobile crane, could be stood on the retaining wall of the basement. A parked mobile crane would occupy a space of only about 12 ft by 8 ft, and this should be easy to find. A small hand derrick would need more space as even on the smallest of derricks the sleeper centres are between 20 ft and 25 ft. A scotch derrick would have more reach than the mobile crane but the latter could readily be moved if required. A choice between the two methods may require careful thought.

In the centre of a large city even the small area needed for these cranes may not be available and the off-loading crane would have to be mounted within the site boundary. In Fig. 7.03 a mobile crane has been mounted on a specially constructed timber trestle built up from the basement. This crane can off-load from the roadway and lift the material over the pavement to lower it into the basement. It will be appreciated from this that it is essential that

@Seismicisolation

the permanent cranes are fixed and ready for operation without delay.

Unless the site of the guy derrick crane can be reached by the temporary off-loading crane, other tackle will be required for the erection of the guy derrick. Possibly a lattice steel derrick mast could be " reared " by the off-loading crane and then " walked " to the position required. The erection of the guy derrick crane then proceeds as described in the previous chapter.

The position of the guy derrick should be carefully studied. All steelwork should be within reach as far as is possible. If the steel in certain corners has to be omitted, this steelwork should be capable of easy erection later by other means. The crane should also be positioned so that it has a clear reach down one bay to the off-loading point.

If possible, all beams in this bay should run from flange to flange of the stanchions so that the closing beams can be brought into position sideways. If the closing beams run into the webs of the stanchions they will have to be lowered into position—a difficult operation as there are often cleats protruding into the space available. Fig. 7.04 makes this clear.

In some buildings of this type the stanchions will be set on grillages to spread the loads. The placing and levelling of these grillages

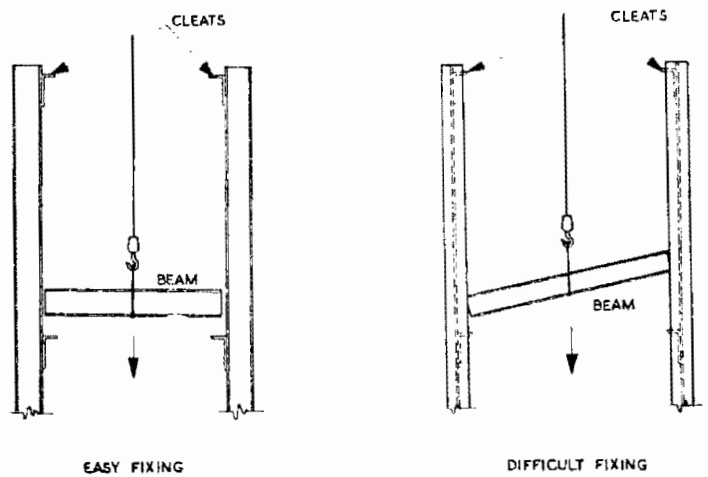


Fig. 7.04: Fixing closing beams

will be the next operation for the erector. As grillage steelwork arrives, he will be able to off-load it direct from the street and, if his erection cranes are correctly positioned, he will be able to place each grillage in turn. Small grillages will be despatched to site

complete but the larger ones will have to be assembled in their final position.

Each grillage has to be accurately set both for line and level, and once they are concreted in position the erection of the steel structure can begin. It is advisable to keep the level of the concrete down a few inches from the top of the grillage so that the bolts to the stanchion bases can be inserted easily. If possible the grillages should be concreted immediately they are set so that no movement takes place. Particular care must be taken that all sections of the

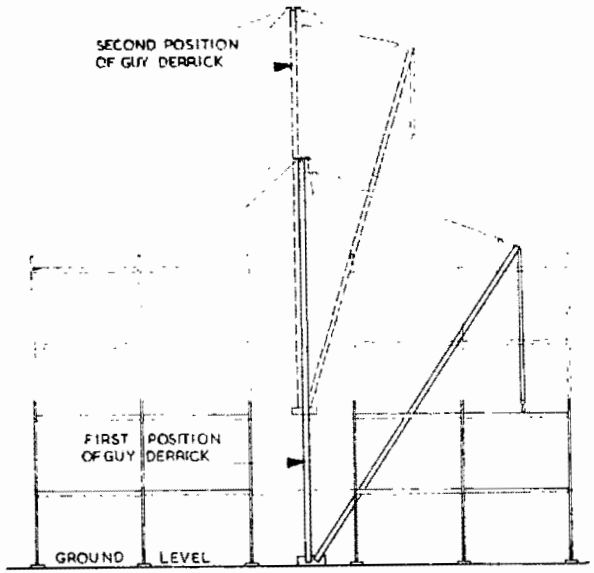


Fig. 7.05: Erecting with a guy derrick crane

grillage bear evenly on each other and that the stanchion base is also resting firmly on the grillage.

Erection of steel with a guy derrick crane will commence at the outside of the building and work into the centre. Each bay will be erected to a height of two or three floors, depending upon the reach of the crane, the position of stanchion splices, and also on how far it is intended to erect before " jumping " the guy derrick. Two floors at a time is the usual practice, as shown in Fig. 7.05. The work of erection is assisted considerably if all stanchion splices occur at the same level.

If the guy derrick crane has been correctly located all the steelwork in the lower lift of the building can be completed. Two or more guy derricks will be used for the erection of a wide structure. Arrangements are now made for the guy derrick to be lifted to rest

@Seismicisolation

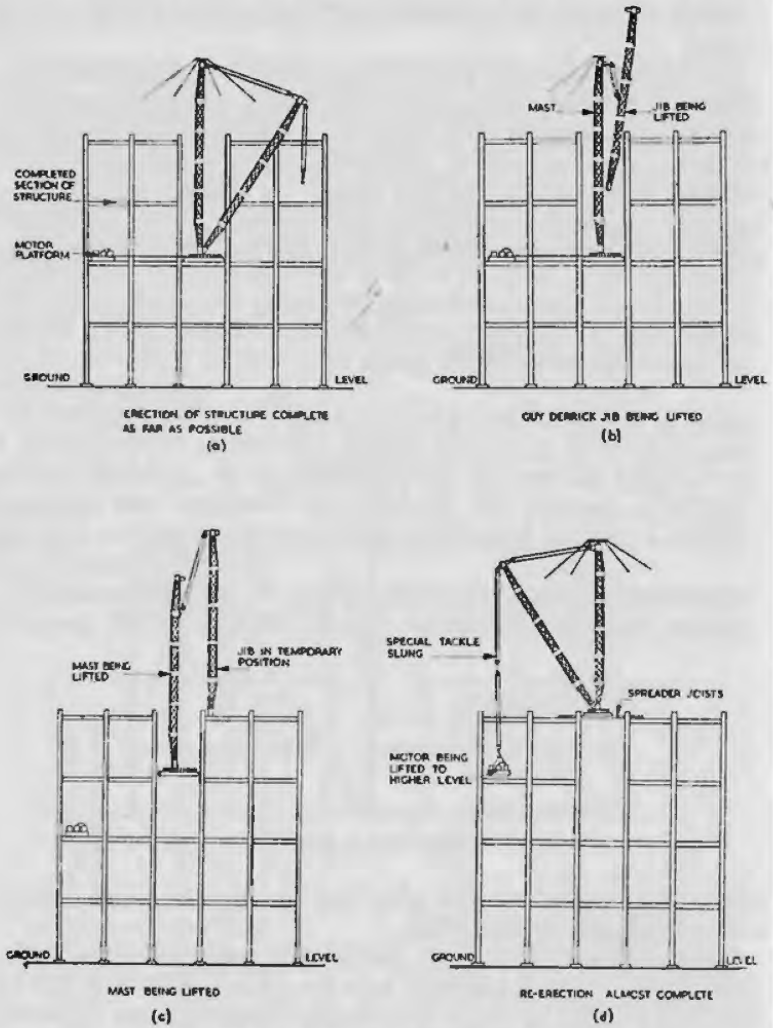


Fig. 7.06: " Jumping " a guy derrick crane

on the completed steelwork in preparation for the continuation of erection.

The jib and mast of the guy derrick are so constructed that one can lift the other if required. The mast section lifts the jib to a higher level and then the jib raises the mast, after which the sections are reconnected to work as previously. Fig. 7.06 shows the operations in the " jumping " of a guy derrick.

The first stage is the disconnecting of the derricking blocks from the head of the jib. The jib is slung in these blocks. The permanent motor of the derrick can now lift the jib. Before the jib is positioned on the higher level it is swung round so that the front faces the mast. The hoisting blocks hanging from the jib are then in a position to lift the mast. It is, of course, necessary to guy the jib with temporary wires.

Before the mast is lifted the derricking and hoisting wires which run through the footblock are run off the drums of the winch. The derricking wire is tied to the mast to be out of the way, and the hoisting wire is run through snatches from the foot of the jib back to the drum on the motor platform. The mast can now be hoisted using the jib as a derrick. The footblock, to save making a separate lift, can be lashed to the foot of the mast. Preparations to receive the footblock and mast should be in hand before lifting commences so that the footblock can be positioned immediately at the new level. If temporary joist bearers are to support the guy derrick on the steelwork, these beams can be laid ready on one side. When the mast and footblock have been raised to their full height the beams are slid underneath.

Once the jib has been replaced in the mast, the motor is lifted. The jib is derricked out until the hoisting blocks hang over the motor. Both hoisting and jibbing wires are clipped to hold the jib and blocks in this position. A separate winch with a set of blocks slung from the hoisting hook are used to lift the motor. Immediately the lift is made the bearing joists for the motor platform are slid underneath.

The footblock for the mast can be carried on a twin beam spanning across the bay over which the derrick is positioned. The motor platform and cabin are carried by bearing joists. All these joists are securely clamped in position. The guy anchorages previously used will possibly not be satisfactory for the new position of the crane, and will most likely be in the way of the building contractor thus preventing him from completing the concreting of the lower floors.

The usual practice is to anchor the guys to the steel structure at the level at which the derrick is standing. Short wire strops will loop round the stanchion and beam connections and the turnbuckles are connected to these by shackling. The strops must be carefully packed with bags and timbers so that there is no danger of any sharp edge on the steel cutting through the wire. These packings are tied in position so that they do not work loose and fall.

Anchoring a guy derrick to the structure in this manner will throw some stresses on the structure. There will be thrusts at the

@Seismicisolation

foot of the mast and pulls on the guys. These forces will be felt when the crane is used but they are not as considerable as would seem. It is, however, advisable to brace the structure against them. As shown in Fig. 7.07, wires run from the tops of the stanchions to the feet prove satisfactory. These wires should be tightened with union screws.

When erection progresses to a higher level some place will be required for the storage of steel as it arrives at the site. The area between the guy derrick and the off-loading point at street level should be decked out solidly with timber. This area will serve ideally, enabling the steel to be lifted from the lorry and stacked without slewing the jib. Care must be taken that the steel is safely stacked and that the timber decking is not overloaded.

Erection of this next lift of the building will continue in the same manner as the lower portion. The erection continues two floors at a time until the full height is reached. As the building rises the

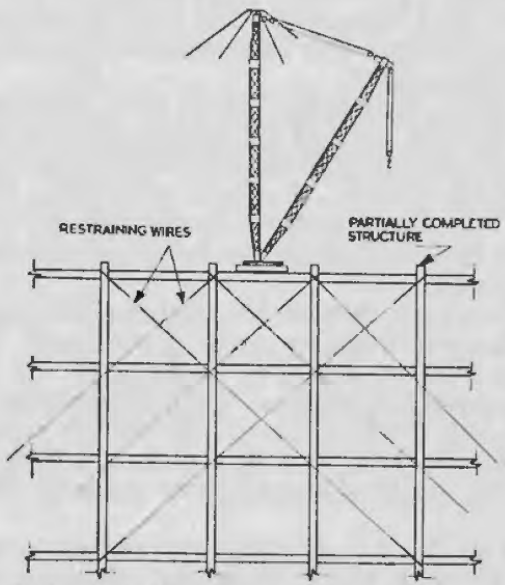


Fig. 7.07: Guying the building against stresses from a guy derrick crane

size of the floors usually decreases and it is sometimes found that sufficient spread of the guys will not be possible at times. An outrigger, constructed as shown in Fig. 7.08, is used in such a case and in this case the guy is continued to an anchorage down the outside of the building.

When the full height of the structure is reached, the guy derrick completes the erection and builds itself in. It is then dismantled and lowered to the ground for removal.

If it is not feasible to off-load the steelwork outside the area of the building, the trestle, constructed as in Fig. 7.03 for the off-loading of the tackle at the beginning of the job, could be enlarged.

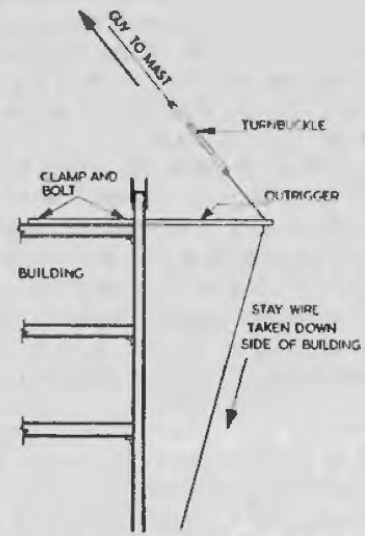


Fig. 7.08: Outrigger for a guy

The lorries bringing the steelwork would be able to manœuvre on to this trestle and the steelwork could be lifted off the lorries and taken up through the building. A section of the floor at each level would be left open for this by arrangement with the building contractor, who possibly would be only too pleased to agree and share the facility.

ERECTION BY SCOTCH DERRICK CRANE

Unlike the jib of the guy derrick crane, that of the scotch derrick crane cannot swing through a full circle but is limited to a sweep of about 270° from one leg to the other. This limits the use of a scotch derrick in a restricted site unless some other arrangements can be made for the erection of that section of the building that it cannot reach. The scotch derrick has, however, two big advantages. In the first place, no guys are required and, secondly, it can readily

@Seismicisolation

be made mobile by mounting it on bogies and moving it along a prepared track.

As stated before, no hard and fast rules can be laid down for the selection of tackle for any type of building, but generally the following holds true: If the structure is tall and the erection has to progress upwards, the guy derrick is ideal. If, on the other hand, the building is of moderate height and erection has to progress laterally, then it is quite likely that the scotch derrick would be more suitable. In this latter case the scotch derrick crane could be set on bogies and track at one side of the building and moved the length of the building, leaving the site clear for other contractors, or it could be run over the building area at ground level.

The sequence of erection would be the same as in the case of the mobile crane. Each bay of steelwork would be erected complete from floor to roof, or as high as intended, before proceeding with the next bay. The increased reach of the scotch derrick crane is, however, an advantage compared to that of a mobile crane as a large area of the building is covered from one setting of the crane. Generally, a scotch derrick crane is designed to lift its rated load at a radius equal to 75 per cent of the jib length. From Table 2.02 it will be seen that, even at this radius, the headroom is considerable.

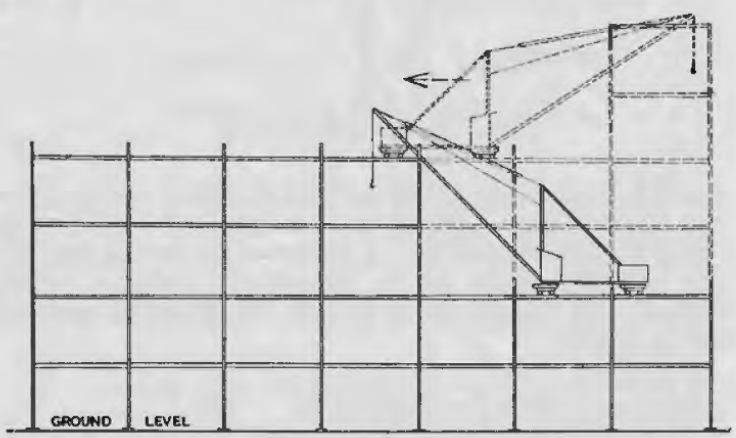


Fig. 7.09: Erection of a building with a scotch derrick crane

On a large building two or more cranes will possibly be used to speed the erection. One method of erection, in which the crane is mounted on the building structure as the latter is completed, is shown in Fig. 7.09. Two floors are erected throughout the length of the building and the crane is then placed on top of this section.

The following two floors are next completed and the crane is moved up again. This procedure is repeated until the full height of the building is reached and all the work has been completed. Stanchion splices usually occur just above every second floor level and this will govern the selection of the levels at which the crane is to be placed. It is very difficult to use a crane on a floor where the stanchions project to any great height as their projecting ends restrict the movement of the jib.

No attempt must ever be made to fit the jib of a scotch derrick between the two back legs to make lifts from this area. This practice is dangerous and illegal. Neither should loads be dragged from behind the legs as the crane may be overstressed. If lifts have to be made behind the crane, either another crane should be erected if the work warrants it or a lattice steel derrick should be used.

The locations and movements of the scotch derrick crane when employed on building erection should be carefully planned. The off-loading area has to be within working radius, all sections of the work should be within reach, and finally the finished position of the crane should be such that it is easily dismantled and the sections lifted clear of the site. It is clearly an advantage to select the final position of the crane so that little or no work remains when the crane is dismantled.

If the erecting crane is of 5-ton capacity or over, it is doubtless necessary to use a smaller derrick crane (possibly hand-operated) to dismantle it and load the sections. The second crane can often be positioned so that, after dismantling and loading the scotch derrick, it can complete the erection of the structure and build itself in entirely. A hand winch coupled to blocks hung from the newly erected structure will dismantle the smaller crane.

The legs of the scotch derrick crane are usually anchored with removable ballast weights in the form of specially prepared iron or concrete blocks, bricks, sand, or water-filled tanks. When the crane is positioned directly on the structure it can be clamped to the steelwork. The section of the structure that supports the crane should be checked to ensure that its carrying capacities for the upward loads, as well as those acting in a downward direction, are satisfactory. Needless to say, all connections in the structure should always be fully bolted, riveted or welded, as the case may be, before the crane is used in this manner.

The uplift on the anchorages of a working scotch derrick are usually taken to be equal to three times the safe working load o the crane, i.e., with a 5-ton crane the uplift would be 15 tons. This is not a hard and fast rule as the uplift possible will vary depending

@Seismicisolation

on the ratio between the sleeper legs and the working radius of the crane. The shorter these legs, the more ballast is required. The amount of ballast necessary should be indicated on the Crane Data Sheet and also on a notice riveted securely to the legs of the crane. If this information is not available for a particular crane, the makers will only be too pleased to give this or any other information required.

OTHER METHODS OF ERECTION

Where suitable facilities are to hand for moving a locomotive crane to the site of the building, this particular plant can often be used to advantage. When worked off one track only, the jib of the crane will doubtless need to be of good size and its capacity such that it will pick all the loads at the required radius.

Even if it is not suitable for erection work on the building frame, the locomotive crane could be used to handle the off-loading and storage of the fabricated steelwork until such time as it is required for the erection. A stocking ground covered by a locomotive crane would prove a boon on any large contract if sufficient area were available, as delivery of steel could be taken in advance of requirements without encumbering the actual erection site. The locomotive crane will handle all this work very satisfactorily and, besides loading the steel on to trucks when required by the erection squads, would also haul the trucks to within reach of the erecting crane or cranes.

Steel or timber derricks are now rarely used for the erection of buildings as progress is very slow and laborious, the derrick having to be moved into position for each individual lift. In certain cases a derrick can be used profitably to erect steelwork beyond the reach or loading of the erecting crane, but this would only be done in isolated instances. In most other cases it is advisable to select a crane of sufficient capacity.

CHAPTER 8

THE ERECTION OF BUILDINGS
(CONTINUED)

SHED-TYPE BUILDINGS

THIS general classification covers a host of widely varying structures, ranging from the smallest of farm buildings with spans of no more than 18 ft to the largest of aeroplane hangars having clear spans of 250 ft and more. Within this wide range of spans the erection methods naturally vary greatly but, as will be seen, these divergences are caused more by the building layout than by size, although heavier tackle is, of course, necessary on the larger buildings.

In small sheds all trusses are usually almost identical and are designed to span directly across the building. As the span increases, however, this roof arrangement ceases to be economical and the designer will vary it. For spans of 80 ft and over, deep lattice girders are often planned to span across the building and the trusses carrying the actual roof covering are arranged to frame into and be carried by these. Arch-type roof construction is sometimes used when large, clear spans are required and the erection of this type of structure is also described later in the chapter.

The roof layout has a large influence on the choice of the erection procedure as the arrangements of the main sections determine the order in which the components are erected. For the most simple form of roof, that in which the trusses span the building, the order of erection will be, first the stanchions to carry the truss, then the truss itself, and finally the purlins spanning back to the previous truss. Any bracing or special framing occuring in a particular bay will also be erected at this time. After completion of this work, the tackle will be moved to a suitable position and the same procedure adopted for the erection of the next bay.

For the erection of a shed building with a lattice girder type of roof an entirely different procedure must be adopted as the girders have to be erected before the roof trusses can be lifted into position. This means that the crane or derricks have to be moved back sufficiently to permit the erection of the lattice girder and its supporting stanchions. When this girder has been stayed or strutted in position, the intermediate trusses between it and the previous girder are erected, followed by the roofing purlins. This operation

@Seismicisolation

will mean that the crane has to be moved back under the newly-erected girder unless it is large enough to reach over the top.

A mobile crane is a very useful machine for this type of erection. It can easily be taken under the erected girders with its jib lowered, and so presents no problems in this respect. On the other hand, a scotch derrick cannot usually be moved back under the girders as they are seldom at a sufficient height for this. The only alternative with the scotch derrick is, therefore, to make sure that the jib is long enough to reach over the girder to fix the roof trusses.

An economical method of erection for a lattice girder type of roof with a clear span of about 150ft is illustrated in Fig. 8.01,

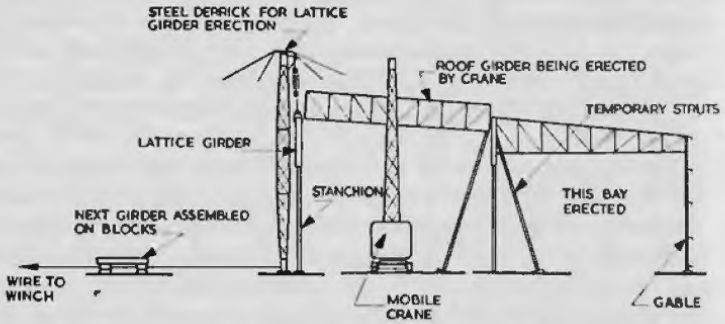


Fig. 8.01: Erection of a large span lattice girder roof with a mobile crane

and will now be described briefly. Lattice girders of this span weigh up to 24 tons and, for the purpose of this description, it is assumed that conditions are such that the girders can be assembled complete before lifting. The main items of tackle required will be two steel derricks to lift 15 tons each (i.e., load on blocks plus lead line load from Table 3.01) with a headroom of 40ft, and also a mobile crane of such capacity that it will fix roof trusses, stanchions and all other steelwork, excluding the lattice girders. The steel derricks will be used solely to erect the girders and there will be no difficulty in moving them about the site as the mobile crane will be available for this.

The mobile crane will first assemble the first lattice girder just below the position it is to occupy when erected. The girder may be assembled either laid flat or stood vertical in preparation for lifting. If laid flat it will have to be reared. This is a difficult operation with a deep lightly built girder. Whichever method of assembly is chosen, the girders should be built clear of the ground so that all bolts or rivets can be inserted or all the welding completed without further movement.

The camber to which the girder is to be built will be specified on the lay-out drawing of the girder. If the girder is assembled in a vertical position, the foreman will set the packings to the required heights with the surveyor's level before the bottom chord is placed in position. If assembled flat, the camber will be checked from a line between the girder seatings.

As the sections of the girder are assembled they should be strutted so that they do not move and when the assembly is complete the girder should be lashed against the lifting derricks and all connections should be fully bolted. If bolts are used, two men can be left to insert and tighten these while the remainder of the erection squad put up the stanchions and prepare the tying-in steelwork so that this can be erected immediately the girder has been lifted. If bolts are used on a large girder, they will probably be of the fitted type, and the holes will have been drilled to a small clearance. Care must be taken that when these bolts are inserted neither they nor the holes are damaged.

The girder is now ready for lifting but before this operation is commenced all connections in the lattice girder should be inspected

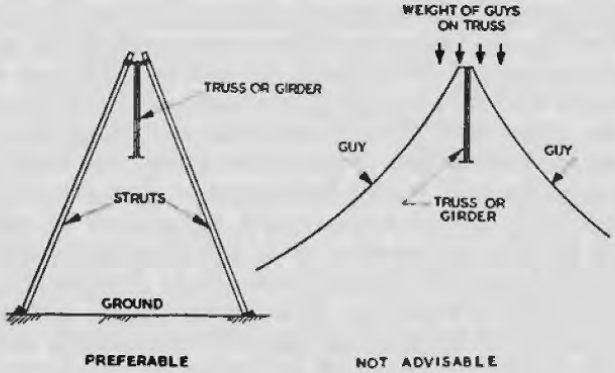


Fig. 8.02: Strutting a lattice girder

and the lifting gear checked. Particular attention must be given to the guys and anchorages. Up to this stage the erection squad may not have consisted of more than about five or six men. If hand winches are to be used, then this squad will have to be increased. The expense could be kept to a minimum by arranging with the building contractor to hire labourers from him for an hour or two. At least one experienced man should be employed on each winch to ensure that the foreman's instructions are fully understood and carried out. When the girder has been lifted, it

@Seismicisolation

will be carefully strutted while the mobile crane inserts the connecting steelwork. Struts are always preferable to guys as a guy is not effective until it is drawn tight, and in this state its load might be sufficient to cripple the girder and cause collapse. Strutting is shown in Fig. 8.02.

These temporary struts should be left in position as long as possible and at least until a complete bay of bracing has been erected. This affords a good measure of safety against any sudden winds that may arise or any unforeseen erection loads during the further erection of the building. When the first bay has been completed, the mobile crane can lift the steel derricks to their next position, and the erection of the next bay will commence.

When planning the erection of large lattice girders, the supervisor will have to compare the respective costs of using heavier tackle, which will enable him to lift the girder as one unit, or erecting sections of the girder with lighter tackle and completing the assembly in the final position. If the heavy tackle is not required for any other work on the contract, the latter method may be more economical but the extra cost of erecting and dismantling the trestling should not be omitted from the estimate.

When the site is a considerable distance from the tackle storage depot, transport charges may have a large effect on the economics of using temporary trestling. If this trestling has to be hired an alternative method of erection may well prove to be less costly. A point which may be overlooked when comparing the costs of various methods is that riveting and bolting costs will also be increased if the work is done from staging. Assembly work on the ground usually shows a large saving in this respect.

Until the first one or two bays of a building have been erected, the structure may not be stable and it should therefore be carefully supported with guys or struts. Where the rafter and vertical bracing occurs in the end bays, the building will be sufficiently stable once this bay has been erected and the erection of the remainder can proceed unhindered. If high winds are likely, no chances should be taken, however, and the original stays should always be left in position as long as possible. Usually the gable frame or truss must be positioned before the second truss can be erected, and it thus has to be stayed so that it will stand safely while the cranes are moving away and erecting the second truss and connecting material.

ERECTION OF TRUSS SPAN BUILDING

The position of the scotch derrick crane will have to be decided first. This crane will usually be moved along the centre of a one-bay building. In a two-bay building the king post bogie of the crane

will be set close to the centre line of the bases, or even over them, if feasible. If the building is too wide for one crane, two may be used or one section of the building may be completed first and the crane moved into a new position to finish the remainder.

To enable the crane, before it is dismantled, to complete the building, a run-off will have to be made. The crane should be taken a sufficient distance past the gable of the building to enable the jib to be swung round. The Crane Data Sheet will give the minimum operating radius of the crane and this, added to the length of the crane, will give the minimum length of run-off required. If the crane cannot be run out of the building, it will have to build itself in and be dismantled inside the building area. This may mean that a portion of the building has to be erected later by hand or by other means.

When selecting the line of movement of the crane, the off-loading point for the steelwork will have to be taken into consideration. This should be within the working radius of the crane so that double handling of the material is not necessary. Correct sequence of delivery is essential as all steelwork will have to be erected as the crane works along the line of the building. If any important piece is missing, the erection work will be held up completely. If space is unrestricted, the steelwork could be delivered well in advance of erection and laid out for easy handling later.

An additional crane for off-loading purposes and for passing the material to the main erecting cranes will increase the speed of erection. This extra crane can also assemble trusses and lattice girders in advance so that these pieces are immediately available for lifting as the erection work progresses. A mobile crane of suitable capacity could be used to advantage on this type of work.

It is advisable to set the level packs before the stanchions are erected. This saves work later as the stanchions will otherwise have to be wedged or jacked up for adjustment. Plates of varying thicknesses are used and set with the surveyor's level, as described in Chapter 13. To prevent these plates from being knocked out of position they should be set in a cement-sand mixture. Sometimes a base may be found to be too high to allow for packing or grout. In such a case it may be possible to insert a thin lead sheet to transfer the load from the column to the concrete base.

The stanchions, roof girders, eaves beams, and crane girders (if any) are erected first. This erection work will seldom present difficulty. The trusses are likely to be sent to the site piece-small or in sections and therefore have to be assembled at the site. The off-loading crane should do the lifting for this assembly which must be carried out ahead of the erection to enable the bolting, riveting

@Seismicisolation

or welding to be completed in time. Any small pieces that may not have been delivered can be noted and efforts made to obtain them immediately.

If space prevents the assembly of large-span trusses, these can be built in sections and then completely assembled by the erection crane under the position they will finally occupy. Alternatively, one half of the truss could be erected and propped until the other half was in position.

Steel purlins are usually designed to span two bays, the joints in the purlins being staggered as in Fig. 8.03. When joints are

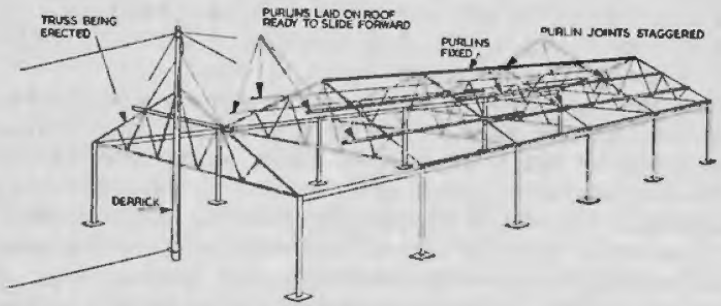


Fig. 8.03: Truss roof showing the purlins

thus arranged, erection work is simplified as the erector can lay purlins across two trusses on the completed portion of the roof. After he has lifted the truss into position all he need do is to slide the purlins across to the newly erected truss. He can then fix them before he releases the truss from the crane or other apparatus that has lifted it. Even if the purlins span only one bay, the same procedure can be followed if temporary long purlins are used. When this cannot be done for any reason, the purlins will have to be hauled up by hand or another crane used for the purpose. It is not essential that all the purlins are fixed before the truss is released from the erection tackle but it certainly is to be recommended that a minimum of three are used. These will be positioned one at the apex and the others half-way down each rafter, so that the danger of the truss buckling is minimized.

LIFTING OF ROOF TRUSSES

Roof trusses are occasionally lifted by slinging them near the apex as in Fig. 8.04 (a). Examination of this illustration shows that this method of lifting creates a compressive stress in the bottom tie of the truss. This member of the truss is normally

designed to carry tensile stress only, often being merely a flat, and even a small reversal of stress is sufficient to cripple the bar.

Damage to the truss can be prevented by slinging at points a distance down the rafter backs, but a better method is to lash a suitably sized timber across the truss, as shown in Fig. 8.04 (b). This will withstand the compressive force and thus keep the truss in its correct shape.

PORTAL-FRAMED BUILDING

This type of shed is becoming popular. It does, however, present the erector with problems which are peculiar to this type of building. With a little forethought these difficulties can be overcome easily and, provided the correct plant and methods are employed, the erection of a portal-framed building should proceed as quickly as, or even more quickly than, the erection of one of more normal construction.

Transport restrictions may require that the portal frames be sent to the site in sections. This means that these connections must be either riveted or welded after assembly. To conform with

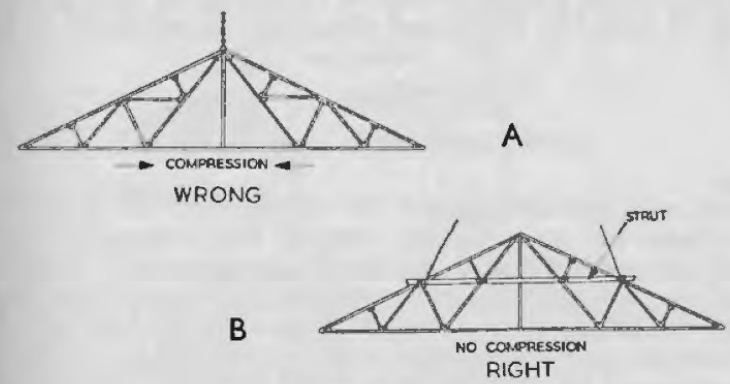


Fig. 8.04: Slinging a roof truss

the designer's assumptions, these connections must usually be fully rigid when complete and this demands close consideration by the erection engineer. From the erection point of view it is nearly always advisable to lift the frame in one piece so that there should be no difficulty in ensuring rigid connections whether they be riveted, welded, or bolted.

More attention must be paid to this matter of connections when the frame has to be erected in sections. Close-fitting bolts will be

@Seismicisolation

used for bolted work. Heavy use of the drift will enlarge the holes and destroy the efficiency of the joint. It should, therefore, not be allowed. The bolts can usually be inserted more easily while the erection tackle holds the weight of the rafter of the frame. The same applies to riveted work. When the connections are welded, it is essential that the temporary connections are amply strong enough to ensure that the pieces to be welded are held securely in place. Any movement on the temporary connection will leave a joint that is difficult to weld, and it may also be difficult to ensure that the work is satisfactory on completion.

Greater economy will often result in most cases if the frame is assembled on the ground and lifted complete. As in the case of lattice girders, site joints are cheaper and easier to make if done at ground level as little or no scaffolding or trestling is required. Riveting work requires a fair amount of scaffolding and the welder, although he usually works alone, requires room to manœuvre because he is seriously encumbered by his protective clothing, gloves and headshield.

The usual practice on building construction is to erect the whole framework complete and to undertake the lining-in work later. There is always a certain amount of " play " on the holding-down bolts as set by the builder and this permits the stanchions to be

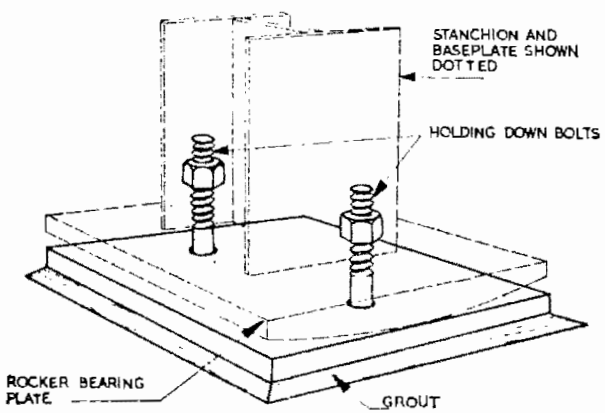


Fig. 8.05: Portal frame rocker plates grouted in position prior to erection of the frame

moved slightly in a horizontal direction so that any small errors in the original setting of these bolts can be corrected. Although quite suitable on the normal type of building, this procedure is not to be recommended on portal-framed buildings. One of the peculiarities of the portal frame is that it will quickly spread under

its own weight and, when this happens, it is often only with difficulty that the bases can be brought together to their correct measurements. Sometimes this can only be achieved by lifting the frame again. This procedure is naturally expensive, both in terms of money and of time.

The best method of preventing any error in the original setting of the bolts from occurring is to grout solid in their respective positions all the holding-down bolts before the stanchion erection commences. Some portals are designed to rock on bearing plates. In this case, the plates can be set level and in their correct position by the engineer before erection begins. In other cases an accurate

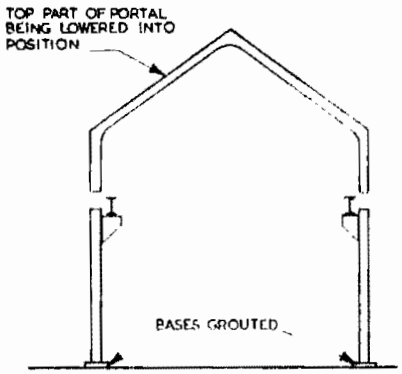


Fig. 8.06: Erection of a portal frame in sections

template of the holding-down bolt holes in the stanchion base should be prepared and the bolts grouted using this template as a guide. The template must be well made and strong enough to prevent it from being knocked out of true during use on the site. Fig. 8.05 shows how the bearing plates are grouted in position and used as a template. To ensure accuracy, these templates must be set with the aid of a theodolite and, if the final levels are given at the same time, the subsequent setting of the building is a very simple matter indeed.

With some portal-framed designs it is permissible to erect the stanchion sections of the portals and grout these before erecting the truss section. This is shown in Fig. 8.06.

The connections between the top and bottom sections are straightforward seating connections and the erector should have no difficulty. This type of joint will provide the welder with a simple weld which is further simplified by being downhand. If the portal also carries a crane girder on each leg, the stanchion may be broken

@Seismicisolation

just above this point and often the section is also changed here. The crane girder, when in position, will form a ready base for scaffolding for the welder.

WATER-TANK TOWERS

If a tower had to be erected on an isolated site a lattice steel or timber derrick would most likely be chosen. An engine-driven winch would help to speed the erection and it might be possible

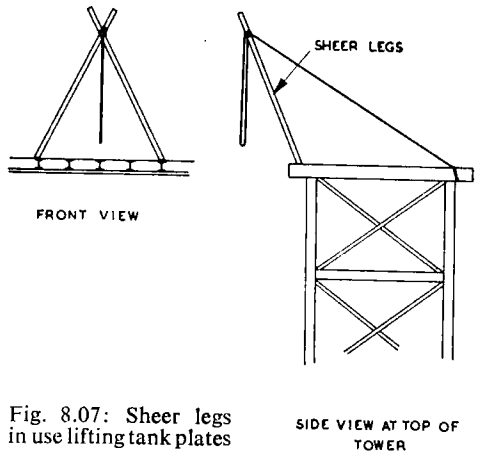


Fig. 8.07: Sheer legs in use lifting tank plates

to economize on labour by using this plant. No matter how small the tower, fewer than four men should never be sent to carry out the erection as one man will be required on each guy when the derrick is moved. Should the tower be too high for erection with a derrick at ground level, it should be erected as high as possible, after which the derrick could be "jumped" to a higher level on the structure itself. The guys could still be led to anchorages in the ground unless the structure was too high even for this. In that case, they would have to be anchored to the tower structure. A derrick used in this fashion need be long enough only to erect one length of the stanchion at a time and would be "jumped" to a higher level as required.

For a large and complicated tower structure a scotch or guy derrick crane may be advisable, and the time spent on the erection and dismantling of this tackle would doubtlessly be saved by the speedier handling of the platform beams, the bracing, and other small items. A suitable space would, of course, have to be available for the scotch derrick but none, or practically none, would

be required for a guy derrick crane. When considering whether to use a scotch or guy derrick crane for the erection of a tank tower, the costs of erecting and dismantling would have to be weighed against the slower working without this plant. It is likely that a crane would be more economical for a tank structure of a total weight of 50 tons or more.

The tank itself is often erected by a specialist firm. If the erector is also responsible for the tank, then the erection cranes can lift the plates. If the tower was erected by lattice derrick or if the erecting crane is required urgently somewhere else, other arrangements will have to be made to lift the plates. A set of sheer legs luffed out over the side, as shown in Fig. 8.07, will enable the plates to be hauled up and pulled in without trouble. The engine-driven winch would be of assistance at this stage. The tank floor should be decked out first to give some space for working and also for stacking the plates.

SPACE FRAMES

The erection of a space frame poses a problem for the erection engineer as the weight-carrying girders are usually inclined and form part of the trusses. The roof structure itself is not self-supporting until all members are in place and fully connected. This will mean that nearly all individual pieces will have to be propped, erection will not be speedy and much trestling will be necessary. When possible, it may be advisable to assemble the space frame on the ground and to lift it in one piece, as is illustrated in Fig. 8.08.

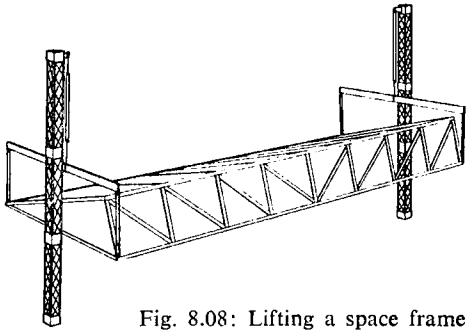


Fig. 8.08: Lifting a space frame

Here the space frame is about 100 ft long and spans one bay of about 30-ft width. A mobile crane and two lattice erection masts are employed. The girder is assembled on the ground directly below the position it will occupy when erected. The mobile crane

@Seismicisolation

will do this work. The two lattice derricks are stood one at each end and the complete frame is lifted by them. Lifting beams are used so that the frame is lifted at the point at which it rests on the stanchions, thus throwing no undue stresses on it. When the frame has been lifted to a sufficient height, the stanchions are erected and it is lowered on to them. Particular attention must be paid to the slinging points to ensure that these are strong enough to withstand the erection loads. Slinging at the points at which the frame sits on the stanchions would be quite safe, but the slings will have to be arranged so that the stanchions can be inserted without any difficulty.

ARCH-ROOFED BUILDINGS

Exhibition halls, railway station roofs and some aeroplane hangars have been designed in this manner. The arches may be spaced about 30 to 40 ft apart and may be connected by trusses or lattice girders. Like the arch-type bridge, the arch rib may be three-pinned, two-pinned, or fixed.

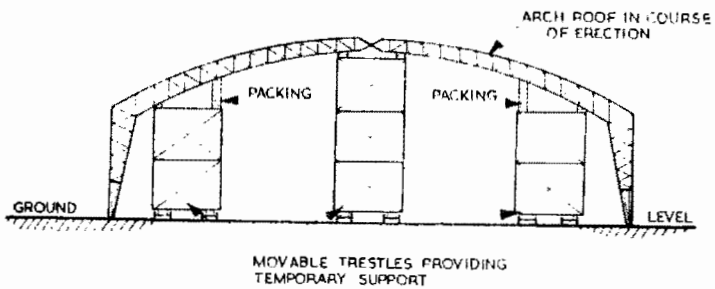


Fig. 8.09 (above): Erecting arched roof from trestles

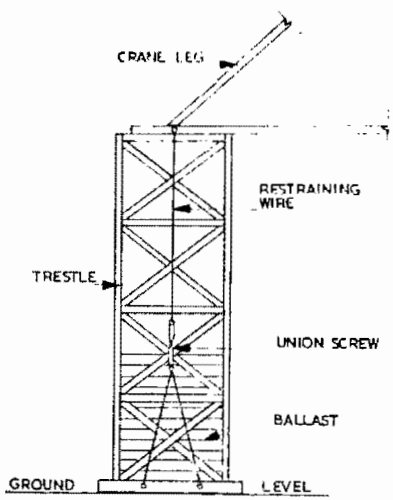


Fig. 8.10 (left): Anchoring a scotch derrick crane leg to a trestle

The arch will be assembled usually in its final position on timber or steel trestles. When assembly is complete and all connections have been made, the trestles are removed. Often the height of the structure will make it necessary to mount the erection crane on trestles as well. All these trestles are moved along the building as the erection of the arches proceeds. Fig. 8.09 shows an arched roof supported on trestles, and Fig. 8.10 illustrates a detail of how the erection cranes are anchored to the ballast at the foot of the trestle that supports them.

NOTES ON ERECTION

1. See that the equipment is not overloaded. Be certain of the weight to be lifted.
2. See that all bolts and splice material on lattice derricks and crane sections have been inserted.
3. Use timber to pack chain and wire slings off sharp edges on the steel, and to prevent the load from slipping.
4. Do not open the legs of brother chains to too large an angle. Consult Tables 5.04 and 5.05.
5. Check on all guys and anchorages, particularly on those for the back guys which will bear most of the load.
6. Do not allow small tools to lie about a building in case they fall. Drifts are very liable to roll off beams and scaffolding.
7. Be sure that the ring of chain slings is big enough for the crane hook.
8. Do not drop chains from a height.
9. Avoid sudden shocks when lifting as this increases the load on the gear.

A simple rule for wrought iron chains is:

Maximum safe working load $= 6d^2$ tons,
where d = the diameter of the chain in inches.

Example

With $\frac{1}{2}$-in. diameter chain,
Maximum safe working load $= 6 \times \frac{1}{2} \times \frac{1}{2}$ tons
$= 1\frac{1}{2}$ tons, as in Table 5.06.

POINTS TO NOTE BY THE DRAWING OFFICE

It is always advisable to have separate erection drawings, although no detail work need be given on these. The essential information required by the erector on the site is the mark of each piece, its position, and the major dimensions of the building so that he knows the size of the piece he is looking for. The scale of the

@Seismicisolation

erection drawings must not be too small, otherwise the drawings will be too confusing. This applies particularly to arrangement drawings as they soon become soiled when used outside in all weathers. Each drawing should cover a separate area of the building.

The draughtsman should put himself in the position of the erector at the site. The erector will always stand outside the structure to erect sheeting rails. Drawings showing these should always be drawn as though the draughtsman stood in this position.

Threading connections should be avoided, where possible, as they are very difficult to make at site. The closing beams in a building should run preferably from flange to flange of the stanchions. It is very difficult to thread beams down between the webs when the remainder of the structure has been erected. If it so happens that a section when finally drawn exceeds its estimated weight, the erection engineer must be told at once as this may affect the selection of his tackle.

CHAPTER 9

ERECTION OF BRIDGES

BRIDGE construction falls into different spheres which govern, to a large extent, the method chosen for the erection of any particular structure Erection may be entirely on land, as in the case of a bridge over an existing road or railway, or it may be over a river or other stretch of water. Again, the bridge may be erected in an entirely new locality or it may have to replace an existing bridge which has not proved strong enough to carry present-day traffic. In the latter case arrangements will have to be made to cope with the traffic present if it cannot be diverted. Often one-half of the bridge must be constructed and put into commission before work can commence on the remainder.

Before going into a more detailed account of the customary methods of erection of the common types of bridges, it would be appropriate to say a few words on the general problems which are likely to occur.

TRANSPORT OF MATERIALS

If the bridge is constructed over a navigable water-way there is possibly the choice of using water transport as an alternative to road and/or rail facilities. If the fabricator's works are situated within easy reach of a suitable loading point for water transport, this alternative is a matter worthy of careful consideration. Water transport might enable sections to be despatched to the site with few of the restrictions on size that are imposed for road or rail transport. The capacities of the lifting cranes on the erection site would possibly be the only criterion.

If rail transport is eventually chosen as most fitting for the job in question, special sidings may have to be laid out at the site so that sections can be stored until required and so that larger assemblies can also be made before handing to the erection cranes. Frequently this storage ground is some distance from the site of the erection work, and special track will have to be put down so that the materials can be brought to the job site as required.

USE OF TRESTLING

In a number of cases the use of trestling for the erection of small bridges will facilitate and speed the progress of the work. This method is, of course, only permissible when the space under each span can be utilized fully. Over a busy water-way, or a road

@Seismicisolation

or railway track, some other method would have to be considered. When the bridge consists of more than one span, an alternative solution would be for one span at a time to be left open so that traffic passing underneath could use this passage-way until the trestling could be removed from the other span.

ERECTION LOADS

Some form of stiffening may be necessary either to take care of loads from the erection gear or to withstand stresses which may be present in the partially constructed frame itself until all the frame members have been inserted. When considering the placing and moving of the erection gear, the strengths of the individual members supporting this should always be investigated, as well as the stability of the structure as a whole. In some designs it is assumed that the steel stringers for the floor of the bridge work in a composite action with the concrete decking. As this decking is not in place while erection proceeds, the decking stringers may have to be stiffened before they can carry the erection gear.

When considering the erection methods for a cantilever bridge, it is often found that the procedure that best fulfils the set conditions would be to arrange for the movement of the erecting cranes along the top chords of the cantilever truss. The strength of these top chords must be investigated carefully as they are usually designed to withstand only a tensile force and may therefore not be capable of carrying the erecting cranes without suitable reinforcement.

WIND LOADS

Wind loads on bridges under construction need careful examination. These forces may be considerable when the bridge is sited on an open stretch of water where high wind velocities are likely to be reached. Temporary bracing of some kind is almost certain to be required on a partially completed structure. When considering wind loads, the effect of the wind on the erection cranes and trestles, if any, should not be forgotten if these are supported by the main bridge structure. The reaction of the tackle on the structure, both in its incomplete and complete states, should also be investigated.

RIVETING OF CONNECTIONS

This merits careful consideration to obtain satisfactory results. For example, butt joints designed to bear over their full areas should never be fully riveted until the component parts are in full bearing. This stipulation is made to ensure that the milled bearing

areas transmit their designed loads. With certain erection methods reversal of stresses may occur when the structure is complete. In these instances, the riveting should therefore be postponed until full bearing is obtained.

The correct time to rivet compression joints is always when the final load has been reached.

The reverse of the above is true with joints which have to withstand tensile forces. Every effort should be made to rivet such joints completely before even a fraction of the full load is attained. If the riveting operation is left too late, it may be found that the tacking bolts will be strained to such an extent that rivets cannot be inserted in the remaining holes without straining them as well. In serious cases the holes have to be reamed out and a larger size of rivet used in place of that specified.

BRIDGE ERECTION METHODS

PLATE AND TRUSS GIRDER SPAN BRIDGES

The possible spans for the plate girder bridge will range from about 20 ft to anything up to 150 ft. With smaller spans the main longitudinal beams are not likely to be actual plate girders, but will more often be standard rolled steel joists with, possibly, a flange plate added for strengthening. The longer span girders may be as deep as 12 to 15 ft. The erection methods adopted are unlikely to vary except that heavier tackle may be required for the longer spans. As with most erection work, the method of construction is determined primarily by the site conditions.

Truss girder bridges with the roadway carried on either the top or bottom chords of the truss are often used for road and rail spans over 100 ft in length. Sometimes the bridge may consist of two truss girders only, or there may be a truss between each roadway or track. The floor is carried by stringers and cross girders with the loads transferred to the main girders at the panel points. Standard British practice calls for all truss joints to be riveted rigidly but in some other countries (notably the U.S.A.) pin joints are used and the erector has to insert these pins after he has positioned the members.

Wherever possible, the simplest, and therefore least costly, method of erection is usually to lift the components of the bridge into position individually with a crane or cranes. Figs. 9.01 (a) and (b) show two versions of this method. In each case the two main girders must be positioned first, followed by the cross beams and stringers, after which the decking will be placed. Very little

@Seismicisolation

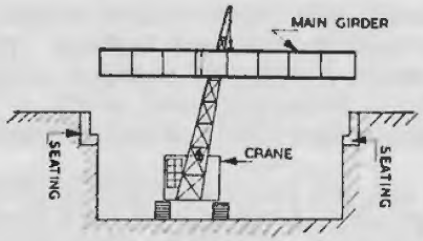
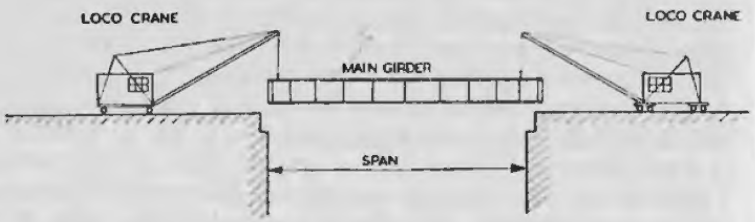


Fig. 9.01: Erection of plate girder bridges

A (left)
B (below)



trestling work is necessary, as can be seen from the illustration, and expenditure on this item will be very low indeed.

If trestling or piling can be used across the whole of the span as in Fig. 9.02, a temporary structure can be utilized to support the bridge until it is completely assembled. Packings and other supports are placed under the panel points only, so that no bending is caused in the horizontal truss members. These supports will be set to the levels of the camber specified and checks will be made on these points during the course of construction to make sure that no sinking has occurred. After the erection of the structure and the completion of the bolting or riveting, the trestling will be dismantled and the piling withdrawn. It will be noted that in the case illustrated the trestle or piled support has been constructed of greater width than the bridge itself and that it also supports a

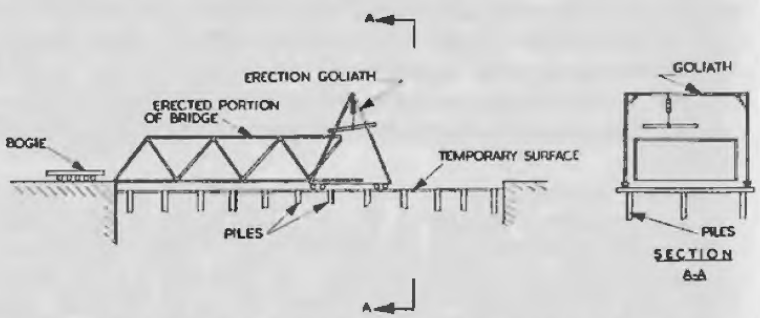


Fig. 9.02: Using piles to support a truss girder bridge during erection

goliath erecting crane. This crane handles all the erection work and a temporary track is laid along the completed section of the bridge to bring the steelwork from the stocking ground.

'LAUNCHING' OF SINGLE GIRDERS

The girders of a plate or lattice girder bridge can often be hauled separately across the opening, and the floor can be assembled with a crane advancing across the bridge over the floor steelwork as

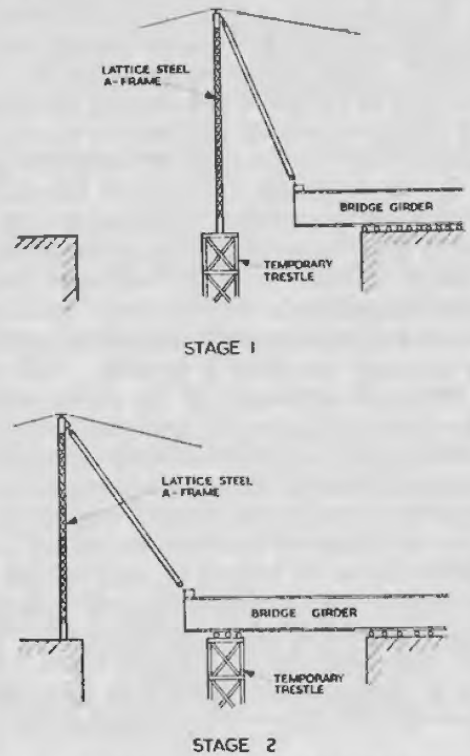


Fig. 9.03: " Launching " a girder

it is erected. Fig. 9.03 shows how the girders are " launched ", as this operation is termed. In this instance the span is too large for the girders to be hauled across in one movement, so the tackle is rearranged, after the first stage is completed, as shown.

The lifting derricks shown in the illustration are coupled together at their heads with a beam from which the lifting blocks are suspended. This type of twin derrick is termed an " A-frame " and

@Seismicisolation

will possibly be assembled from two standard steel derricks with suitable modifications to the heads. When a lift is made with this type of rig, the load hangs centrally between the masts and does not tend to drag against the derrick as often happens with a single derrick.

Each girder should first be assembled on a track of rollers behind one of the abutments, as shown, and should be cantilevered as far as possible over the span. The lifting blocks are then fastened to the outermost point of the girder and the heaving wire is coupled to the winch. It is advisable to restrain the rear of the girder and release it gradually so that there is no danger of any sudden forward movement. This can be accomplished by rigging a set of blocks to the rear of the girder and running the wire to a winch which must, of course, be securely tied back to an anchorage.

The first haul on the lifting winch will bring the girder to rest on the trestle A. By re-slinging the girder at this point, it can be hauled farther between the two legs of the derrick and partly over the second half of the span. The seating for the girder on the top of trestle A will be, in effect, a series of rollers so that the girder moves easily past this point.

The twin erection derricks are now moved to a position on the far side of the span and the girder is re-slung. This last haul will complete the horizontal movement of the girder which will now only have to be eased slightly into its final position. With careful planning and siting of the tackle it is often possible to complete this setting at the same time as the launching operation, particularly if the girder remains at the level at which it was launched. Bridge girders, however, are frequently set below the level of the abutments so that each girder has to be lowered to complete the work. The end held in the tackle could be lowered immediately the launching is complete, if time permitted, but it may be necessary to jack down the other end. This operation of "jacking down" often occurs in the erection of bridges, and is studied in more detail later in the chapter.

'LAUNCHING' BY CANTILEVERING

The launching of individual girders, or even of complete bridges, can also be carried out by cantilevering only. Sometimes the girders are cantilevered across the complete span in one operation but it is often necessary to use an intermediate support as in the previous example. This entails keeping the weight of the overhanging portion of the girder at a minimum and counterbalancing the overturning force by maintaining the heavier portion of the girder to the rear of the abutment, suitably ballasting this if necessary.

The girder is hauled across the span with a set of blocks. In this case the load on the blocks will be a horizontal pull only and the derricks are not necessary.

Naturally, a girder can only be cantilevered out a certain distance, depending on the balance between the overhanging section and the remainder. A temporary light extension of the type shown in Fig. 9.04 is sometimes fitted to give this overhanging portion more

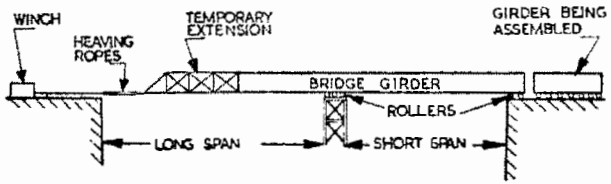


Fig. 9.04: Temporary extension to a girder to facilitate "launching"

"reach". Once this extension has reached the other abutment, the girder can be safely rolled across until the permanent part is in position. In the illustration the erecting cranes are situated on the right-hand abutment and the assembly of the girder is carried out from this point. The girder shown is continuous over two spans.

CANTILEVERING

On a twin span bridge it may be possible to close one span to traffic and erect the girders over this from trestling or piling, as is shown in Fig. 9.05. After the first girders have been constructed,

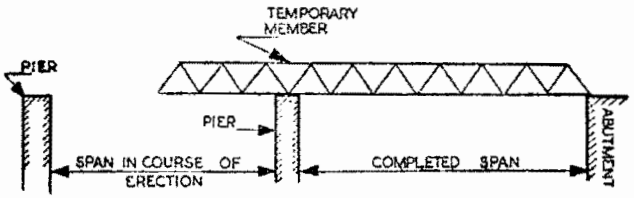


Fig. 9.05: Cantilevering a truss span

the second span is cantilevered across utilizing the first span as a counterbalancing weight. The bridge illustrated is not designed to function as continuous over two spans but, instead, each span is independent of the other. A temporary erection member must therefore be constructed and inserted, as indicated. The erection of the second span proceeds by building out the girders until they are over the supports. If the temporary erection member is

@Seismicisolation

constructed so that its length is adjustable, it can be lengthened to lower the girder to its seatings when the erection is complete. This temporary member may then be dispensed with.

When investigating the possibility of cantilevering a bridge, the designer must be brought into the discussion and his approval must be obtained. Cantilevering a span in this manner throws stresses opposite to those for which individual members were designed on most parts, and it is not often that the erection engineer has the original calculations to hand to enable him to check that his proposed method of construction does not endanger the safety of the structure.

ROLLING IN

When the new bridge is intended to replace an existing structure, the change-over usually has to be made with the least possible interruption to traffic. It is seldom possible to use the methods described above as they require considerable time for the assembly and riveting work, as well as for the placing of the decking. Where speed is the criterion, it is usual to assemble the bridge complete on one side of the existing structure and as soon as demolition of the existing bridge is completed haul the new structure into position. Often the concrete or other decking is also completed before the rolling operations so that, when the bridge reaches it final position, little additional work is needed before traffic can operate.

The change-over is usually made at week-ends when traffic is generally at its slackest. Due to the limited time available, the success of the whole operation depends to a large extent upon a carefully made schedule. Before the allotted week-end the new bridge will have been built on the trestles and rollers and as much of the old bridge as possible will have been dismantled. Immediately traffic has been halted or diverted, the old bridge is dismantled speedily and lifted clear, and the work of rolling in the new bridge can commence. If, as often happens, the telephone, gas, and water authorities had used the old bridge to carry their services, then they should be notified well in advance so that they can arrange for the transfer of their cables and pipes to the new structure while the change-over is in progress.

Sometimes it is necessary for the work to be carried out in two stages, one half of the existing bridge being removed at a time. This keeps interference to traffic at a minimum. Such an operation will now be described. The stages in the work are shown in Fig. 9.06.

The new structure shown cannot be assembled in two identical sections as the centre girder is common to both sides. The right-hand half of the bridge is first constructed and the centre girder is

temporarily utilized so that the floor beams and plates in bay No. 3 can be assembled. With the centre girder connected, all riveting is completed except for the connections to girder No. 3 which are bolted temporarily. The concrete decking is also cast, finishing

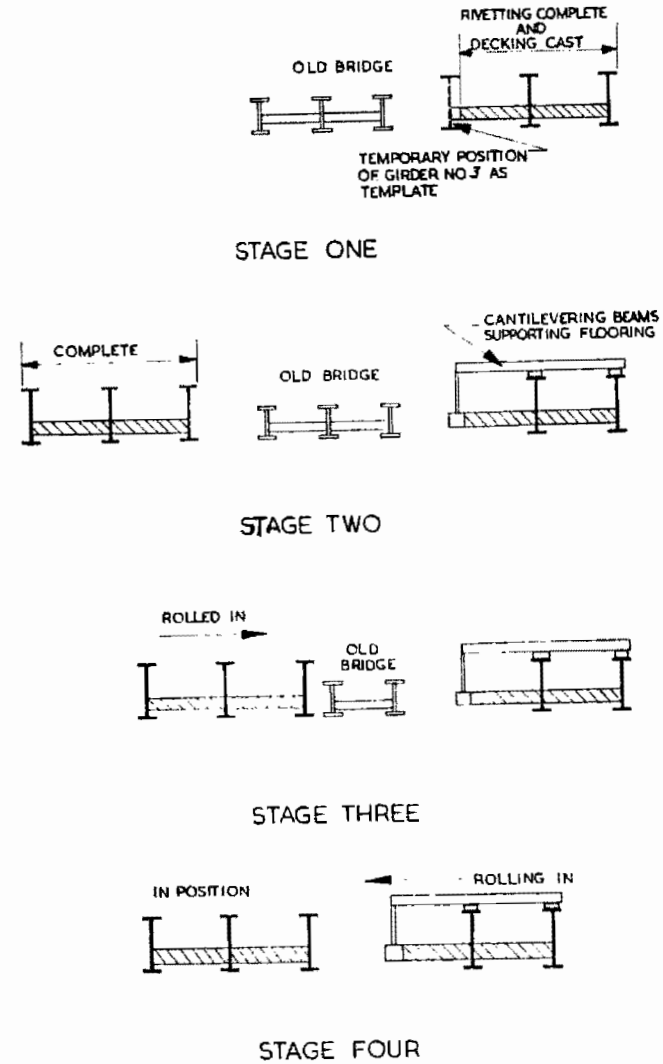


Fig. 9.06: Operations for " rolling-in " a bridge in sections

at a line clear of girder No. 3, so that this can be disconnected. This whole operation is shown as Stage 1 in Fig. 9.06.

In the second operation, cantilever beams have been positioned across girders No. 4 and No. 5. The ends of the floor beams connecting to the centre girder have been suspended from these

@Seismicisolation

beams so that the girder can be removed. The remainder of the bridge is now assembled on the other side of the existing structure, and riveting and concreting in this section are completed.

At a convenient time the work on Stage 3 can be commenced. The traffic is diverted to the right-hand half of the old bridge and the remainder of this is dismantled. The three girders with the two fully completed bays are now rolled across and, after jacking down and setting, traffic can operate on this section. The remaining moves are to dismantle the rest of the old bridge and to roll the second section of the new structure into position. If the tracks have been accurately set and the two sections of the bridge carefully constructed, little difficulty should be experienced in joining the sections where they meet at the centre. The use of the centre girder as a jig for the setting of the floor beams in bay No. 3 will ensure perfect fitting.

The setting of the roller tracks and the position in which the bridge is first assembled require careful attention. Any slight error in the alignment of the bridge when it is assembled usually increases during the moving and it is difficult to rectify this trouble. Before rolling operations are begun the track should be marked off in 1-ft

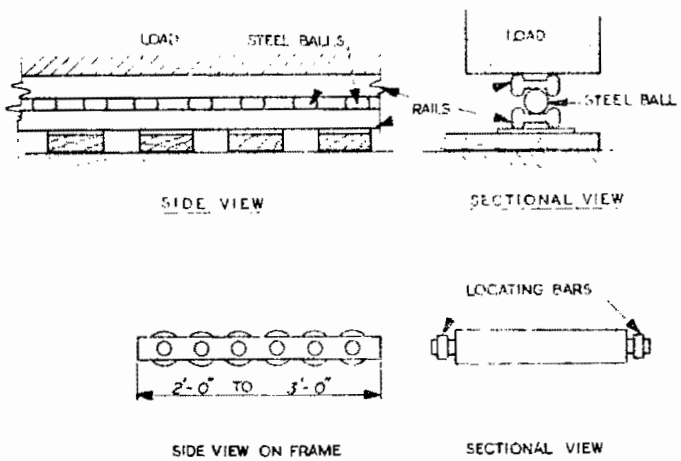


Fig. 9.07: Rolling gear

divisions so that, as the bridge is moved, its progress can be followed easily and it will be noticed readily whether one side is advancing more rapidly than the other, thus twisting the bridge structure from the rolling line. As the bridge approaches its final position, the 1-ft divisions on the track should be further subdivided so that progress can be followed even more closely.

A more detailed sketch of the gear used for rolling is given in Fig. 9.07. The rollers are constructed in frames which are about 3 ft long for ease in handling. The joists must be truly level and firmly packed so that there is no movement. Joints in the bearing joists should be staggered so that the rollers will pass easily from one joist to the next. Steel balls running between two layers of bull-head rail are often used, as shown, in place of the roller frames.

OTHER METHODS WITH SMALL BRIDGES

Fig. 9.08 shows a method of bridging a small span. This could possibly be applied when the distance between the supports is not

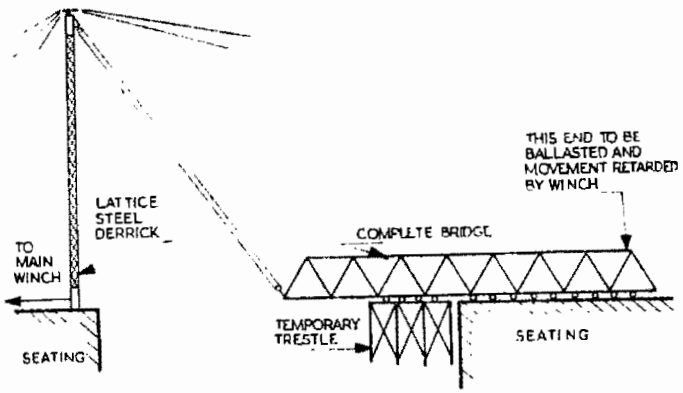


Fig. 9.08: Lifting a complete span into position

more than about 100 ft. The approach roadway to one side is completed first, and the main span is assembled there on rollers with the front cantilevered over the opening. The insertion of only the main structural members into this cantilever section will keep this as light as possible and, with the rear of the span ballasted, the main girders can be cantilevered past the span centre point without danger. Meanwhile a lattice steel derrick has been assembled and erected on the opposite bank and a set of blocks hung from this. The front of the span is now picked up and the whole is hauled into position. Two light winches suitably reeved and anchored to the rear of the span will prevent the latter from moving too fast.

If the bridge is to span a water-way which has to be kept open, it is impossible to use piling as described above, and some other method will have to be found. In some cases one solution would be to assemble the bridge span on barges, as shown in Fig. 9.09, and float it into position when complete. This method requires that the water be reasonably calm and that a suitable location is available

@Seismicisolation

close to the bridge site, where the assembly work can be handled without undue difficulty. To complete the work, the barges are so positioned that the span is over its final location and jacks are then used to lower the span to its seatings. Alternatively, the barges are sunk slowly by flooding the ballast tanks.

Sometimes the approach to the new bridge can be utilized, but no interference can be allowed with the road underneath. In such a

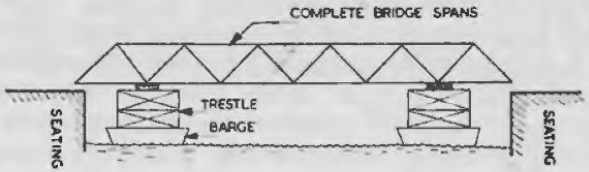


Fig. 9.09: Floating a span into position

case the bridge could be constructed on a trestle in the position shown in Fig. 9.10. The foot of the trestle is set on a track and, before the bridge is positioned, further track is laid over the roadway. The trestle with the bridge is hauled across this track. The rear of the bridge is supported on a special track of rollers. When the bridge is across the span, jacks are used to remove the trestles and rollers, and to lower the structure to its permanent seatings.

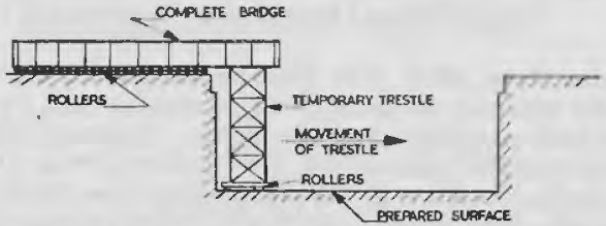


Fig. 9.10: Another rolling method

JACKING DOWN

On the erection of nearly all small bridges jacking will be necessary and will usually be one of the final operations in the positioning of the bridge structure. In all cases where the bridge has to be moved into position, jacks are used to lower the bridge to its final position and to remove the roller frames and other material. These jacking operations must be studied carefully when the erection of the bridge is first considered. With forethought the operations can often be greatly simplified. The more straightforward the work is

made, the quicker it is done. Often provision can be made for special cleats on the sides or ends of the girders on which the jacks can bear. Suggestions are illustrated in Fig. 9.11. These cleats can be made and fixed in the construction shops at the same time as the girders are fabricated. A jacking cleat often eliminates the use of a toe-jack and much packing. Toe-jacks are never recommended for heavy work as the toe is not too reliable and can be fractured easily.

On an important jacking operation every member of the erection squad must be clearly instructed in his duties. A practice operation

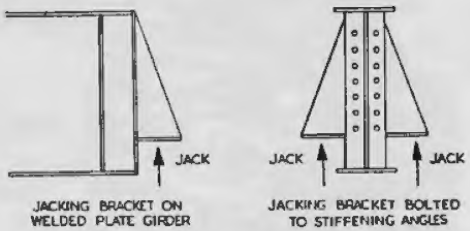


Fig. 9.11: Jacking cleats and brackets

would acquaint each man with his work and would also indicate whether the time allowed for the whole job was satisfactory. Hydraulic jacks should never be stressed to their limits as, except when new, fluid may possibly leak past the glands and valves and thus cause trouble at a crucial moment.

A large number of packs of varying thicknesses should be supplied when a load is to be either raised or lowered with jacks. The movement of the load on the jacks is followed up or down with these packings, the gap between them and the girder never being more than about 1 in. Should the jacks fail, the load will then not fall any great distance. The height of the lift of a particular jack will be stated in the maker's information sheets or can be found by practice. In calculating the movements in the jacking operations, more than 50 per cent of this figure should never be used. This will minimize any danger of the ram of the jack being driven too far and coming out of the barrel. Also, there is always some " give " in the packings when the weight is transferred to them and this may lose a precious inch or two.

Operations should be watched carefully to ensure that in all cases the lift is truly vertical. If a jack is used at an angle, this may cause the head to slip and, in addition, it throws a bending stress on the ram which may fracture either it or the casing. A thin piece of

@Seismicisolation

hardwood inserted between the head of the jack and the ram minimizes the chance of slipping. When two or more jacks are used in conjunction with each other, care should be taken that the load is lifted squarely and that each jack is taking its share of the load.

TIMBER PACKINGS

Timber packings are often assembled in what is termed a " birdcage ". This is illustrated in Fig. 9.12. The essential points to watch are that the packing has a foundation worthy of the weight

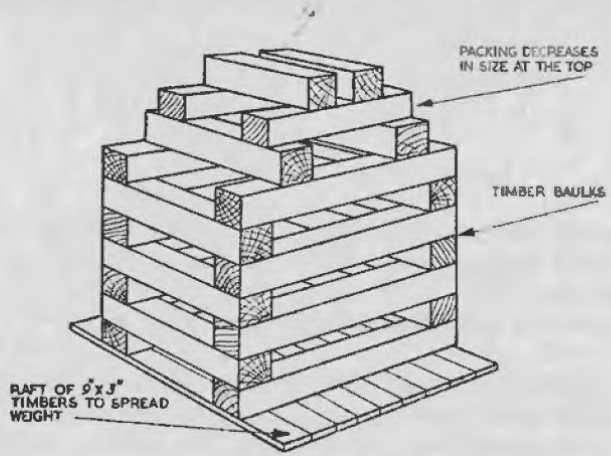


Fig. 9.12: A " birdcage " timber packing

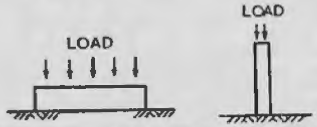
it is to support and that each timber is bearing firmly on the member below it, thus taking its full share of the load.

The ground should be carefully levelled and a grillage of timber sleepers laid before the birdcage is constructed to ensure that the safe bearing pressure on the ground is not exceeded. For heavy loads or semi-permanent packings a concrete slab, suitably reinforced and possibly with spreader beams, may be constructed. A table of safe bearing pressures for various types of ground is given in Chapter 6, and the figures given should never be exceeded. Table 9.01 sets out the recommended safe bearing loads for timber packings and props.

SUSPENSION BRIDGES

This type of bridge is one of the most elementary design, and is often constructed by the inhabitants of primitive countries from material found in the locality. The method of construction is more

Table 9.01. SAFE BEARING LOADS FOR TIMBER PACKING AND PROPS

Type of timber	Max. stress perpendicular to the grain in lb/sq in.	Max. stress parallel to the grain in lb/sq in. L/d = 11 or less
Western red cedar	200	950
Douglas fir	320	1,450
Eastern hemlock	300	950
European larch	265	1,330
European redwood	240	1,330
European whitewood	190	1,200
Ash	500	1,450
Oak	500	1,350
Sketch of loading		

suited for the larger spans, as most of the main members are in tension and the self weight of the structure is thus low.

Suspension links were originally of iron or steel but cables formed from steel wires are now used. The roadway is suspended by hangers from this cable and, to spread the weight of the traffic, the roadway beams are carried by truss-type girders which distribute the load and prevent the suspension cables from assuming alarming

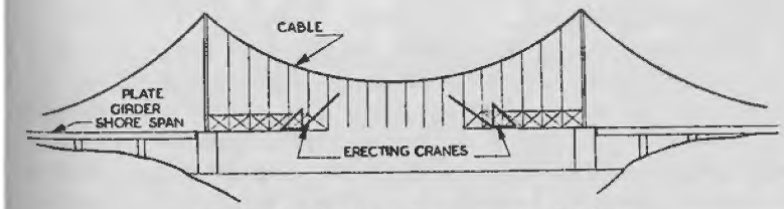


Fig. 9.13: Erection of a suspension bridge

shapes. Horizontal bracing between these girders carries the wind loads.

Erection of the towers is usually undertaken with a specially adapted crane which erects steel ahead of itself and then lifts itself to a higher level. Two cranes are used if the size of the structure

@Seismicisolation

warrants it, and in this case one crane can lift the other. An enlarged version of the builder's cathead is sometimes employed. This fits inside one of the legs of the towers or fastens to the side. When it has erected all steel within its reach it can be lifted to a higher level before commencing erection of the next section of the structure.

For small suspension bridges the cables are supplied ready for erection and require only hoisting into position. On the larger bridges the size of the cable required becomes so great that it must be spun in position from a large number of small strands. Once the pilot cable has been established across the span, walk-ways are constructed and the cable laying trolley is installed. This runs back and forth across the span laying a wire or wires on each journey. Each individual strand is then carefully laid in position to form the finished cable. When the cable spinning is completed, the strands are compacted to give the final shape of the cable and the cable is usually bound after painting.

If the complete cable is hauled across, care should be taken that the wire does not dip into the water as the action of some waters can cause rapid deterioration of the wire. When the wire is supplied made up to the exact length required, the positions of the anchorages, the saddles at the head of the towers, and all the hangers should also be marked.

The hangers are clipped to the cable with special brackets and can be slid down the cable to their allotted positions and then bolted securely. Erection of the hangers will then start at the span centre and work symmetrically back to the towers to keep the cable balanced. Erection of the roadway commences at the towers and the work is again carried out symmetrically. The erection cranes advance along the roadway as they erect.

STEEL ARCH BRIDGES

Three types of steel arch bridge are shown in Fig. 9.14. They are respectively the three-pinned arch, the two-pinned arch, and the fixed arch. In each case the roadway may be either slung from the arch, as in Fig. 9.14 (a), or carried above and supported by struts, as in (b) and (c). The latter type is adopted when the available support for the thrust blocks is below the level of the proposed roadway. The erection procedure selected for the construction of any particular arch bridge will usually be governed more by the site conditions than by the type of arch.

Sometimes the erection of a fixed or semi-fixed arch is carried out as though the structure were a three-pinned arch. The feet are set on hinges and, when the sections meet at the centre, a temporary hinge is inserted. At a certain stage in the erection these

temporary hinges are converted into permanent fixings. The conditions which must be satisfied before this is undertaken will be decided by the bridge designer. He will consider the weight of erected steel and also the temperature. This conversion from a three-pinned arch would possibly take place after the ribs had been erected and before the fixing of the hangers and roadway beams.

The two usual methods of erection of arch bridges are by supporting the structure off trestling until the closing sections of the ribs

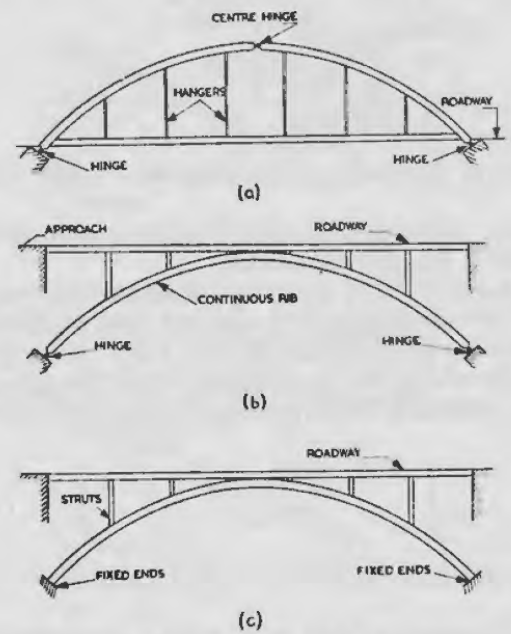


Fig. 9.14: Types of arch bridge

have been inserted, or by cantilevering the ribs out from each side of the span. The latter method is more applicable to the erection of an arch spanning a deep gorge. Over a shallow water-way it is possible that the most economical method of construction would be to use piling or trestling, and erect from this temporary structure.

If the structure is cantilevered out from each side, the erecting cranes may work their way along the top chord of the arch carried on a specially constructed frame called a "creeper". This is hauled along in stages as the arch is constructed ahead of it. Alternatively, a cableway could be employed. Both methods are shown

@Seismicisolation

in Fig. 9.15 and Fig. 9.16. The creeper frame is set on the top chord of the arch and mounted on it are the erecting cranes and, possibly, other cranes which are employed solely to hoist the steel and place it within reach of the erecting cranes. The whole creeper frame, complete with cranes, can be hauled along the arch as the steelwork

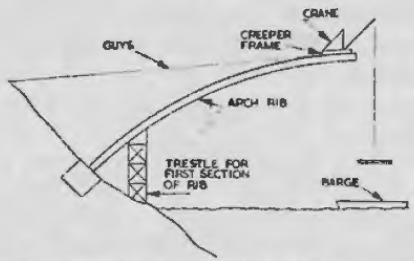


Fig. 9.15: Erection of an arch bridge with " creeper " cranes

is completed. Stops and clamps are used to prevent the frame from moving once it has been positioned.

The cableway erection procedure eliminates the weights of the cranes on the cantilevering arch ribs and thus considerably lessens the loads on the guys holding the arch back. Its uses are limited to the smaller bridges but, nevertheless, it can often be satisfactorily employed. Standard cableways can be obtained taking loads of

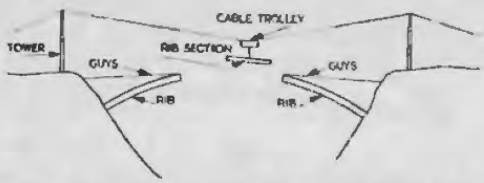


Fig. 9.16: Erection of an arch bridge utilizing a cable-way

up to 10 tons. The levels between the towers must be very nearly the same for satisfactory operation.

Occasionally a steel arch bridge can be erected by a floating crane operating off a barge. Material will have to be taken to this crane by boat.

Nearly all the sections of the arch itself are sloping when fixed. When these sections are slung prior to erection it is therefore necessary for them to be lifted at the correct slope to make fixing easier. Either special lifting brackets or slings with legs of differing lengths are used.

The first major operation in constructing a steel arch bridge is the setting of either the hinges of the arch rib or the footing if the arch is of the " fixed " design. Careful survey work is essential at this stage and the success of the construction will depend upon the attention and care given to this operation. The setting of the hinges or the first section of the rib must be very accurate. Any slight error in alignment at this point will increase as the erection of the structure progresses so that the two sections may not meet exactly when they

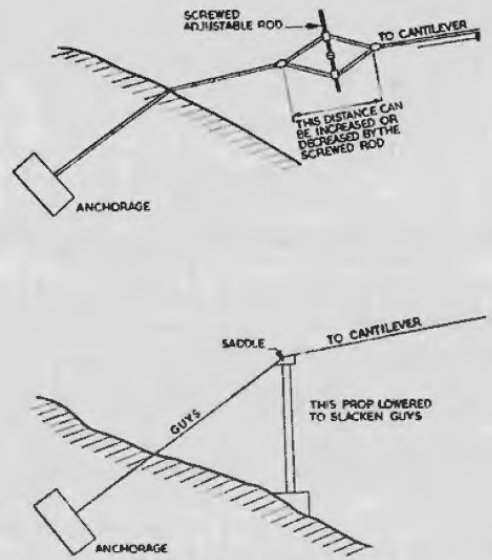


Fig. 9.17: Slackening the guys restraining the arch sections

reach the centre point. Quite often this possibility is considered in the design and detailing stages and making-up sections are fabricated so that adjustment is easily made if necessary.

The first section of the arch is assembled on trestling. Both this section and the hinges can be reached from the shore so that it may be possible to use standard erection tackle for this work. After the next sections have been erected, they are tied back to specially prepared foundations. These anchoring guys are usually made to be adjustable so that, when the two halves of the ribs have been completed, the tension can be eased slowly and the gap between the two sections closed.

Various methods are adopted to slacken the guys. If the guys consist of a large number of separate wires, each wire is slackened

@Seismicisolation

individually—the load being gradually transferred from the shorter wires to the longer ones. Other methods are to insert some kind of toggle, the length of which can be adjusted, or to pass the wires on a saddle over a prop which is moved to deflect the guys. Both methods are shown in Fig. 9.17.

When the arch has been erected by cantilevering, it may be found that the closure of the centre does not take place as anticipated.

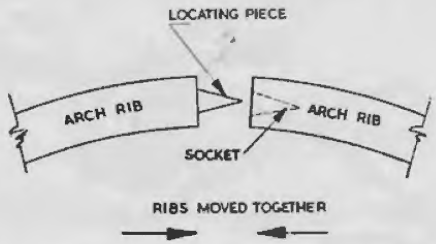


Fig. 9.18: Locating the arch sections as they meet at the crown

Adjustments will have to be made to overcome slight errors in line and level of the two sections. This can sometimes be done with the aid of clamping plates. Another method is to use a tapered locating device which settles into a corresponding opening in the opposite section as the two sections meet (see Fig. 9.18). The erection of an arch rib on trestles is comparatively simple once the trestling has been constructed (see Fig. 9.19). After the arch ribs are completed

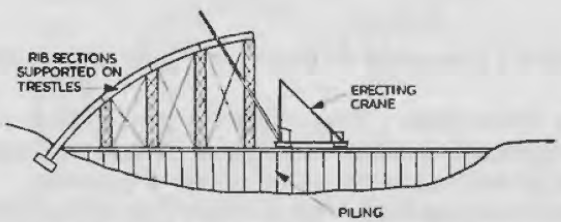


Fig. 9.19: Arch bridge erection from trestling

and the span closed, the hangers and roadways are erected. The same equipment will possibly erect these, and in that case erection commences at the span centre and works back to the shores.

CANTILEVER BRIDGES

The cantilever type of bridge is seldom adopted for a small span as the design is not often economical in these cases. The erection

procedure follows the design principles for the structure. The towers are erected first and the spans are cantilevered out from each side. With this method it is, of course, essential that work each side of the tower is carried out at an identical rate so that the balance of the structure is preserved. The closing spans between the cantilevers are usually assembled on barges, floated out, and hauled into position with tackle hung from the structure.

If the bridge spans a water-way suitable for piling, the bridge could be assembled complete on this temporary structure which would be withdrawn on completion of the erection work. In Fig. 9.20 that section of the bridge nearest the shore has been constructed on timber piling before the centre spans are cantilevered

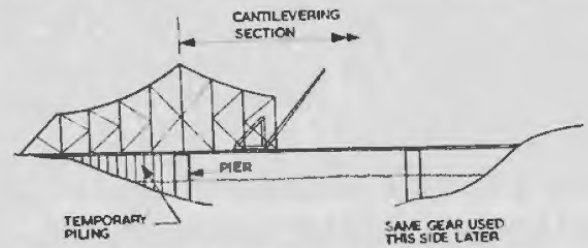


Fig. 9.20: Cantilever bridge erection

out. The erecting cranes are run at roadway level the full distance, as all lifts are within reach.

In either of the above erection methods little difficulty will be experienced with the actual erection work. When cantilevering the structure, the erection cranes may have to be moved along the top chords. In this case it is advisable to use a travelling crane with adjustable back legs as the slope of the chords will vary along the span. In addition, as has already been noted, the strengths of the chords should be investigated to ascertain that they will withstand any bending moments from the erection gear. A temporary track at roadway level is used to bring the bridge members within reach of the erecting cranes.

@Seismicisolation

CHAPTER 10

BOLTING AND RIVETING

BOLTING

A LARGE proportion of site connections are made with black bolts. From the point of view of the erector this makes for simplicity as the erection can be completed in almost one operation. The additional cost of special labour for riveting and the plant required is also avoided.

Black bolts cannot, however, carry loads equal to those of a rivet with the same diameter, and this means that in certain highly stressed connections this type of bolt is not used. In such cases some designers favour the use of turned bolts which are capable of carrying much higher loads. The diameters of the holes and the clearances allowed for the bolts will be specified on the drawings. On the site greater care must be given to the lining of the holes and the insertion of the turned bolts so that no damage is caused either to the bolts themselves or to the metal surrounding them.

HIGH STRENGTH FRICTION GRIP BOLTS

Structural engineers and others have long searched for a method of bolting that would enable site rivets to be replaced by a connection which, retaining the same joint strength as the riveted connection, could be assembled with the ease possible when black bolts are used.

Bolting offers many advantages over riveted construction when the work has to be undertaken at the site. It would be useful to list these advantages:—

(a) The structure may have to be dismantled. Bolts can be easily withdrawn to enable the sections to be separated for removal.

(b) Often the site may be in an area where only a certain noise level is permissible and riveting may thus only be allowed during certain hours, if at all.

(c) Riveting requires special equipment—compressors, heating fires, riveting hammers and holding-up hammers. This equipment is required whatever the number of rivets to be driven—whether it be one hundred or one hundred thousand. If the number of rivets to be driven at site is low, the expense of supplying the equipment will represent a very high proportion of the cost per rivet, whereas with high strength

bolting, hand torque spanners (Plate 10.01) only need be used when the quantity of bolts to be tightened is small.

(d) A further advantage is that when the work is undertaken above ground a minimum of staging is required compared with that necessary for riveting work.

Until recently the only solution for connections that were highly stressed was to use turned and fitted bolts. There are many difficulties in using such bolts for site work. Insertion of the bolts usually presents the major problem. Specifications covering the use of turned and fitted bolts allow, as a maximum, 1/100 in. clearance between the bolt shank and the sides of the hole. When undertaking the assembly on site, and often aloft, it is difficult to bring the sections together so that the bolts can be inserted without damage to either the bolt shank or the hole. When the specifications state that the holes should be lined so that the bolt can be driven by tapping lightly with a 2 lb hammer, it will be appreciated how difficult correct assembly becomes. Any greater force used to drive the bolt will be certain to cause damage to the bolt or hole and should never be tolerated.

Difficulties in lining connections for fitted bolts are often overcome by having the holes shop-drilled undersize, assembling at site with temporary tacking bolts, and then reamering the holes to the correct size, before the bolts are inserted. When fixing a large number of bolts this method is both time consuming and expensive. The method of bolting, now generally known as "High Strength Bolting" which is described below overcomes most of the difficulties mentioned in connection with the use of turned and fitted bolts, and the structural designer can now specify "high strength bolts" knowing he will have a bolted connection equal to the strength of a riveted connection yet which will cost, for the labour involved in fitting the bolts, little more than if the connection were to be made with standard black bolts.

It is important to realize at the outset that the use of high strength bolts is an entirely new approach to the problem of assembling a connection. Riveting and previous methods of bolting may be visualized as dowelling. In the majority of such connections the shear load on the bolt or the bearing loads on the metal have been the governing factor in the design. When high strength bolting is employed the bolt is tightened to such an extent that the various plies in the connection are clamped together and what would be a shear or bearing load is carried by the friction between the fraying surfaces.

The essential differences in approach to the same problem are illustrated in Fig. 10.01. In (a), the black bolted or riveted connection,

@Seismicisolation

the plies 'give' until they bear on the side of the bolt or rivet. Bearing stress occurs at these points and the bolt or rivet is subjected to shear loads on the section a-a and b-b. In (b) the high strength bolt is tightened until the washers exert a compressive force on the plies and the friction on the surfaces a-a and b-b holds the plies in place. Ideally the shank of the high strength bolt remains clear of

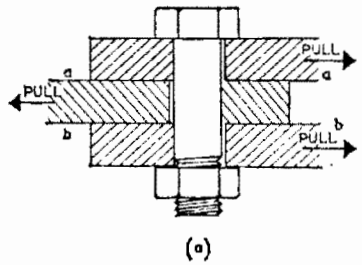


Fig. 10.01(a) Black-bolted connection under shear load (shear stresses occur on bolt shank at sections a-a and b-b)

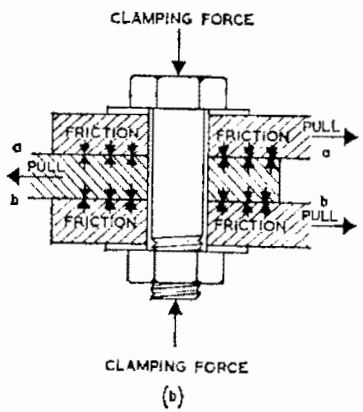


Fig. 10.01(b) High strength-bolted connection under shear load (the clamping effect of the bolt produces frictional forces on the contact surfaces of the connection)

the sides of the hole so that a 'normal clearance' hole can be used. This means that the hole diameter is 1/16 in. greater than the diameter of the shank of the bolt. Site assembly of the connection is thus greatly simplified.

Many respects of the high strength bolt may be compared to the claw tooth and split ring connector now being used on an increasingly larger scale in timber construction. These timber connectors transfer the load between the members by what might be termed their friction on the bolt merely clamping the connectors in place. So with the high strength bolt—the stress is transferred by the friction between the surfaces of the plies in the connection and the function of the bolt is to hold the plies clamped so this friction may take effect.

Although the high strength bolt is not a machined bolt in the same sense as the turned and fitted bolt, there is one essential refinement in

their manufacture—that is besides the fact that they are manufactured from high tensile steel. The underside of the head and the bearing surfaces of the nut are semi-finished—otherwise the bolt and nut are used as forged. In addition each bolt is provided with two hardened washers which must be fitted under the head and the nut. These washers spread the load preventing the head and the nut becoming embedded in the softer steel of the structural members (again note the parallel with modern timber construction). A High

HIGH STRENGTH BOLTING

Table 10.01. WASHER DIMENSIONS AND BOLT TENSIONS AND TORQUE VALUES

Bolt Diameter (ins.)	Washer Dimensions: Inside Diameter (ins.)	Washer Dimensions: Outside Diameter (ins.)	Washer Dimensions: Thickness Gauge No.	Recommended Bolt Tension for Calibrating Impact wrenches (lbs.)	Required Minimum Bolt Tension (lbs.)	Approximate Equivalent Torque to Give the Required minimum Bolt Tension (lbs.–ft)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{3}{8}$	12	12,500	10,850	90
$\frac{5}{8}$	$\frac{11}{16}$	$1\frac{3}{4}$	10	20,000	17,250	180
$\frac{3}{4}$	$\frac{13}{16}$	2	9	29,000	25,600	320
$\frac{7}{8}$	$\frac{15}{16}$	$2\frac{1}{4}$	8	37,000	32,400	470
1	$1\frac{1}{16}$	$2\frac{1}{2}$	8	49,000	42,500	710

Strength Bolt, with the special washers, is shown in Plate 10.02. Note the identification symbols on the bolt head.

Assembly of connections utilizing high strength bolts follows a different procedure from that used to assemble a connection made with ordinary black bolts. Black bolts and rivets are inserted and so tightened that they will not work loose—high strength bolts have to be tightened until they exert a specified clamping force on the members making up the connection. These clamping loads will depend upon the diameter of the bolt.

The required minimum tension for each bolt size has been set out in Table 10.01 column 6. The dimensions of the hardened steel washers that must be used under both the head and the nut are also shown in this table in columns 2, 3 and 4.

The required load on the bolt (or pre-load as it may be termed) is a figure which may be easily measured under laboratory conditions but cannot easily be measured on the site. For ease of reference on the site the value of the pre-load is translated into terms of a minimum torque. Strictly speaking this will not give a true relationship and there may be some variation but, for all practical purposes, the

@Seismicisolation

value of the torque can be considered as a practical method of measuring the pre-load. The approximate value of the torque required for each diameter of bolt is shown in the last column of Table 10.01.

There are various ways in which the necessary torque can be given to the bolts. For the smaller diameter bolts the hand torque spanner is possibly the best tool to use. These spanners can be pre-set to the required torque and are then used to tighten the nut in the usual manner continuing until the set figure for the torque is reached. At this point the spanner will ' collapse ' and the nut can be turned no farther. When the number of bolts to be tightened is small the torque spanner is an ideal tool.

A disadvantage of the torque spanner is that it is a fairly heavy tool and for the larger sizes of bolt becomes too heavy for practical use. For repetition work the practical limit of the hand torque spanner is reached when a torque of over 500 lb-ft is required. Torque multiplying spanners (which are in effect small torque spanners operating through a geared head) will answer the problem but, although the torque applied to the handle is brought down to within a reasonable figure, the complete tool still remains heavy. Another disadvantage in the use of the torque multiplying spanner is that a reaction plate (stop) has to be provided against which it can operate.

To deal with a large number of bolts of large diameter the impact wrench will be found to be the best tool. Impact wrenches are usually operated by compressed air although electrically operated models are available. In operation the impact wrench runs the nuts up tight and then begins to hammer them round by a continuous series of blows. Reaction from the machine is low and there is little operator fatigue. A compressed-air-operated model is shown in Plate 10.03.

To use the impact wrench successfully some means must be found of establishing the tension that is being exerted on the bolt so that when the required tension figure is reached the machine can be cut out. Many methods have been suggested and tried. One method is to experiment with the air supply until a pressure is found at which the machine just begins to stall. A reducing valve is fitted to the air supply line adjacent to the wrench and each morning a test is made on a specimen bolt fitted in a special calibrating machine. The air supply is adjusted by the reducing valve until the wrench begins to stall at the required figure. A note is made of the interval that has elapsed between the point at which the nut was made tight (i.e. when the wrench began to hammer) and that which it reached the necessary tension value. This ' count ' is used throughout the day

by the operator. To allow for any variations that may occur in the air supply during the day the specified minimum tension to be used in calibrating the wrenches should be some 15% higher than the required minimum bolt tension. Thus the values for setting the wrenches are those that are shown in column 6 of the table.

There are impact wrenches on the market that incorporate devices for cutting out the air supply when the specified torque figure has been reached, but it is recommended that even these machines be tested each day against some known standard.

Experiments are still being conducted to obtain simpler methods of giving the bolts the specified tension and one of the best suggestions to date is what may be termed the " turn of nut " method. Experiments have shown that if a nut is tightened by hand and then given one complete turn the bolt will have reached the required tension. There is another method which is a slight variation on this procedure. If the impact wrench is used to run up the nuts, the nut should be given one half of a complete turn from the point at which the wrench begins to impact—that is another way of saying that the point at which the wrench begins its impacting action is half a turn past the point at which the nut may be considered to be hand-tight. If the socket of the impact wrench is marked the degree of rotation can be easily watched.

When using any of these methods of assembly special attention should be paid to the procedure of bolting. Approximately 25% of all the bolts in the connection should first be tightened so that all the plies in the connection are brought fully together. The remaining bolts are then inserted and then either made hand-tight and given one full turn or are run up with the impact wrench and given one half turn after impacting commences. The bolts previously used for clamping the plies are then slackened and tightened using the procedure outlined above.

It is most essential that the testing of high strength bolts is carried out in an orderly fashion. It is elementary to say that all bolts should be checked to see that correct sizes are being used but still this should be done. To check that the tension (or torque value) is correct at least 10% of the bolts in each connection should be tested. For connections with less than 10 bolts at least one bolt in each connection should be checked. Testing can be by means of a correctly calibrated torque spanner or by the use of a special spanner that will indicate the torque value reached. Bolts that have been checked and found correct should be marked in a distinctive manner. In order that the chance of the plies slipping under load is considerably reduced the usual practice of painting the contact surfaces of the connection should not be performed.

@Seismicisolation

RIVETING

Before the development of pneumatic equipment special long-shafted hand hammers were used to form the rivet heads. The rivets were inserted and held up by one man and a series of blows, delivered in quick succession to a definite pattern by two riveters, formed the shape of the head. Hand riveting as such is now seldom seen, and the present-day use of the term is intended to mean work carried out with hand pneumatic tools.

In the construction shops jaw riveters are used having a C-shaped arm large enough to encircle the member, and the rivet is closed by air, hydraulic or electric power, which operates the ram of the machine. This type of plant will only be used on the site for very exacting work as it is very unwieldy. Hand riveting requires a pneumatic hammer for forming the heads and a dolly or some form of jamback to hold the rivet tightly in place while this is being done. Two hammers are occasionally used, one on each end of the rivet.

The usual riveting squad consists of three men, riveter, holder-up and heater. If the hot rivets have to be passed some distance a fourth man will be employed. Quite often the riveting squad are allowed to erect their own scaffolding as they proceed but this naturally slows the work down. The amount of scaffolding for a given number of rivets will depend upon how scattered the work is. If scaffolding has to be used to any great extent, it is usually preferable to scaffold in advance of the riveting squad.

Whether sections can be site jointed on the ground and lifted in one piece will have been decided when the erection procedure was considered. Riveting of large plate and lattice girders on the ground will be considerably cheaper, scaffolding will be eliminated to a certain extent and the connections will be completed before any stress is thrown on them.

Availability of the necessary heavy lifting gear, and a study of the difference in costs between providing trestling to support the sections until they are jointed, as against the erection and use of the heavier lifting gear are important factors in deciding which method is to be used.

As the erection crew assemble the structure they will have inserted service bolts intended to hold the uncompleted structure safely and will have drawn all connections tightly together. It is essential that sufficient service bolts are used and that they are all fully tight, otherwise the holes will tend to move out of line before the riveting squad begin their work.

After connections have strained in this manner it is almost impossible subsequently to return them to their original standard for the insertion of rivets.

Large connections and particularly those which have to be threaded between gusset or splice plates will cause most trouble. Drift pins are used to line the holes. Tapered drifts are driven as a preliminary, followed by barrel drifts to bring all the plates in the connection into line. Care must be taken to ensure that the hole is not damaged or forced out of shape. In special cases, the original holes are drilled a size smaller and reamed to the designed size immediately before riveting. This practice ensures a perfectly clear hole.

The work of the rivet heater may appear very simple but he is an important member of the riveting squad. The rivet is heated uniformly so that, when the head is formed, the shank swells and completely fills the hole. If this requirement is not fulfilled, the rivet will not carry its share of the load on the joint. The control of the temperature to which the rivet is heated is most important. Too high a temperature will burn the steel of the rivet and yet, unless the whole of the rivet is heated, the shank will not swell sufficiently to fill the hole.

Normally riveting will follow very closely upon the erection of the structure but, when this is not feasible or convenient, all connections must be well bolted by the erection squads. Sometimes, however, it may be advisable to allow the structural member to reach its full load before riveting to ensure that the butting surfaces are carrying their designed load, leaving the rivets merely to hold the connection in line. This exception applies only, of course, to joints transmitting compressive loads; the opposite argument holds good in the case of connections carrying tensile loads. In the latter, the full number of rivets in the connection must be inserted at once or, if this cannot be done, the connection must be completely bolted as a temporary measure. If important tension joints are left in a weak condition it will be found that those bolts which have been inserted are strained to such an extent that it may be impossible to line the remaining holes and insert the remaining rivets or bolts. Riveters must therefore never carry out the work in the order most convenient to them but must follow the plan laid down by the erection engineer or foreman.

THE SHAPE OF THE RIVET HEAD

The shape of the rivet head required will be specified on the drawings by one of the conventional signs shown in Fig. 10.02. To obtain the shape specified, the riveter will need a suitable snap for his riveting hammer. The cup head shape is used for the vast majority of structural riveting but the countersunk pattern is

@Seismicisolation

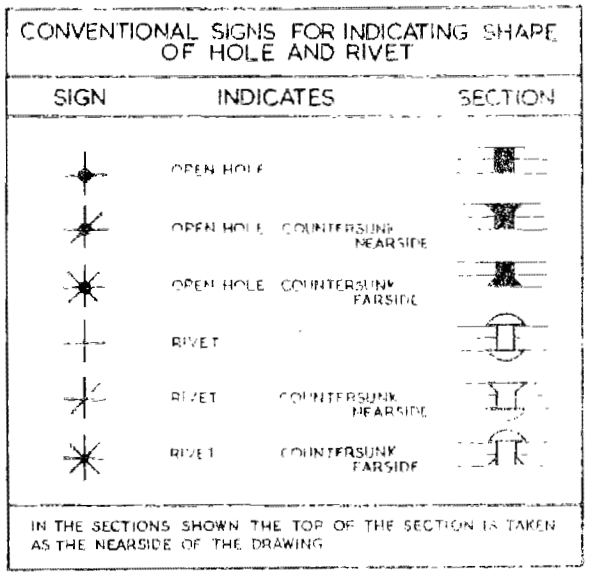


Fig. 10.02: Conventional signs to indicate the shape of rivet heads

required where a flush finish is necessary. The other shapes are seldom used.

INSPECTION OF RIVETING

During and on completion of the riveting, inspections must be made by the erection supervisor to check that the quality of the work is satisfactory. Holding the hand on one side of the rivet head and tapping the other side with a light hammer soon reveals loose-fitting rivets.

Rivets with badly formed or eccentric heads are also objectionable, and any rivet that is faulty in any way must be cut out and renewed. It is as well to note here that a lip on the rivet head does not give a good-looking finish but is to be preferred to a rivet which is loose in its hole. Rivets can be rapidly cut out using the oxy-acetylene cutting torch fitted with the special nozzle as described in Chapter 11. Great care must be taken not to damage the surrounding metal while this is done.

EQUIPMENT FOR RIVETING

COMPRESSORS

If work has to be carried out in existing factories it is sometimes possible to make use of an air supply already in operation. Many large works have a piped supply of compressed air circling the important buildings, and it will only be necessary to tap this supply.

Plate 10.01: Using a torque spanner on friction-grip bolts

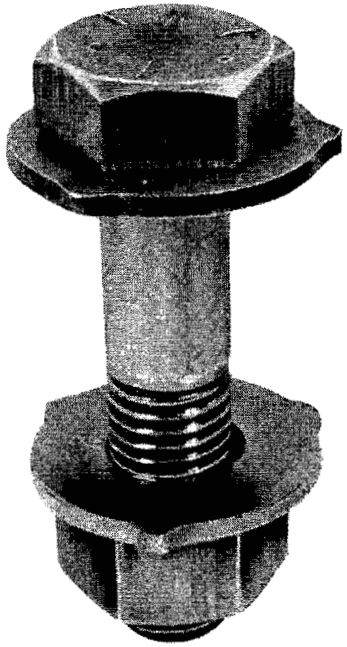


Plate 10.02: High strength friction-grip bolt with special hardened washers

@Seismicisolation

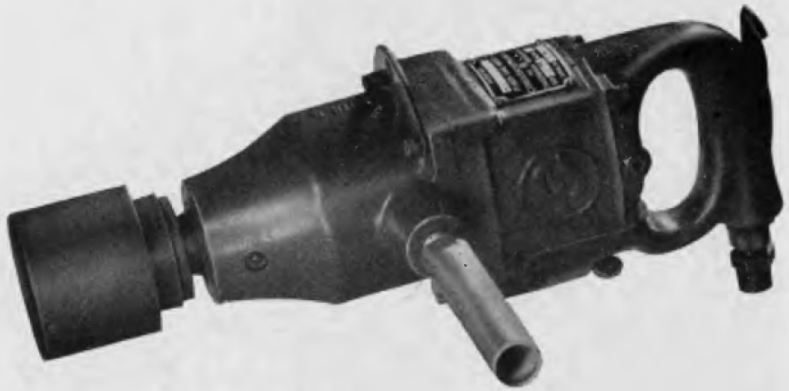


Plate 10.03: Compressed-air operated impact wrench

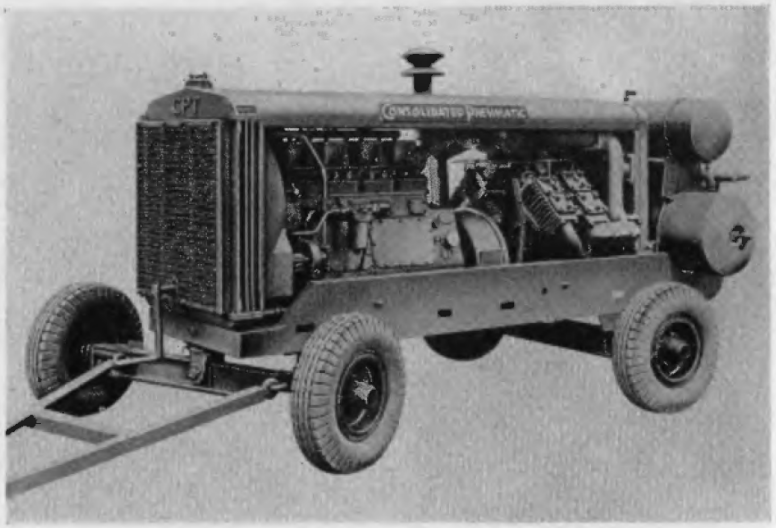


Plate 10.04: Portable air compressor mounted on pneumatic-tyred wheels

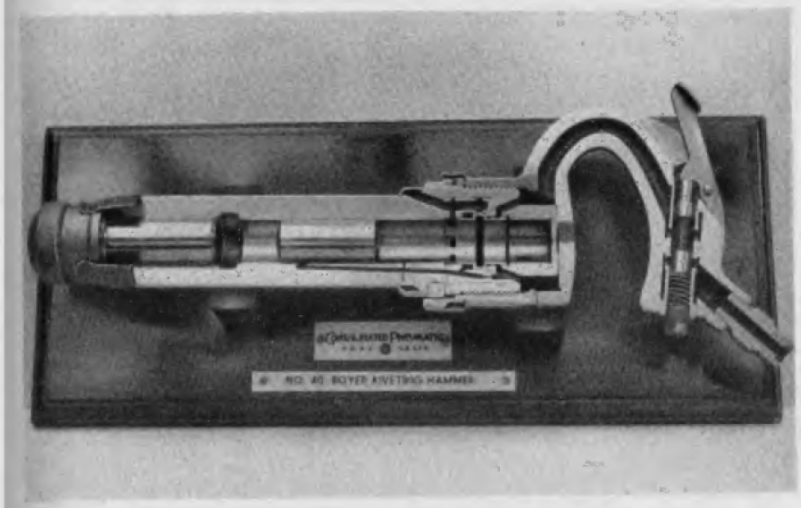


Plate 10.05: Sectional view of a pneumatic riveting hammer

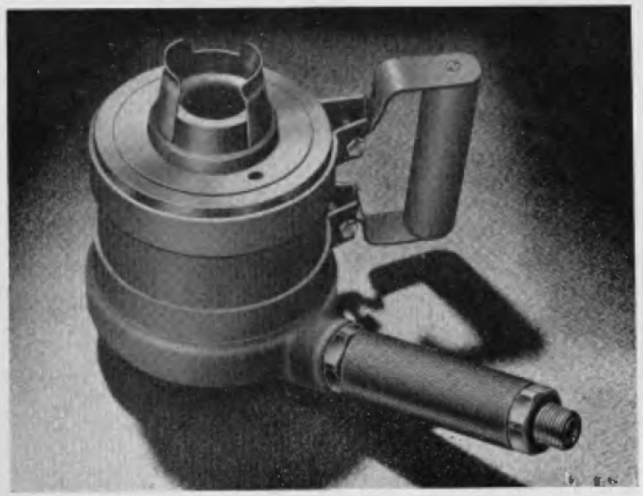


Plate 10.06: Holder-on

@Seismicisolation

Plate 10.07: Hammer-type of holder-on

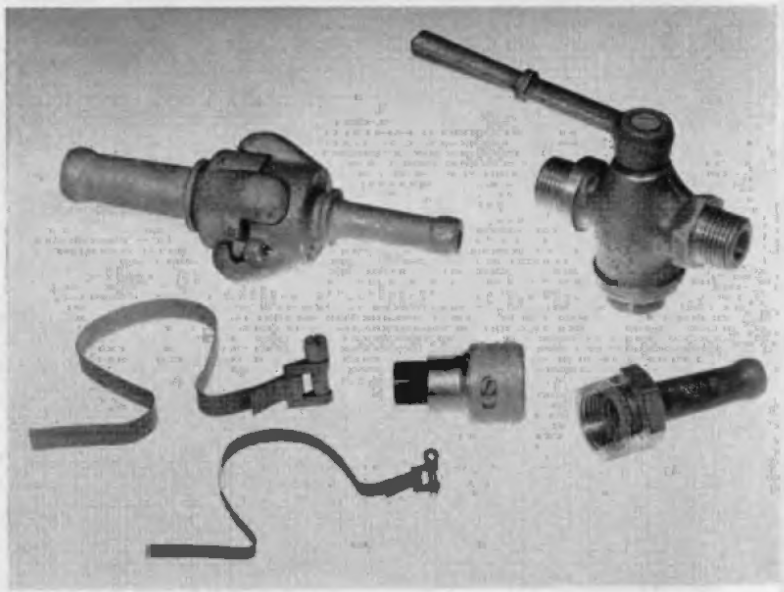


Plate 10.08: Quick-release connections for air hose

Table 10.02. AIR CONSUMPTION OF PNEUMATIC BOLTING AND RIVETING TOOL

Type of machine	Size of nuts or rivets handled	Cu ft of free air per minute at 80 lb/sq in.
Impact wrench	Up to ¾-in. nuts	19
,, ,,	,, ,, 1¼-in. nuts	36
Riveting hammer	¾-in. rivets	24
,, ,,	1-in. rivets	26
Rivet burster	—	3 (per rivet)
Hammer holder-on	—	28
Holder-on	—	⅛ (per rivet)
Squeeze riveter	¾-in. rivets	2 (,, ,,)
,, ,,	⅞-in. rivets	2¾ (,, ,,)
,, ,,	1-in. rivets	4 (,, ,,)
,, ,,	1¼-in. rivets	6 (,, ,,)
,, ,,	1½-in. rivets	9½ (,, ,,)
Rivet heating forge	—	6
Jam and yoke riveters	¾-in. rivets	26
,, ,, ,, ,,	1-in. rivets	28

@Seismicisolation

to purchase models of holders-on having the piston eccentric to the main body of the machine so that close-quarter rivets can be inserted and held with ease.

The usual type of holder-on operates telescopically and forces the rivet into position, holding it there while the head is being formed on the other side of the connection. Hammer-type holders-on are also available, and these act as the others, except that a hammering action can be brought into play which helps to swell the stem of the rivet. Plate 10.05 shows this type of machine.

JAM RIVETER

This riveting tool enables rivet heads to be formed in positions where space is limited. Some of the models require as little as 6 in.

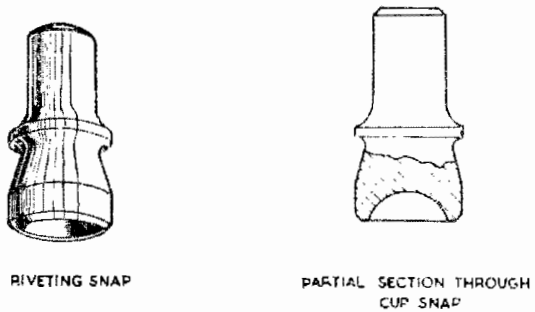


Fig. 10.04: Rivet snaps

for operation. The riveting hammer, of necessity of a different shape to the usual pattern, is held against the rivet by a telescopic movement of the casing which bears against any convenient shoulder. The holder-on shown in Plate 10.07 can also be used as a jam riveter.

YOKE RIVETER

This comprises a C frame with a jam riveter on one side and a dolly on the other. The jam riveter works with a percussion action in the same manner as the machines described earlier.

SQUEEZE RIVETER

This is of similar construction to the yoke riveter but the operation of closing the rivet is made with a squeezing action. Some means of manœuvring these last two types of riveter will be necessary.

RIVET SNAPS

The shape of the rivet head formed will, as stated before, depend upon the type of snap used. Snaps for forming the various patterns

of rivet heads are shown in Fig. 10.04. They are obtainable to suit all the standard sizes of riveting machines and rivets. Special steel, suitably hardened, is used in the manufacture of these snaps.

HEATING FIRES

A well-designed fire must be used so that the rivet is heated uniformly and not burnt or under-heated in any section. Gas- and oil-fired heaters are available but are seldom used for site work unless the number of rivets to be heated justifies the additional cost of the installation.

A coke burning fire, such as is illustrated in Fig. 10.05, is typical of the plant found on most construction sites. The forced draught for the fire was generated originally by foot bellows worked by the rivet-heater, but now, as can be seen from the illustration, the forge is adapted for use either with a fan or with the piped compressed air supply.

AIR HOSE AND CONNECTIONS

Hose used for work outside will need to be particularly tough as it will be dragged about over sharp ground and may possibly be run over by motor vehicles at times.

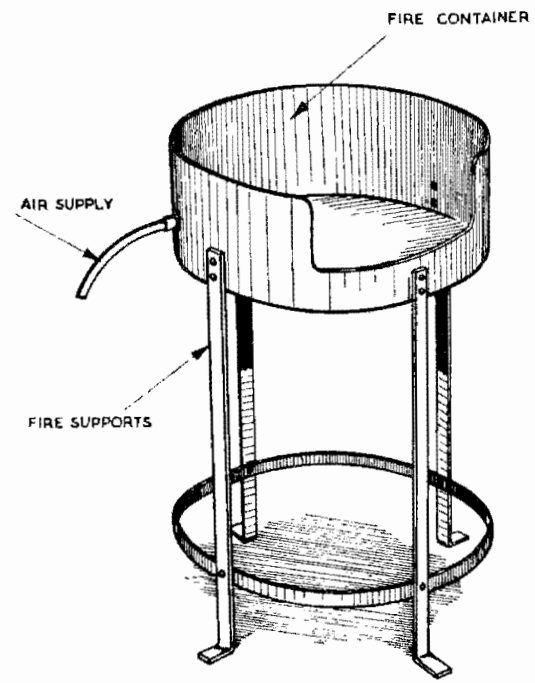


Fig. 10.05: Rivet heating fire

@Seismicisolation

Suitable hose is available in 30-ft and 60-ft lengths approximately, and in ½-in., ¾-in., 1-in., and larger diameters. For long runs of piping the larger-diameter hose is coupled to the compressor, and reducing connections are inserted at stages, followed by a smaller-diameter hose. This practice reduces frictional losses on the passage of the air.

The connections to the hand-tools are of ½-in. diameter. The diameters recommended for various quantities of air at 80 to 100 lb/sq in. pressure are shown in Table 10.04. Connections

Table 10.04. RECOMMENDED AIR HOSE CONNECTIONS

Inside diameter of hose in inches	Quantity of air at 80–100 lb/sq in.
½	Up to 60 cu ft/min
¾	60–100 cu ft/min
1	100–160 cu ft/min

between sections of hose can be made by ordinary screwed nipples. The quick release bayonet fastening illustrated in Plate 10.08 is a time-saver on the site.

CARE OF RIVETING EQUIPMENT

No tools can be operated efficiently and economically unless they are carefully maintained both in use and in storage. Pneumatic riveting equipment is particularly liable to abuse.

Clean, dry air is the first essential for any pneumatic tools, and great attention must be paid to the air supply so that these requirements are obtained. The supply hose should always be blown clean with the compressed air to dislodge any dirt or dust before any tools are coupled to it. Filters are not only fitted on the air line itself, but a fine gauze filter is fitted to the inlet of each pneumatic tool. The latter filter must be handled carefully on cleaning to prevent any damage. If it is damaged or worn at all, it should be replaced at once as otherwise dirt from the hose can enter the tool.

Attention should be paid to the air supply line and its connections, and also to the compressor and hand-tools. Wastage of air is costly and should be kept to a minimum by careful inspection and rectification of leaky joints as soon as possible.

Each riveting hammer or other piece of equipment should be thoroughly cleaned before storage and examined for damage. Light oil in an open bath is an ideal storage medium and the tools,

without their pistons, can be suspended in the oil. The pistons and snaps are dipped in the oil and then placed on a rack, and the surplus oil is allowed to drain back into the bath. When required for use, the tool is lifted out of the oil and hung up to drain clean. During use, oil applied at intervals throughout the day helps to keep the tools in good condition.

LIST OF RIVETING GEAR

The following is a list of gear suitable for the use of a riveting squad on the construction site:

1 Portable compressor 105 cu ft/min capacity at 90 lb/sq in.
  Tools to fit
  Fuel can and filler funnels } if necessary
  Oil can
  Grease gun
3 60-ft Lengths ½-in. diam. air hose with connectors
2 Riveting hammers with snaps to suit the work
1 Holder-on with snaps to suit the work
1 Riveter's hearth with spare tuyeres
2 Pairs tongs
1 Navvy-type shovel
1 Small shovel
1 Poker
2 ¾-in. Podger spanners
  Spanners to suit air hose connections
2 Hand hammers
  Tapered drifts } to suit holes
  Barrel drifts
2 Side sets
1 Cold chisel
  Scaffolding to suit

@Seismicisolation

CHAPTER 11

WELDING

THE use of welding in the construction of steel-framed buildings and bridges has increased rapidly in the last 20 years. Every effort should, however, be made by the designer to limit welding that must be done after the structure is erected. The main reason for this is that welding after erection is much more difficult, not only because of the weather, but also because the welders have to work from scaffolding and must weld joints on steelwork that is already fixed and cannot be turned over as in the shops. These facts tend to increase cost and slow down progress.

Site joints should be designed for downhand welding wherever possible, as working in this position has many advantages. Heavier gauge rods can be used, thus giving greater rates of deposition of weld metal. At the same time, less fatigue is incurred by the operators. Other advantages of downhand welding are sound welds and, possibly, the fact that less scaffolding may be required. These considerations reflect on the cost of the work and should be borne in mind at the design stages.

Girders, columns, and the like are sometimes delivered to the site for assembly, and the cost of this work must be carefully considered when estimating and also when arranging the erection programme. If possible, the detailing should be such that the complete item can be fully welded without having to be turned over. Provision should be made in the estimate for the time and money that will be spent positioning the work before welding can begin. In addition, unless time is allowed in the erection programme for this assembly work, serious delays may be caused which will be reflected in the cost.

Only fully qualified welders should be employed and they should undergo regular tests for proficiency. Welders should be graded according to the results of these tests and should only be employed on the type of welding for which they have qualified. While it is not entirely essential that a successful welding supervisor be a fully qualified practical welder, actual experience of the work will always prove of great assistance in solving the various problems which often arise. If the erection engineer or foreman wishes to learn the fundamentals of electric welding, there are some excellent trade schools, where it is possible to attend either fully practical or partly theoretical courses.

Full details of the procedure to be adopted for the welding of each joint must always be given to the site, and the drawings should

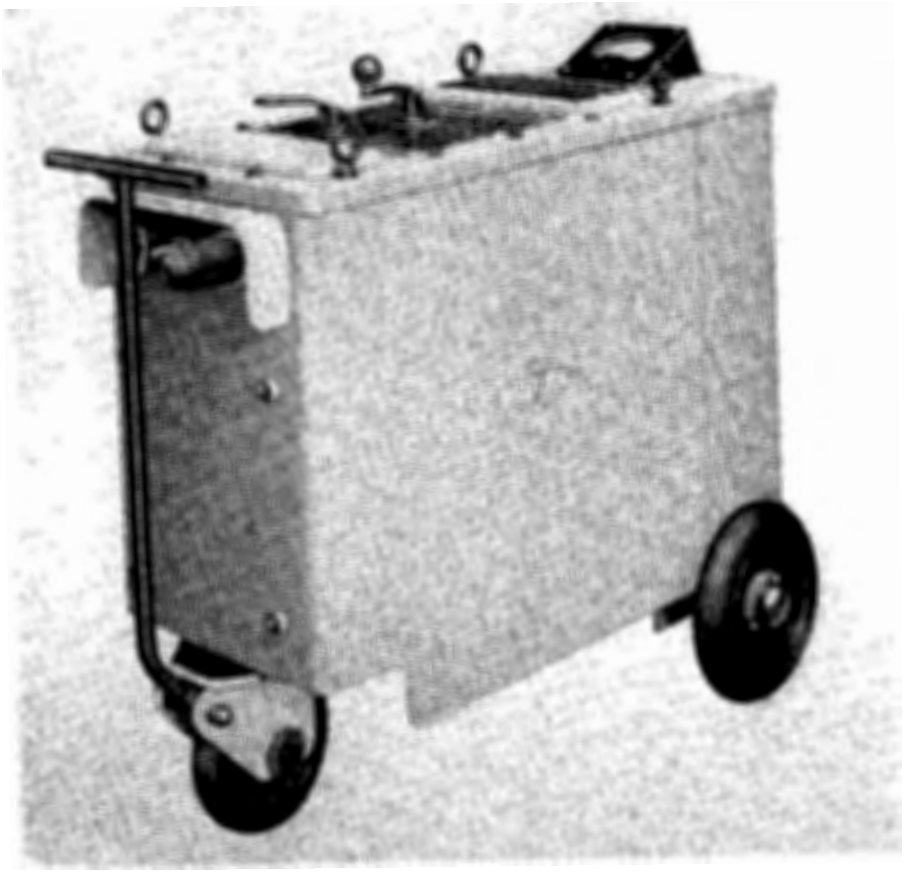


Plate 11.01: Oil-cooled arc welding transformer

@Seismicisolation

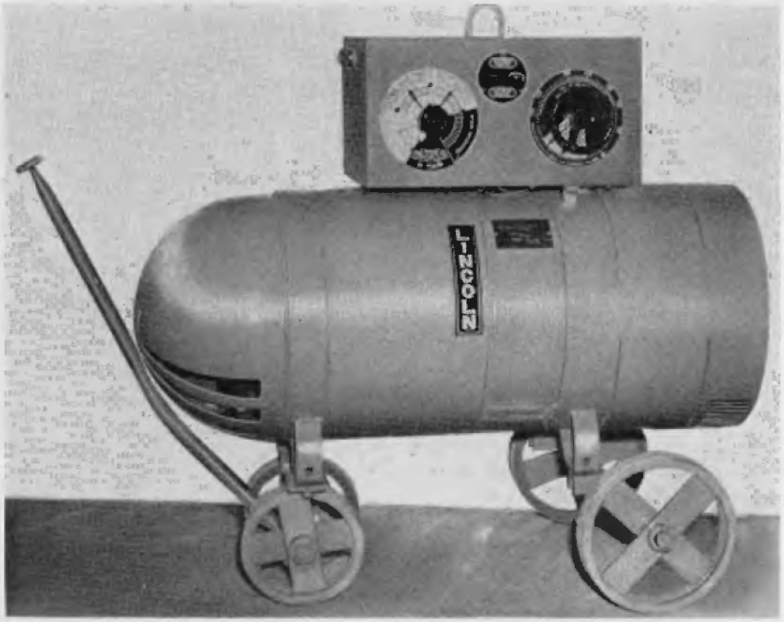


Plate 11.02: Arc-welding generator

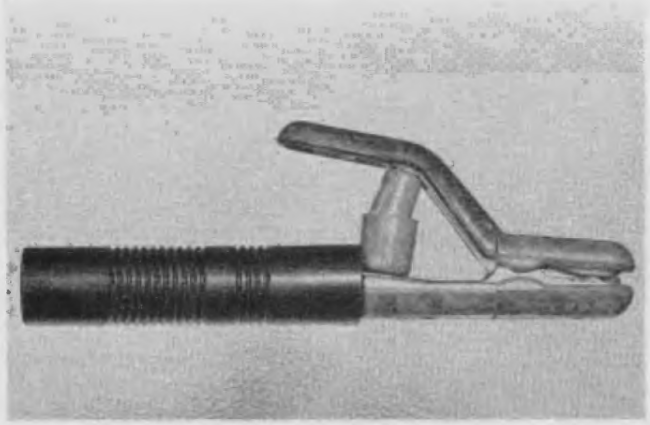


Plate 11.03: Electrode holder

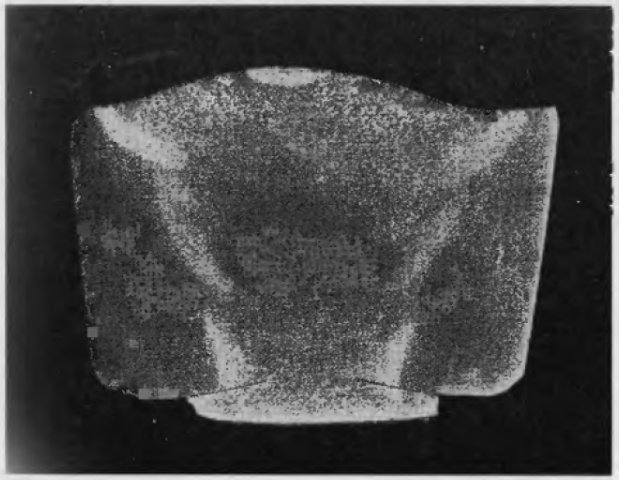


Plate 11.04: Macrograph of a weld

@Seismicisolation

Plate 12.01: Oxygen and acetylene cylinders

clearly indicate the order in which the joint is to be welded as well as show the gaps required and the electrodes to be used. If the site supervisor is ever called upon to decide the welding procedure, he should bear in mind that during welding considerable heat is passed into the metal adjacent to the joint, and that this heated metal will tend to contract on cooling. Unless there is provision for this movement to take place freely, cracking or distortion can be expected. A wide experience of welding is required before the correct procedures can be given with certainty. When the erection engineer is in any doubt, he should therefore always obtain more expert advice. If a special procedure is necessary on any particular joint, the operator must be clearly instructed before he commences work.

METAL-ARC WELDING

This process utilizes the heat generated by the electric arc to melt the two contiguous surfaces of the metal to be joined. Additional metal (called the filler) is added when the electrode melts, and the joint is completed on cooling. The arc used is of low voltage and high amperage, and is drawn between the electrode and the metal itself. The electrode is connected to one terminal of the source of electrical power, which may be either a generator or transformer, and the work (as the member to be welded is sometimes called) is connected to the other. When a joint on an erected structure is welded, the steel frame is used to provide the return path for the current and the generator terminal is connected to a convenient point near the work.

The operator strikes the arc by drawing the electrode along the work and, as soon as current flows from the electrode to the base metal, he withdraws it slightly until the correct length of arc is obtained. The intense heat generated by this arc rapidly causes both the base metal and the electrode to become very hot and melt. Molten globules of metal from the electrode, aided by the action of the arc as well as the force of gravity, cross to the base metal and, together with the molten metal there, form a pool. When this pool cools and solidifies the weld is formed.

In comparatively thin metal, only one run of weld is required to give sufficient strength. For joints in thicker metals more than a dozen runs may be necessary.

The skill of the operator enables him to advance the electrode along the joint at the speed which gives the correct deposit of weld metal. At the same time, the arc must be held at a constant length. Too long an arc can result in inferior welds and, in addition, the arc itself will be difficult to maintain. To compensate for the reduction in length of the electrode during use, the electrode holder itself

@Seismicisolation

must gradually be moved towards the work. Originally bare electrodes only were used, but difficulties were caused by impurities entering the molten metal. In addition, the arc was hard to maintain when using a.c. power. After much experiment it was found that far superior results could be obtained by using electrodes with coatings of various fluxes, and this type of electrode is now used almost universally. The heat from the arc causes the flux to melt and to form a gaseous shield over the puddle of molten metal, and this shield solidifies into a slag covering as it cools. After

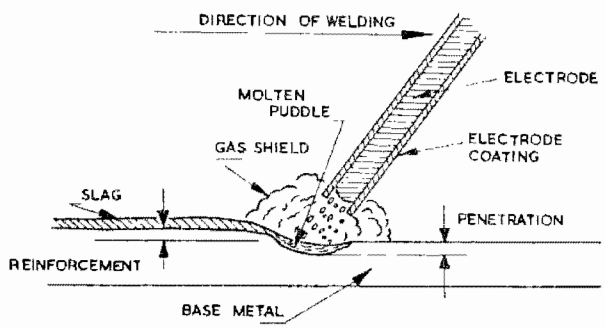


Fig. 11.01: Action of the gaseous shield

the weld is completed, or before another run of weld is placed over the joint, the slag covering must be removed. Fig. 11.01 shows the action of the gaseous shield and also illustrates how the slag forms over the cooled metal to protect it.

Either a generator or a transformer can be used to supply the necessary electric power, but only plant designed specifically for welding work should be used. Electric power is usually supplied by the Boards as alternating current, and both generator and transformer sets can be obtained to work off this supply. The required welding voltage is generally in the region of 80 to 100 volts and, if a transformer set is used, it will step the supply voltage down to this value. When direct current is necessary for the type of welding in hand, a generator set has to be used. The electricity supply is used to drive an electric motor coupled to a generator which delivers the direct current at the correct voltage.

In some country districts, or when working on an entirely new site, it may be impossible to obtain a supply of electric current. In these cases a diesel or petrol motor is employed to drive the generator set. It would be prudent to say here a few words on the selection of these sets, for the internal combustion engine, if used in this

manner, will be operating under conditions entirely different from those encountered in, say, a motor vehicle. In the latter, the driver would quickly notice any small fault developing in the engine of his vehicle and could take precautions to guard against failure. On the other hand, the engine driving a generator may run most of the day without close attention, and the welding operator may be too far away to see or hear any fault in the engine, if one did occur. Bearing these points in mind, the wise welding contractor will always purchase a generator set with an engine having an ample reserve of power and will never be tempted, either by low first cost or by low running costs, to choose under-powered machines.

Welding work on a building frame is quite scattered. Only occasionally will an unusual technique require the welders to work in pairs, for the majority of joints can be completed by only one operator. Single operator sets will, therefore, prove more convenient. The extra size of the multi-operator set makes it very unwieldy to move around the site and, unless it is working with its full complement of operators, an excessive amount of power will be consumed. A single operator set of 300-amp capacity will prove quite sufficient for normal construction work. Smaller sets can be used in certain cases, but they soon become over-heated in continuous use or in very hot weather. Plates 11.01 and 11.02 depict a single-operator welding transformer and an engine-driven generator.

ELECTRODE HOLDERS

Plate 11.03 illustrates an electrode holder of suitable pattern. The ease with which the holder can be used has a great effect on the output of work from the operator as he will be using the holder all day. A pattern which causes him undue fatigue because of its heavy weight or awkwardness when electrodes have to be changed will not be at all popular.

The grips of the holder must be light to work yet strong enough to hold the electrode firmly and ensure good electrical contact. The connection to the lead cable is made in the handle, and the joint should be well soldered so that no current is lost here.

WELDING CABLE

The construction of the operator's cable is very important if it is to be easy to handle and use. Many fine wires are specially woven together in its manufacture. This allows for movement between the individual wires as the cable is handled and accounts for its flexibility. To protect this woven cable, it is wrapped in waterproof cable and finally covered with a fabric and rubber insulation. The ground, or earthing, cable is not handled to the same extent as the

@Seismicisolation

Table 11.01. RECOMMENDED SIZES FOR WELDING CABLES

Machine size in amperes	Cable sizes for the following lengths:		
	Up to 50 ft	50–100 ft	100–250 ft
Up to 150	2	2	2
200	2	1	2/0
300	0	2/0	4/0
400	2/0	3/0	4/0 *
600	2/0	4/0	4/0 **

* Recommended longest length of 4/0 for 400-amp welder is 150 ft.
** Recommended longest length of 4/0 for 600-amp welder is 100 ft.

operator's cable so that it need not be so flexible. It is therefore made of heavier wires and is somewhat cheaper to purchase.

CLEANING TOOLS

A light chipping hammer, strong wire brush, a dusting brush, and possibly a steel scraper are required to clean the surfaces of the metal preparatory to welding. Light rust can be quickly removed, but when large patches of rust are encountered (such as on repair work to old structures) then either the heating flame of the oxy-acetylene cutting torch or one of the special flame-cleaning torches will have to be used. The slag left on the weld by the flux coating of the electrode can be quickly removed by the chipping hammer.

CHOICE OF CURRENT

Considerations of the work in hand will guide the decision as to what type of current is to be used. Both alternating current and direct current have certain characteristics which make them more suitable for different sets of conditions. For work on specially alloyed metals, such as may be met in chemical factories, direct current will be necessary; but if a joint is welded where strong arc-blow will occur, alternating current should be selected. Arc-blow is a condition present when a deep joint is welded in thick metal. It is due to the magnetic attraction of the metal pulling the arc in towards the centre of the joint. The direct current arc with the current flowing one way only accentuates this phenomenon.

Alternating current is, on the whole, more adaptable for the normal run of work. The transformer is a much simpler piece of

equipment than the generator used for direct current. Transformers have no moving parts, so that the first cost is lower, running costs are less, and maintenance is less complicated. However, transformers can give rise to disturbances in the electric power supply. Before a set is connected, therefore, the people responsible for the power supply should be consulted. A voltage limiting device is advisable when using a transformer set, as the rather high open-circuit voltage can be dangerous.

PREPARATION FOR WELDING

With the steel correctly detailed and fabricated, all edge preparation for the site joints will have been made in the constructional shops. The full penetration of the weld depends on whether this edge preparation is entirely satisfactory, and the fabrication shops have the necessary machinery to ensure a good fitting joint on assembly.

Before welding can commence the plates must first be brought together and firmly clamped at the specified gap. This temporary connection has to be strong enough to hold the parts accurately in place without any movement. In certain cases, it may also have to

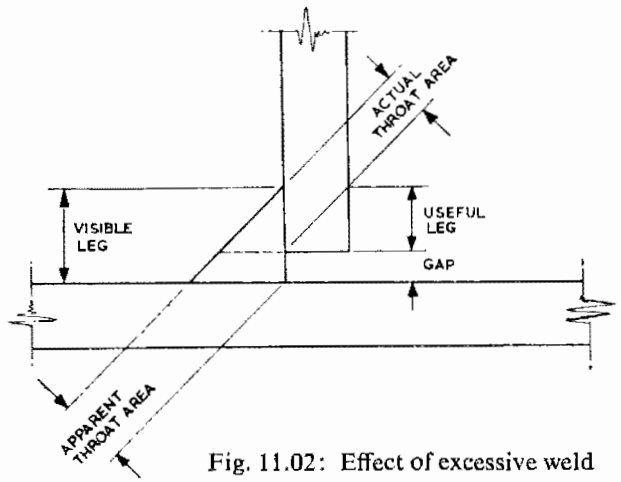


Fig. 11.02: Effect of excessive weld

carry the full weight of the member until the final welding is completed. If possible, these site joints should be designed in such a way that they can be fully welded without having to remove any of the temporary connection material.

Connections between erected members must be strong enough to allow erection to proceed irrespective of the welding operations,

@Seismicisolation

and should have enough connection holes to enable the erector to use his podger spanner when fixing as is his normal manner.

When fillets are used to join parts, these parts must fit together as closely as possible. If the gap between the two pieces is greater than $\frac{1}{16}$ in., the leg of the fillet weld will also have to be increased. Unless this is done the required strength for the joint will not be obtained, as is illustrated in Fig. 11.02. When the plate preparation is such that this gap is greater than $\frac{3}{16}$ in., the joint will require special treatment.

A satisfactory weld will not be obtained unless all surfaces forming part of the joint are first cleared of slag or rust scale. Slag is often left by the cutting torch with which the plate was cut in the first place but is easily removed. Structural steelwork is often shop-painted before being sent to the site and the shop manager should ensure that the painters leave clear those surfaces of the metal which are to be joined by welding. Occasionally these are painted in error and this paint must be removed for a distance of at least 2 in. each side of the joint before welding. When this is not done, the paint mixes with the molten metal and the fumes from the surrounding hot metal are very irritating and can be dangerous to the health of the welder. Where natural ventilation is poor, the fumes should be extracted by a fan or some other artificial means.

Welding must never be attempted when the surfaces of the metal are wet or covered with snow or ice. Under these conditions the operator is very liable to electric shock as the current travels more readily along a damp member. Shock can be extremely dangerous

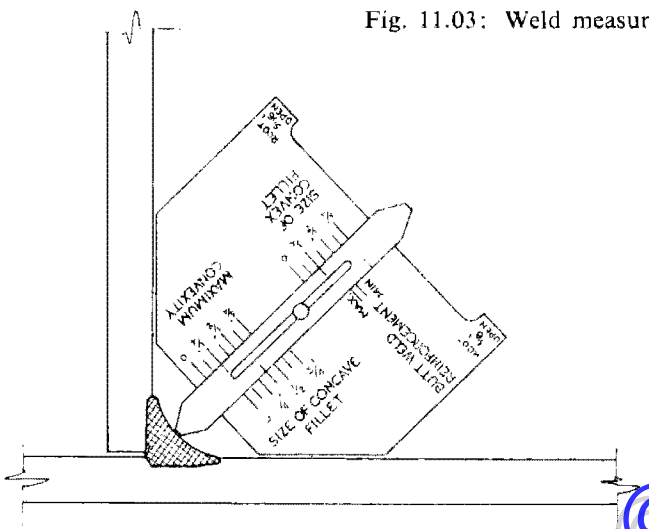


Fig. 11.03: Weld measurement gauge

if the operator is working on a small scaffold on the steel frame as he may lose his balance.

High winds tend to blow out the arc and usually result in porous welds which will not be acceptable. When the weather conditions are such, work can often be continued by providing suitable shelters to protect both operator and work from the elements. Collapsible canvas tents will prove suitable for work on the ground, but more elaborate arrangements will have to be made for work on the structure. In very cold weather the base metal surrounding the joint must first be warmed, otherwise undue cooling may occur.

The welding of high tensile steels calls for additional care. Special welding procedure should be indicated, and attention will have to be given to the electrodes and the manner of welding. Preheating of the joint may be necessary to ensure a satisfactory result and, if the joint is such that more than one pass is required, an indicated temperature may have to be maintained before each pass.

INSPECTION METHODS

Many specifications call for welding tests to be made. Inspection methods for welded joints can be considered under two headings: non-destructive tests and destructive tests.

NON-DESTRUCTIVE METHODS

(*a*) *Visual examination*

Visual examination of the joint before, during, and after welding is by far the most popular method used at present. It is easy to apply, no elaborate equipment is required, and, provided the method is fully understood, satisfactory results are obtainable. Specialists will be required for the other methods to carry out the tests on the site and also to interpret the results.

Checking before welding entails examination of the root openings after the parts have been brought together to see that they agree with the details given on the drawings. The edge preparation also has to be checked, both for shape and for the presence of scale, rust, or paint which must be removed.

The inspector will satisfy himself during welding that the weld is made under the specified conditions and with the specified welding rods. In butt joints in thick plates the root layer is most important and must be thoroughly examined for cracks. Very minute cracks in this layer will readily spread through the remainder of the joint as welding progresses, so that soundness in this particular case is quite essential.

On the completion of the welded connection, the shape and size of each individual weld has to be checked. A weld gauge, shown in

@Seismicisolation

Fig. 11.03, is used to measure each weld profile. Welds that do not conform with the requirements should be given careful consideration and, if the strength of the structure is adversely affected, they should be cut out and remade.

Fig. 11.04 illustrates a number of defects likely to occur in fillet and butt joints. Undercutting is a serious defect as it results in a notch which creates an accumulation of stresses. This type of defect should never be allowed in the butt joint on a tension flange of a welded girder. It may also be mentioned here that, if the joint has to be ground to a flush finish, the grinding machine should be held so that any minute scratches made follow the stress lines and do not cause a notch effect.

Too much weld metal can be almost as big a problem as too little. Besides being a waste of extremely valuable weld metal, overwelding often creates warping and buckling due to the excessive

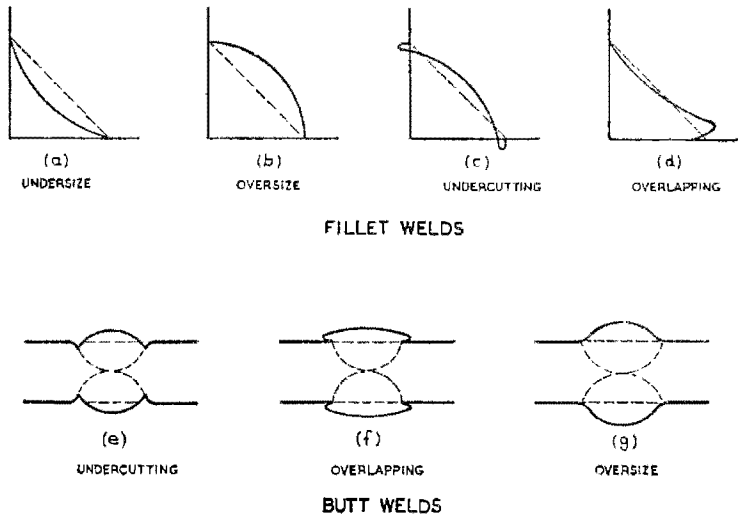


Fig. 11.04: Defects in welds

heat put into the joint. The supervisor should never permit weld sizes larger than those specified on the drawings although, if he is in any doubt as to the carrying capacity of the weld detailed, the matter can be referred to the designer. Fig. 11.05 shows the tremendous increase in weld cross-section due to a $\frac{3}{8}$-in. fillet being deposited in place of a $\frac{1}{4}$-in. fillet.

(*b*) *Magnetic particle inspection*

Although intended primarily for the detection of surface cracks, the skilled user of the equipment is also able to locate sub-surface

defects. When the work is magnetized, a crack in or near the surface of the metal causes a break in the magnetic lines of force. These lines can be traced by dusting on the surface a quantity of fine iron particles which form a definite pattern corresponding to the lines of force. Any discontinuities are thus brought to light. An

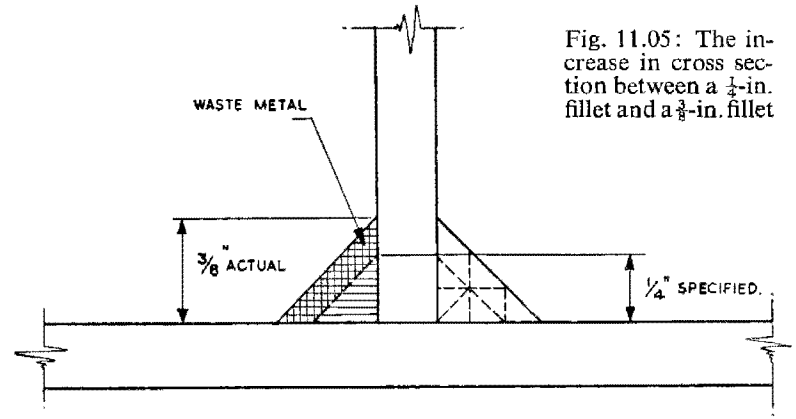


Fig. 11.05: The increase in cross section between a $\frac{1}{4}$-in. fillet and a $\frac{3}{8}$-in. fillet

alternative method of applying the iron particles is to suspend them in a light oil.

The joint is magnetized either by passing a heavy current directly through the metal or else by wrapping it with a conductor and magnetizing by induction. The size of the welded members will limit the application of the latter method. In the other method, the current is passed into the joint by copper prod-type contacts which are held against the steel before the current is switched on. The iron particles are usually dusted on while the current is flowing.

(*c*) *Examination using penetrating oil*

This method of inspection provides a quick and easy means of testing for surface cracks. The weld surface is cleaned and penetrating oil is applied with a brush. After a few moments the oil is thoroughly cleaned off and the surface is dried. Powdered chalk is then dusted on and, if a crack exists, some of the oil will have been retained in it and will seep out into the chalk and show plainly.

(*d*) *Radiographic testing*

It is fairly well known that X-rays and gamma-rays will penetrate steel to a certain extent. Radiographic inspection uses these rays by directing them through the steel on to a film. This film is examined afterwards and, if there were any cracks or discontinuities in the weld, they will be visible to the experienced eye.

@Seismicisolation

A number of electrical manufacturing firms possess mobile X-ray equipment which can be hired.

(*e*) *Supersonic testing*

In this method high-frequency sound waves are passed through the joint. Using special equipment, the skilled inspector can check the quality of the welding.

DESTRUCTIVE METHODS

There are three methods of destructive testing of welded joints; a test load may be applied to the joint, or extension pieces of the welded joint may be cut away and examined by either chemical or metallographic means. Mechanical testing to destruction of building frames is undertaken only for research purposes, and the other two methods have a serious disadvantage in that perfectly sound welds may be opened up for inspection and replaced by welds of a lower standard. A brief description is, however, given.

(*a*) *Mechanical testing*

One procedure closely follows that used for testing steel samples at the rolling mill laboratories. The tests are made usually to

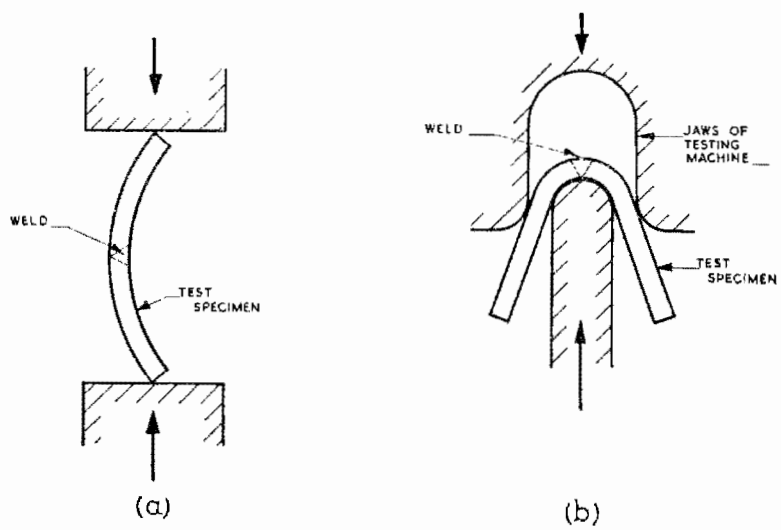


Fig. 11.06: Free and guided bend tests

check either tensile or shear strengths. A steadily increasing load is applied to specially prepared samples until breakage occurs. The bend test, either free or guided, is another method. This also

offers a simple check on the qualifications of the welding operators, as faults such as porosity, lack of fusion, and minute cracks are brought to light. The bend tests are performed on samples cut from the actual welded joint. These samples are bent (to a definite radius in the case of the guided-bend test) and the results examined. Fig. 11.06 shows the methods of making the bend tests.

(*b*) *Chemical testing*

Although unlikely to be specified for the examination of welds on steel framed building construction, this method may be applied to the checking of joints on storage tanks which are to hold corrosive liquids or gases. Analysis of the results will be conducted in the laboratory and not on the site.

(*c*) *Metallographic testing*

Metallography may be defined as the study of the inner structure of metals. Examination is carried out either by the unaided eye or by a high-powered microscope. Samples of the weld are obtained from the actual joint and are cleaned and treated to suit the particular method of examination to be employed.

For examination by the unaided eye a common method of treating the sample is to set it in a 50 per cent solution of hydrochloric acid. After the acid has been boiled for about half an hour, the structure of the metal will become clearly visible, as in Plate 11.04. Other methods of preparing the surface entail grinding and polishing before etching. The student of welding is well recommended to cut out specimens from welds he has made and then examine them as above. In this manner he will learn much, not only about his own welding skill but also about the behaviour of the structure of the weld in the heat-affected zone. Examination by the unaided eye is termed " macro-examination ".

For examination by the microscope (" micro-examination "), the sample must be very highly polished before etching. A much more detailed examination can, of course, be made with a high-powered microscope than with the naked eye.

REMOVAL OF FAULTY WELDS

If a weld, or section of a weld, has been found faulty, it must be removed and replaced with sound weld metal as the efficiency of the structure as a whole will otherwise be impaired. Removal can be effected by chipping, grinding, or using a flame-cutting torch fitted with a special gouging nozzle. Gas-cutting methods should, of course, not be selected for work on any member carrying stress.

@Seismicisolation

Special care must be taken so that the sound part of the weld is not damaged. Only that section of the weld which has been condemned should be removed, subject, of course, to any requirements for the insertion of the replacement weld metal.

SAFETY DURING WELDING OPERATIONS

Inherent features of the electric arc welding process make it essential that careful attention be paid to the safety of the operators and other people who may be in the vicinity. The danger of shock is ever present with faulty equipment, and the operator is not likely to give of his best when he is not sure of his tools.

The rays emitted by the arc are dangerous to the sight and can burn the skin. Hand-shields or helmets are obtainable, fitted with the necessary glass filters to protect the eyes. The type of helmet that can be raised or lowered by a tilt of the head is preferable as this leaves both hands free. The welder should be well protected by apron, gloves, and armshields from the effects of rays and flying sparks. The rays can affect the eyesight over a considerable distance and, where the public or other workmen may be troubled, special screens should be erected for their protection.

SAFETY HINTS

All welding cables and connections should be in the best condition. Loss of current through faulty leads is a mere detail compared with the danger of shock. Weak arcs, hot cables, holders, and machines are all signs of current leakage. An electrode holder wrapped with insulation tape is a bad sign, and all such weak spots should be examined and scrapped if necessary. The danger of fire is always present when welding occurs near inflammable materials, and suitable precautions must be taken. Petrol fumes and those from other volatile liquids linger for a long time.

If the steel frame of the building is to be used as an earth for the return of the current, be sure that no conditions exist in the frame which could give rise to electrolysis or sparking to cause a fire. If the welder has to work at a height, do not forget that, although he may be agile enough, he is encumbered by his protective clothing and, when working, by his headshield. Give him suitable staging.

The fumes generated by the welding process may not be harmful to the health of the welder in the normal way. Nevertheless, they can be irritating, to say the least. To make the operator feel at ease, good ventilation should exist. Artificial means of ventilating will have to be used when welding is carried out in closed spaces.

LIST OF PLANT FOR SITE WELDING

A list of equipment to cover the needs of one welding operator is now given:

1	Welding set (state type)	
	Tools for welding set	if necessary
	Petrol can and filler funnels	if necessary
	Oil can	if necessary
	Grease gun	if necessary
1	Operator's cable (state length)	
1	Earth cable with clips (state length and type of clips)	
1	Welder's head shield—with spare glasses	
1	Pair electrode holders	
1	Chipping hammer	
1	Soft brush	
1	Pair gloves	
1	Apron	
1	Pair armshields	
1	Weld gauge	
1	Electrode quill	
1	Hand hammer	

@Seismicisolation

CHAPTER 12

FLAME-CUTTING

THE flame-cutting torch with its allied equipment is undoubtedly one of the most useful tools that could be included among the tackle for any contract. Its uses are so numerous that it would be difficult to itemize any one in particular. Possession of this equipment would, on the whole, be an asset on any site, and would tend to speed up the work—always provided that the flame-cutting torch is handled with due regard for its proper use.

Important cutting of metal does not usually have to be undertaken at the erection site. The chance that this necessity may occur still exists, however, and the site supervisor should have the necessary knowledge to tackle it successfully. It is the duty of those in charge to be familiar with all tools used so that they can correct any misuse.

Often the work in hand entails making connections to an existing building. When flame-cutting and welding equipment is available, most of this alteration work can be left to the site engineer or foreman, who will be able to fabricate many connections without difficulty. Details of existing steelwork are often difficult to come by because, even when the original drawings are to hand, they are not necessarily correct, and site checks and measurements cannot be obtained accurately if the building is in constant use. Effecting the work on site is almost certain to prove the quickest and cheapest method when the savings on drawing office and fabrication shop work are taken into consideration.

The cutting away of old steelwork, cutting joists, bars, and plates may be more conveniently done by the cutting torch than by the older methods of hacksaw and chisel. Bolt holes for temporary connections can be burned more speedily than drilled, and good results can be obtained by a careful operator. Discretion should be observed in using burning plant where undue heat can weaken a member, such as a girder, which is carrying load.

It is also advisable to take precautionary measures against fire; a falling spark can set a tarpaulin alight. Water buckets should be kept handy and, in cases involving risk, a look-out man or a works fireman should stand by.

Other uses for the cutting torch are constantly occurring. Small items of tackle may be urgently required at site; fabrication errors happen at times on the best of shop work; or again, holes and

notches may have to be cut or enlarged to an extent that the drawing office had not foreseen.

EQUIPMENT

The great advantage of flame-cutting equipment is its transportability. The complete equipment, including the cylinders containing the gases, weighs only about 2 cwt, and can be quickly and easily moved about the site. If work has to be done in an awkward position, say on a roof truss, the full set of gear does not have to be taken there, as the pipes connecting the torch to the cylinders will reach a considerable distance.

The oxy-acetylene cutting equipment as used on the site comprises the cylinders which contain the gases, regulators to adjust and maintain the pressures, hoses to connect the regulators to the cutting torch, and the torch itself. It will be seen on inspection that all the connections for the acetylene supply are fitted with left-handed threads to prevent accidental interchange with their oxygen counterparts. A distinctive colour, maroon, is applied to all the acetylene equipment, including the cylinders, to aid the assembly. The oxygen cylinders, pipes, etc., are painted black.

Steel cylinders are normally used for convenience in transporting the gases and the common sizes are: Oxygen, 110 and 220 cu ft capacity; and acetylene, 100 and 200 cu ft capacity. As shown in Plate 12.01, the two cylinders differ in shape—the oxygen cylinder is longer and smaller in diameter than the acetylene cylinder, while the latter has a flat bottom and can be stood upright without support. The oxygen is stored under a pressure of approximately 1,800 lb/sq in. The acetylene is not stored as a gas but the cylinder contains instead a porous substance, the pores of which are filled with acetone in which the acetylene is dissolved under pressure. It should be stressed here that the acetylene cylinder must always be kept upright while in use, as the acetone may otherwise run out. The correct name for the contents of this cylinder is "dissolved acetylene", and not "gas", as it is often called. Some factories have a piped supply of oxygen, or of acetylene, or of both; and use could be made of this facility, if available. Alternatively, acetylene can be made on the site in a generator but this method is uneconomical unless large quantities are required. Other gases can be used in conjunction with oxygen for cutting operations but acetylene is the most common.

The regulators fit directly to the cylinder outlets and are similar in pattern for both oxygen and acetylene. If single-stage regulators are used, the delivery pressure of the gas will decrease as the cylinder pressure drops during use. When cutting extends over a long

@Seismicisolation

period, the operator will have to adjust the pressure continually at the regulator to counteract this. Two-stage regulators will deliver the gases at a constant pressure and should therefore always be selected. Typical two-stage regulators are shown in Plate 12.02.

A modern cutting torch is shown in Plate 12.03. The knob controls regulate the supply of acetylene and oxygen for the heating flame. The lever controls the supply of cutting oxygen. Before the torch is lit the pressures of the gases must be adjusted. The pressure of the oxygen is adjusted with the cutting oxygen supply valve fully

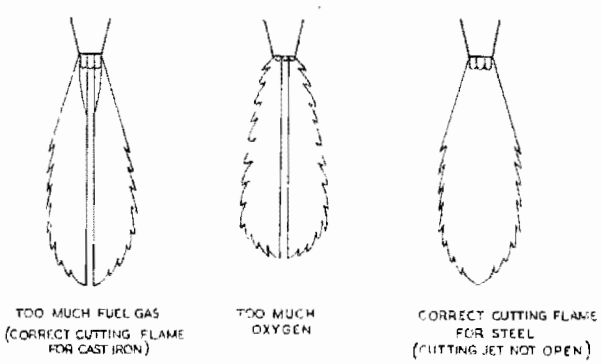


Fig. 12.01: The adjustment of the cutting flame

open. To light the torch, the supply of cutting oxygen is closed with the lever control and the acetylene turned on. Keeping the cutting oxygen valve closed, the flame is adjusted until it is neutral as in Fig. 12.01. The torch is then ready for use.

The older types of cutters were fitted with two-piece nozzles, but the new machines described above employ a one-piece nozzle. This is a great improvement as previously the nozzles could be easily knocked out of adjustment. An additional advantage is that, as the one-piece nozzle becomes worn, the tips can be reground. As much as $\frac{1}{8}$ in. can be taken off in this manner.

ACTUAL CUTTING

Only a minority of the users of the flame-cutting torch fully appreciate the nature of the process. A brief description will, therefore, be given. Steel cutting by the oxy-acetylene torch is a chemical process depending on the great affinity of oxygen for ferrous metals when these are raised to a high temperature. The cutting blowpipe is designed to provide a heating flame to raise the steel to its ignition temperature. When this temperature is reached, the control of the cutting oxygen jet is opened, and a jet of pure oxygen is directed at the steel. This causes combustion and also

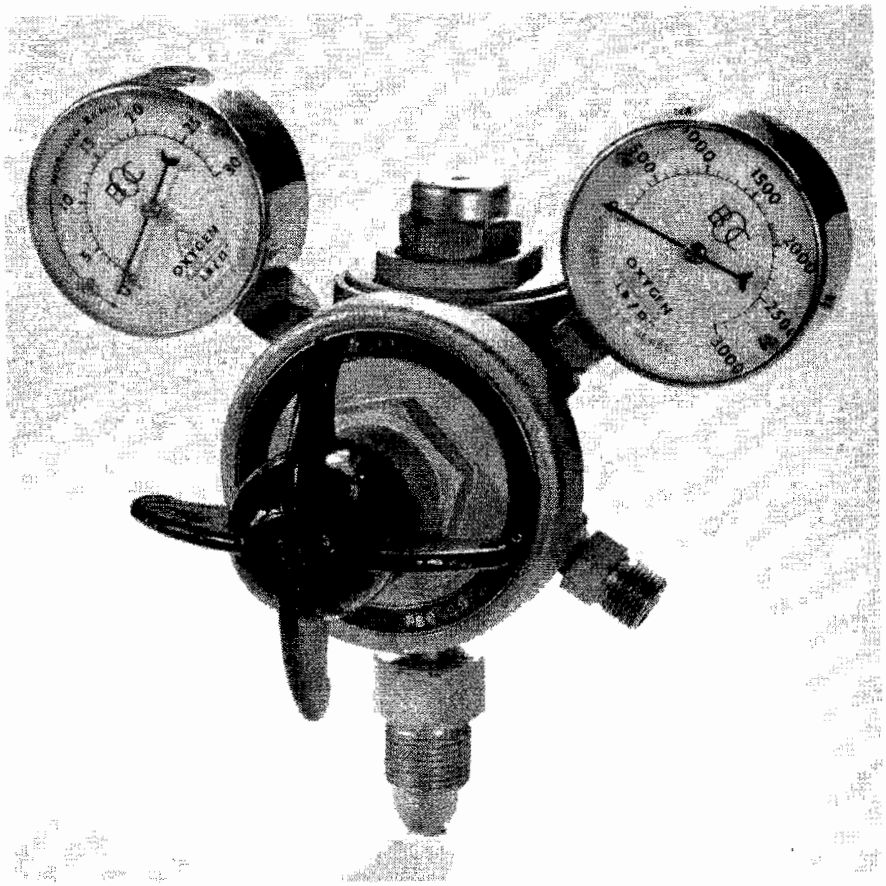


Plate 12.02 (a): Two-stage regulator, oxygen

@Seismicisolation

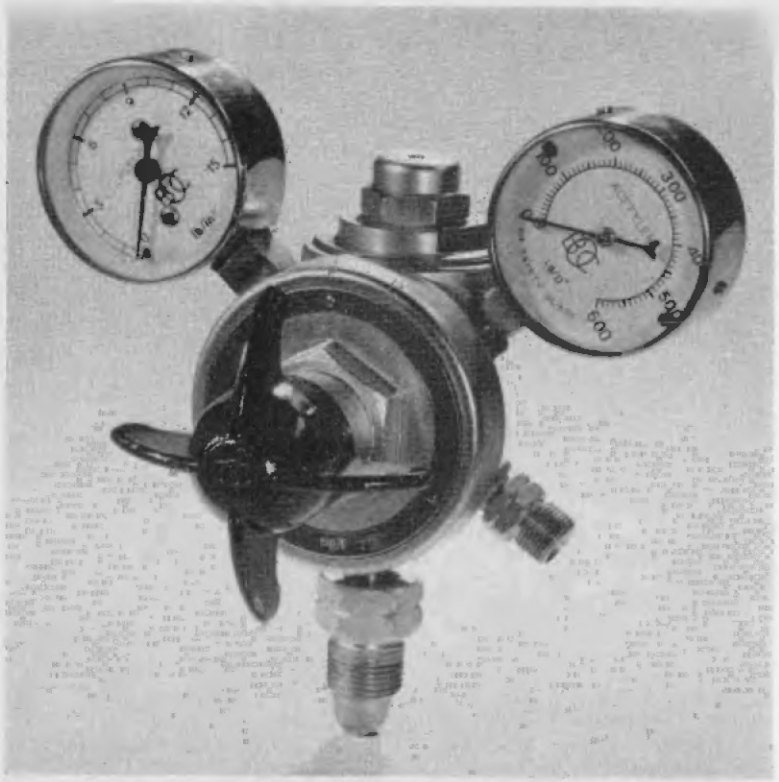


Plate 12.02 (b): Two-stage regulator, acetylene (*see also* Plate 12.02 (a))

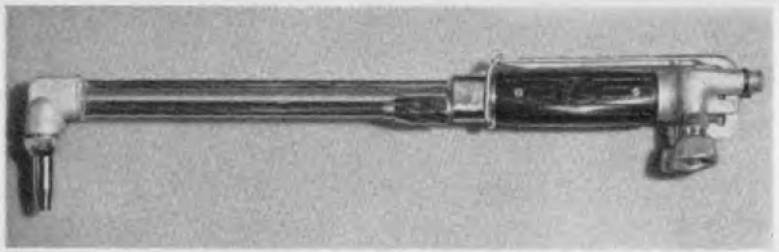


Plate 12.03: A modern pattern of cutting torch

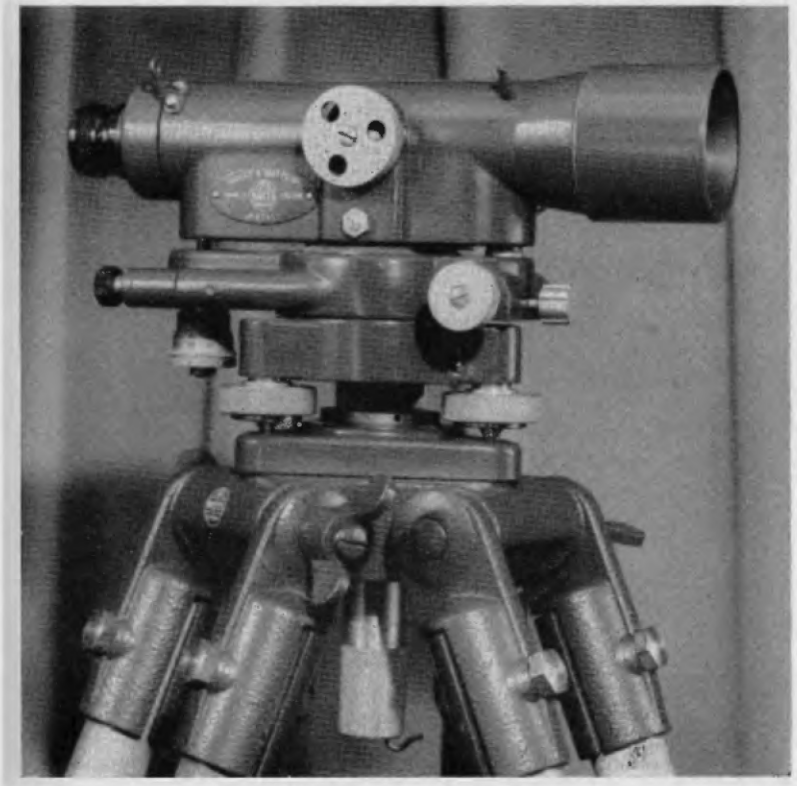


Plate 13.01: A modern pattern of surveyor's level

@Seismicisolation

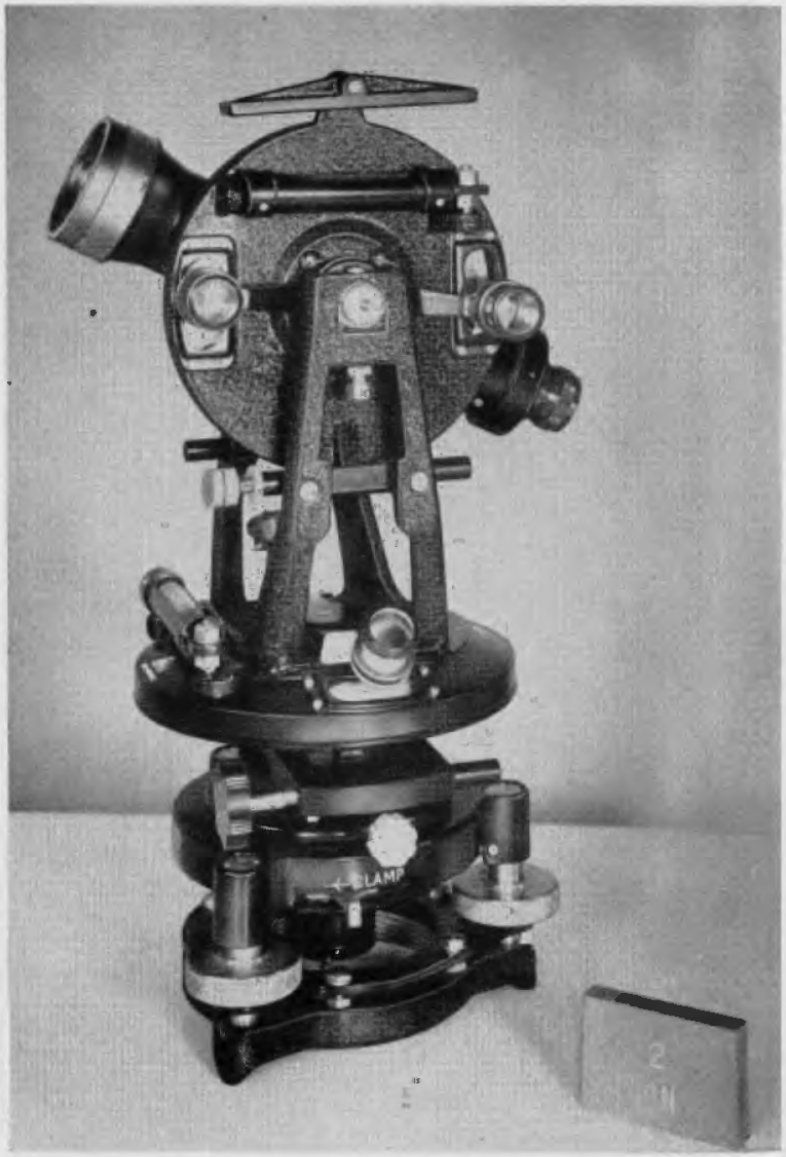


Plate 13.02: Vernier theodolite

blows away the iron oxide that is formed. Once started, this process is progressive and sufficient heat is generated by the oxidization to enable the cutting to continue.

The use of the cutting torch is quite simple once the above has been understood. The accomplishment of neat cuts is more a matter of practice and care than anything else. The foreman or site engineer should be fully proficient in the use of the equipment so that both are in a position to give advice to others, as the cutting torch is misused all too often.

CUTTING TORCH IN USE

Before commencing any cutting operations, the surface of the steel must be fully prepared. Any paint, tar, or heavy scale should be removed as burning paint or flying scale may block the jets of the nozzles. Besides, the fumes given off are none too pleasant for the operator. Rust scale can be quickly removed from the steel by using the heating flame only, holding the tip of the nozzle a sufficient distance away to be clear of any flying pieces.

The manufacturer of the cutting torch will furnish a chart showing nozzle sizes and gas pressures for the various thicknesses of steel. A typical chart for the Cutogen No. 1, which is manufactured by the British Oxygen Co. Ltd., is shown in Table 12.01. Select a suitable nozzle for the work to be cut and fit in the torch. Open the valves on the cylinders and adjust the gases to the correct pressures.

Assuming that a straight cut is to be made across a piece of steel, it will prove advisable to use some type of guide for the torch. A short angle bar will serve this purpose. The cutting of the steel is begun at one edge and the cutting oxygen valve is closed until a

Table 12.01. NOZZLE SIZES AND PRESSURES FOR CUTTING MILD STEEL

Thickness of plate	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	$\frac{3}{4}$ in.	1 in.	2 in.	3 in.	4 in.
Acetylene (pressure $\frac{1}{2}$ lb/sq in.)—							
Nozzle size (inches)	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{32}$
Oxygen pressure (lb/sq in.)	15/18	10/15	20/25	30/36	30/35	45/50	40/45
Cutting speed (ft/hr)	91/112	90/120	90/100	82/95	90/95	62/66	36/50
Propane (pressure $\frac{1}{2}$ lb/sq in.)							
Nozzle size (inches)	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$
Oxygen pressure (lb/sq in.)	15/20	15/20	25/30	20/25	30/35	35/40	40/45
Cutting speed (ft/hr)	90/110	105/120	90/120	100/120	50/65	60/65	35/45

@Seismicisolation

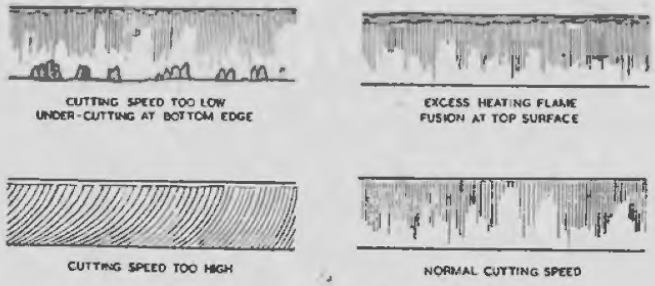


Fig. 12.02: Perfect and imperfect cuts and their causes

small area of the steel is heated to the correct temperature, when it will glow bright red. Thick sections will naturally require more heat to reach this temperature than thin ones. Open the cutting oxygen valve slowly and the cut will begin. Continuing the cut across the steel is now only a matter of moving the torch gradually forwards. Note that the white cone of flame must be kept clear of the surface of the steel. An examination of the finished edge will show whether the correct procedure was used. Fig. 12.02 shows some examples of finished cuts, together with the causes of those which are imperfect.

HINTS ON USING THE CUTTING TORCH

(*a*) *Marking the cut*

The line of the proposed cut should be clearly marked with centre pops which will be readily seen in the light of the torch when goggles are worn.

Fig. 12.03: Rivet-cutting nozzle

(*b*) *Removing rivet heads*

Rivet heads can be quickly removed by the flame-cutting process. Use the standard nozzle and, holding it parallel to the plate, cut down through the centre of the head. Continue to hold the torch at the same angle and work it each way in a sweeping fashion.

This removes the head easily without damaging the plate, and the shank of the rivet can be knocked out with hammer and punch. Fig. 12.04 illustrates this procedure. If a large number of rivet heads have to be cut, it is advisable to obtain one of the special patterns of rivet-cutting nozzles, such as is shown in Fig. 12.03.

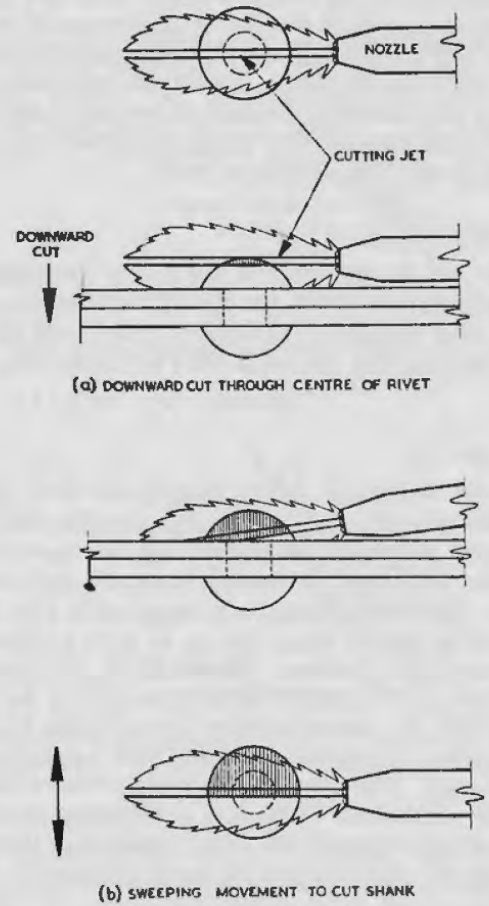


Fig. 12.04: Cutting rivet heads with a standard nozzle

(*c*) *Cutting thick steel*

Only the oxygen pressure recommended by the torch manufacturer should be used, as too high a pressure often causes the cut to be

@Seismicisolation

distorted. In addition, care should be taken not to open the cutting oxygen valve fully until the cut has gone right through the metal, otherwise the cut may peter out half-way through. When this happens, move the torch back and start again. If a cut has to be started in the centre of a thick steel plate, hold the nozzle about $\frac{1}{8}$ in. clear of the plate and heat the metal until it is almost melting. Slowly open the cutting oxygen valve and, at the same time, move the torch along the line of the proposed cut.

On rounds and bars there are no corners to enable the cut to be quickly and easily started, and a good tip in such cases is to make a deep nick in the metal with hammer and chisel at the point where it is desired to commence. The metal round this nick will quickly melt on heating and thus aid a rapid start.

(*d*) *Cutting wire ropes*

Wire ropes can be cut without the use of the cutting oxygen. Using the heating flame only, the individual wires are melted and will tend to weld together. Alternatively, the rope can be bound each side of the proposed cut and a clean cut made using the cutting oxygen jet.

(*e*) *Cutting cast iron*

Although the fact is not widely known, cast iron can be fairly easily cut with a standard cutting torch. Approximately twice the oxygen pressure recommended for cutting the same thickness of steel should be used, and the heating flame should have an excess of acetylene. The heating flame will appear as in Fig. 12.01.

The edge of the metal, where the cut is to be commenced, must be heated from top to bottom. Generally, the warmer the whole mass is, the better. A spot of metal at the top of the edge of the plate should then be heated until it boils. When bubbling commences, the cutting oxygen valve is opened and the slag can be blown away as it forms. Now open the valve wide and move the torch along the line of the cut, holding it at an angle of 45° until the cut progresses right through the plate. Straighten the torch up to approximately 75° and continue the cutting operation as shown in Fig. 12.05.

Cutting of cast iron can be aided considerably by introducing a steel welding rod into the flame while cutting is in progress. This will increase the fluidity of the iron and help its removal. Cast iron cutting is much hotter work than cutting steel, and the supervisor would be well advised to see that the operator dresses accordingly and also that suitable safety precautions are taken.

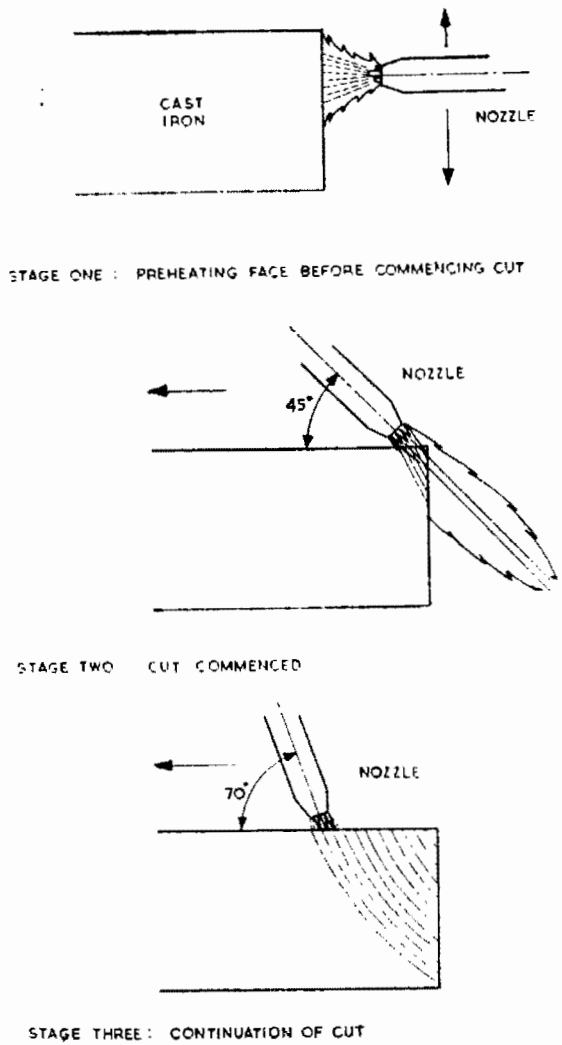


Fig. 12.05: Cutting cast iron

(*f*) *Cutting stainless steel*

Stainless steel is widely used for fabricating vessels and tanks for the chemical and associated industries. The methods used for cutting mild steel are inoperable for similar work on stainless steel, and special processes have been evolved.

Two methods are in common use. In one, an iron powder of about 95 per cent purity is introduced into the flame. The oxidization of this iron increases the flame temperature and, at the same time, the resulting iron oxide fluxes the chrome oxide of the steel and allows a fresh surface to be continually presented. The second

@Seismicisolation

method requires that sodium bicarbonate, mixed with minute quantities of calcium phosphate, be injected into the flame. This creates a fluxing action only and does not increase the flame temperature.

It is advisable to consult the torch or gas manufacturers in all cases before operations are begun, and they will be found to be only too pleased to help.

(*g*) *Cleaning nozzles*

A clean cut will not be made with a worn or dirty nozzle. The one-piece nozzles recently introduced allow an appreciable amount to be taken off the face when worn, to give a new surface. The best method of truing the tips is to rub them against a piece of fine emery paper held on a sheet of glass. When this operation is complete, the corners of the orifices should have sharp edges and be square with the face of the nozzle. Any obstruction in the passages can be removed with the correct pattern of tip cleaner.

After the nozzle has been cleaned and refaced, it should be checked by inspection of the flame, which should be straight and symmetrical, and of the shape shown in Fig. 12.05.

(*h*) *Safety precautions*

Although not as dangerous to the eyes as electric arc welding, oxy-acetylene cutting operations can strain the operator's eyes. Therefore, the correct pattern of safety goggles should always be used for all cutting operations—even the smallest of jobs.

Never handle the gas cylinders roughly and do not allow them to be dropped. On no account should the cylinders be thrown to the ground. It is far, far wiser to spend a little more time and sling the cylinders correctly so that they can be lowered under control.

Oil and grease should never be used on any of the connections between the cylinders and the torch as an explosion of extreme violence may be caused. Before an operator commences cutting, make sure that no inflammable materials are within range of the sparks. Remember, that when cutting is being done at a height, the sparks will travel a considerable distance before they cool sufficiently not to be dangerous.

FLAME-CLEANING

Strictly speaking, the cleaning and painting of structures can be hardly considered as coming into the sphere of steel erecting operations. However, erecting firms are often called in to help with structural painting, so a brief mention will be made here of

a modern method of preparing steelwork for painting. This is yet another of the many uses to which the oxy-acetylene flame is put and it is finding ever-increasing popularity. The results on even very deeply rusted surfaces are effective.

Only a heating flame is used and the special torch gives a brush-like flame, the width of which can be varied to suit requirements by the use of different nozzles. The heat applied expands the rust scales and old paint at a quicker rate than the underlying steel, and they consequently break away. The surface left is dry, clean, and warm. If the priming paint is applied while the steel is in this condition, the lasting properties are greatly enhanced.

LIST OF BURNING GEAR FOR ONE OPERATOR

1	Oxy-acetylene cutting torch
2	30-ft Pipes—1 fitted for oxygen and 1 for D.A.
1	Oxygen regulator
1	Acetylene regulator
1	Bottle key
1	Regulator spanner
2	Spare nozzles
1	Pair burner's goggles with spare glasses

@Seismicisolation

CHAPTER 13

ELEMENTARY SURVEYING

THOSE in charge of erection work should have some knowledge of surveying practice and some experience in the use of surveying instruments. The theodolite is used to establish the centre-lines of the stanchions and to assist in the plumbing of the steelwork, and the level is employed to ensure that the stanchion bases and grillages are set at the stipulated heights. These instruments give greater accuracy than can be obtained with the old-fashioned string-line and plumb-bob.

It is advisable to make certain before erection work on any building is commenced that all concrete foundations which are to receive steelwork have been placed correctly as regards their position and level. Nothing is more annoying when erection is proceeding smoothly than to come across a foundation which is not correct and this is more likely to occur when time is limited. Correction will not usually be the responsibility of the erector but that is of little comfort for time is lost and the erection schedule interrupted. Errors should be brought to light and corrected before erection is actually begun.

Occasionally the erection firm may tender for, and receive the order for, the setting-out and concreting of the bases for the building. This often happens when the structure is small and clad with steel or asbestos sheets leaving little other work for a builder. It is then that the engineer's or foreman's knowledge of setting-out will stand him in good stead.

An assistant is necessary for carrying out the surveying work. The man chosen should be capable and conscientious since much will depend upon his accuracy. It is good policy to employ the same man throughout the whole work. His duties will carry him out of hearing distance and he will have to rely upon agreed visual signals given by the surveyor. Since serious errors and dislocation can very easily occur if these signals are misunderstood, it is imperative that the assistant is fully conversant with the surveyor's method of working.

LEVELLING

Basically levels are taken to determine the elevation of the various points in relation to a given point, termed the "datum". For example, in Fig. 13.01 the level of point A in relation to the pond

surface (chosen as the datum in this particular case) would be "plus 10 ft", and that of point B "plus 4 ft 6 in." Instruments which can be used for the determination of relative levels include the ordinary joiner's spirit level and the old-fashioned water level. The latter consists of two vertical glass tubes, about 12 in. apart, connected by a rubber tube at their lowest parts. The whole arrangement is mounted on a tripod and partly filled with coloured water.

By sighting along the water surfaces on to a staff held on the points to be checked, the difference in levels is quickly found. Modern levelling instruments use the same principle, but the water surface

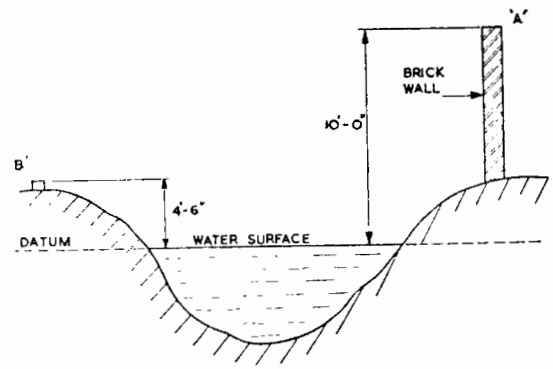


Fig. 13.01: Simple explanation of levelling operations

is replaced by a powerful telescope which is levelled by a very accurate spirit level. Specially graduated staffs are used for ease in reading.

THE DATUM

It will be seen from the above that, before a point can be said to be at a certain level, the datum must be chosen. For building and civil engineering work an arbitrary datum is fixed at a point convenient to the site. All levels given on the contract drawings are related to this datum which is called the "bench mark" for the job. If the contract covers a large area, a number of secondary bench marks will be set up adjacent to each building or section of work. Remember that these are only for convenience and, if there is any doubt as to whether they are true or not, a careful check must be made back to the principal bench mark.

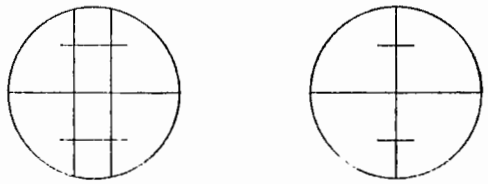
It should be noted here that it is customary for the main bench mark level or datum to be given some appropriate positive value

@Seismicisolation

so that all levels below the bench mark can be read off as positive quantities.

SURVEYOR'S LEVEL

Either the "dumpy" or the "quick-set" type of level may be used for work on the erection site. On both types a telescope is mounted on a metal plate and is free to revolve on a vertical axis.



(a) (b)

Fig. 13.02: Diaphragms

Another plate is connected below the first by adjusting screws. When the instrument is in use, the lower plate is clamped to the top of a tripod. For setting up, the upper plate is levelled by the screws and the telescope can then be swung a full circle and be level in all directions. With the dumpy level the top plate must be levelled very carefully indeed as this provides the final setting of the instrument. When using the quick-set level, however, this top plate is only approximately levelled and the final and accurate adjustment to the telescope level by a special screw is made as required for each reading.

Some models have three screws to level the top plate and some four. Some types of quick-set level have a large-diameter ball on which the top plate swivels and which can be clamped when the plate is approximately level. The four-screw type of adjustment has the disadvantage that, unless it is carefully handled, the screws can work against each other and they may jam and strain the plates. With the three-screw pattern the screws cannot work against each other. Moreover, the instrument can be levelled with one hand only, if need be. The three-screw pattern is the most common in Great Britain.

The telescope has a diaphragm with sighting webs which usually consist of spider threads or fine lines engraved on glass. Diaphragm webs will generally be arranged to one of the patterns shown in Fig. 13.02. The vertical line helps the user to check that the staff is being held plumb, and the short horizontal lines, which can

be seen above and below the main horizontal line in (b), are used only when distances are being measured by tacheometry. They will therefore be ignored in this discussion.

The main spirit level is usually attached to the side of the telescope. If the instrument is out of adjustment, the telescope and spirit level can be moved relative to each other by special screws which must be locked after the correction has been made. The method of checking and adjusting this relationship is described later. A small cross level is sometimes fitted to assist with the preliminary levelling of the instrument.

Plate 13.01 is a modern British surveyor's level which shows all the points described above. Slightly more complicated versions of this particular model can be obtained, but the one shown is perhaps the most useful for normal site work.

THE TRIPOD

The legs of the tripod may be either of solid or open construction, and may be made either of wood or metal. The open construction gives the greatest strength for a given weight but occasionally the joints of the wooden type work loose and the rigidity is impaired. The tripod head carries a plate and clamping attachment to which the instrument can be fastened. Tripods will not always be interchangeable as fastening arrangements vary.

LEVELLING STAFF

As supplied for general civil engineering work, this staff is of telescopic construction extending to a height of 14 ft. and closing to little more than 5 ft. This type of staff is usually in three sections, the top or inner one being solid and the other two of box construction. The bottom of the staff is protected from damage and wear by a brass foot and, when each section is correctly extended, it can be locked in position by means of a special clip. Before starting levelling operations, make certain that the assistant is familiar with the use of these clips as serious errors can occur if they are not correctly locked. Also impress upon him that the staff must be held vertical to ensure that a true reading is obtained.

The staff will be marked either in feet and decimals of a foot, or in feet, inches and eighths. The latter will be more readily understood by the practical man, but the newcomer would be well advised to make himself familiar with both systems for, although steelwork levels are usually given in inches and eighths, use of the decimal system is common for other civil engineering work.

Table 13.01 has been prepared to help with the conversion of readings from one system to the other. When such a table is not

@Seismicisolation

available, the calculations can be done as follows: 6 in. equals half a foot or 0·50 ft, and similarly 3 in. and 9 in. equal 0·25 ft and 0·75 ft respectively. There are 96 eighths of an inch in one foot, so that a one hundredth of a foot can be reckoned as $\frac{1}{8}$ in. For practical purposes the error will not be noticeable on measurements of $1\frac{1}{2}$ in. or less. This approximation can easily be used to fill in the gaps in the mental table which we are building up. For example, $2\frac{1}{2}$ in. would be 0·21 ft, i.e., 0·25 ft (3 in.) less 0·04 ft ($\frac{1}{2}$ in.). Similarly, $9\frac{5}{8}$ in. would be 0·80 ft; i.e., 0·75 ft plus 0·05 ft ($\frac{5}{8}$ in.).

The graduations on the staff are marked in what at first might appear to be a peculiar fashion. Once understood, however, the marking makes for easy reading. There are several variations of marking systems, of which the most common is shown in Fig. 13.03. Here the foot divisions are marked in large red figures: the top of the figure indicating the foot mark measured from the bottom of the staff. Divisions of the foot, whether tenths of a foot or inches, are marked similarly with black figures. Only every other division of the foot is marked, but as the black figures are exactly the height of a division, the top of the figure marks the division it represents

Table 13.01. CONVERSION TABLE—INCHES AND FRACTIONS

[TO DECIMALS OF A FOOT]

		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
0	0	·01	·02	·03	·04	·05	·06	·07
1	·08	·09	·10	·11	·13	·14	·15	·16
2	·17	·18	·19	·20	·21	·22	·23	·24
3	·25	·26	·27	·28	·29	·30	·31	·32
4	·33	·34	·35	·36	·38	·39	·40	·41
5	·42	·43	·44	·45	·46	·47	·48	·49
6	·50	·51	·52	·53	·54	·55	·56	·57
7	·58	·59	·60	·61	·63	·64	·65	·66
8	·67	·68	·69	·70	·71	·72	·73	·74
9	·75	·76	·77	·78	·79	·80	·81	·82
10	·83	·84	·85	·86	·88	·89	·90	·91
11	·92	·93	·94	·95	·96	·97	·98	·99

Example 1. *To convert* $4\frac{5}{8}$ *in. into decimals of a foot.* Enter the table from the left and continue across until under the $\frac{5}{8}$-in. column. The reading in this square is the answer.

Example 2. *To convert* 0·71 *ft into inches.* Inspect horizontally and vertically to find inches and fractions of an inch respectively. Answer in this case is $8\frac{1}{2}$ in.

and the bottom marks the division line below. The small black bands are exactly one-hundredth of a foot wide (or one-eighth of an inch wide, as the case may be) as are the white spaces between them.

When reading the staff, count the hundredths of a foot (or eighths of an inch) from either the top or bottom of the black figures, making a note of which foot division is being read. Two examples are shown in Fig. 13.04. Some difficulty will be experienced at

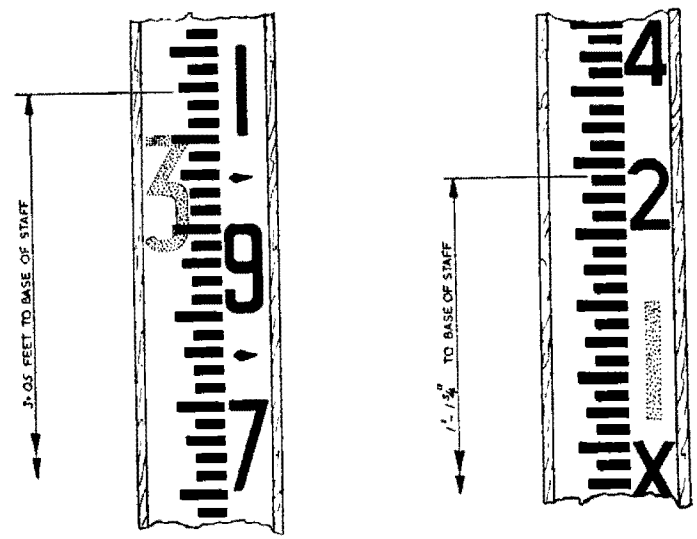


Fig. 13.03: Marking of the levelling staff

first because the image of the staff appears inverted when seen through the telescope, but practice will soon overcome this.

The worn face of a staff can be readily renewed but, if a staff is to be sent anywhere by road or rail, it would be advisable to cover the face to protect it from damage.

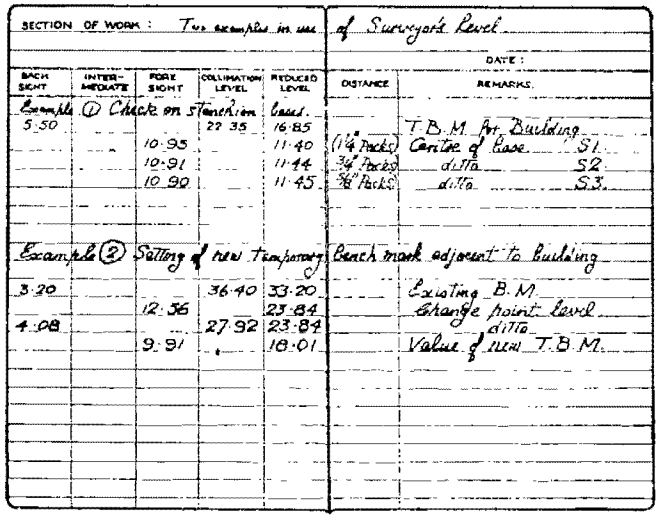
LEVEL BOOK

A special book, ruled as shown in Fig. 13.04, should always be used for entering the readings. The ruling illustrated is that used for the Collimation System of booking levels, and books suitably ruled can be obtained from any drawing office supply stores. Use of the correct book enables all calculations to be made methodically and a permanent record of all levelling operations is thus kept. This can be referred to if any discussion regarding the levels arises at a later date. The method of using the book is described later.

@Seismicisolation

SETTING UP THE LEVEL

At the selected spot plant the legs of the tripod firmly in the ground so that the attachment on the top is approximately level and at a comfortable height for the user. Then clamp on the instrument. Level the three-screw dumpy level by placing the main spirit level parallel to an imaginary line joining two of the screws. Adjust



SECTION OF WORK: Two examples in use of Surveyors Level

DATE:

BACK SIGHT	INTERMEDIATE	FORE SIGHT	COLLIMATION LEVEL	REDUCED LEVEL	DISTANCE	REMARKS
Example ① Check on stanchion bases.						
5.50			22.35	16.85		T.B.M. for Building
		10.95		11.40	(1¼" Packs)	Centre of Base S1
		10.91		11.44	¾" Packs	ditto S2
		10.90		11.45	¾" Packs	ditto S3
Example ② Setting of new temporary Bench mark adjacent to Building						
3.20			36.40	33.20		Existing B.M.
		12.36		23.84		Change point level
4.08			27.92	23.84		ditto
		9.91		18.01		Value of new T.B.M.

Fig. 13.04: Level book

these two screws, turning one clockwise and the other anti-clockwise, until the bubble is central, and then swing the telescope so that it is at right-angles to its previous position. Centralize the bubble again, using only the remaining screw. Theoretically, the bubble should now be central whatever the position of the telescope but this is only seldom true, and the above procedure may have to be repeated a number of times before the setting is correct.

The quick-set level is usually equipped with a small circular level for the preliminary setting and the top plate can quickly be levelled approximately. The final adjustment is made, just before each reading is taken, by the screw provided under the telescope. The four-screw type of instrument is set up by levelling the telescope across the diagonally opposite pairs of screws in turn.

USING THE LEVEL

This can best be illustrated by two practical examples. For simplicity, it is assumed in the first example that all levels can be read from the one position. Part of the foundation plan for a small building is shown in Fig. 13.05. The levels of the tops of

the concrete bases are to be checked and the requisite amount of steel packing placed in position. The temporary bench mark (T.B.M.) for this building is " plus 16·85 ft ", the finished level of the underside of the steel base should be " plus 11·50 ft ", and that of the top of the concrete " plus 11·42 ft " (which allows the customary 1 in. of grout).

The level should be set up at a convenient place and a reading taken on the T.B.M. This reading is called the " backsight " and is entered in the appropriate column of the level book, as is also the value of the T.B.M. Suppose the backsight reading to be 5·50 ft. As can be seen from Fig. 13.06 the height of the instrument above the datum will thus be the addition of the staff reading and the bench mark value. This result is known as the " collimation level ". The value (22·35 ft) is entered, as shown in the level book in Fig. 13.05. Readings are now taken on stanchion bases S.1,

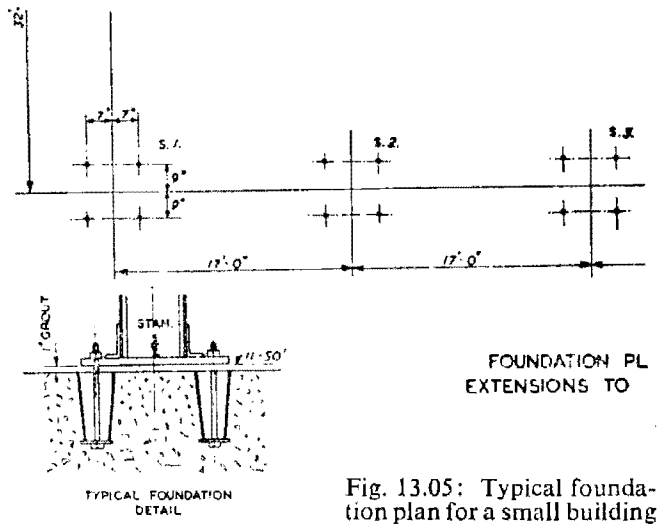


Fig. 13.05: Typical foundation plan for a small building

S.2, and S.3 and booked in the " foresight " column. Subtracting these values from the collimation level gives the levels of the respective bases. The amount of packing required for each base is easily determined and is jotted down for future reference in the " distance " column.

For the second example it will be assumed that the nearest bench mark established by the resident engineer is some distance away and that it would be more convenient to position another close

@Seismicisolation

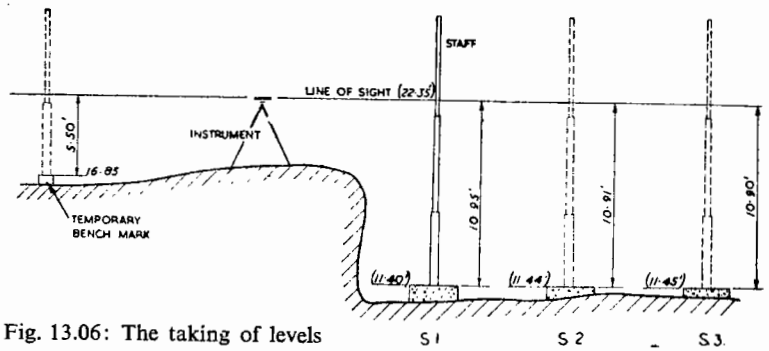


Fig. 13.06: The taking of levels

to the building. In this particular case, obstacles prevent the work being done from one set-up of the level and this makes the working slightly more complicated. The instrument is first set up in such a position that a reading can be taken on the existing bench mark and also on a specially selected spot called the "change point" (C.P.) which should be visible also from the position where the level will be set up for the second time. This change point can be any object sufficiently solid to prevent movement during use. A low brick wall, concrete footing, or a peg knocked into the ground would be suitable. From the first position of the level, the height of the change point is determined; from the second position, the level of the proposed bench mark is established from the change point level. The new T.B.M. must be solid enough and so positioned that it will not be displaced either by the steelwork or by other contractors' plant.

The calculation and method of booking the levels for the above operation should be quite clear from Figs. 13.04 and 13.07. Note that when change points are used to run a line of levels from one point to another, the first reading taken from any one set-up of

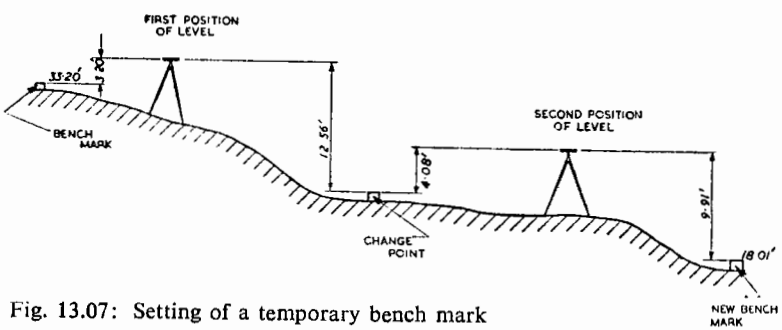


Fig. 13.07: Setting of a temporary bench mark

the level is termed the backsight and the last reading, which in this case is on the next change point, is called the foresight. If there are other readings besides these they are entered in the column headed "intermediate". After the T.B.M. has been established thus, it must be checked by running a level back to the original datum, preferably using another change point.

The above are examples of the commonest uses of the level in steel erection work. When these examples have been digested and fully understood, there is no reason why more complicated levelling operations should not be tackled if the need arises. Provided the level book is correctly used and the readings are accurately made and methodically booked, the beginner should experience no difficulty. Levelling is not as complicated as it may appear at first. Levels should be booked and reduced on the spot, not in the office afterwards.

ADJUSTMENTS TO THE INSTRUMENT

Sometimes, when working the instrument, the user will find that, on moving his eye from side to side, the image of the cross hairs

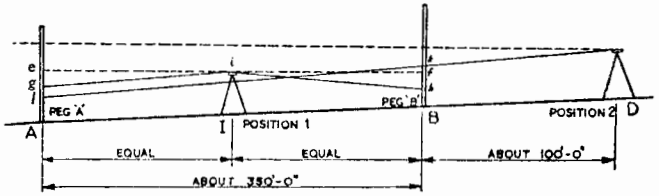


Fig. 13.08: Adjustment for collimation

will appear to move across the image of the staff. To correct this, the telescope is sighted against the sky or against a distant light-coloured object, and the knurled portion of the eyepiece is rotated until this movement is non-existent. The whole operation is called the "adjustment for parallax" and, when complete, the image of the cross hairs will stand out sharp and clear.

Unless the line of collimation (i.e., the line of sight of the telescope) is truly parallel to the axis of the main spirit level, the instrument will be unreliable. Therefore the level has to be periodically checked to see that this relationship is correct. For this check to be made swiftly and accurately, two assistants and two staves will be required. A stretch of clear ground about 500 ft in length and rising not more than, say, 5 or 6 ft is selected, and two pegs, *A* and *B* in Fig. 13.08, are driven into the ground until they

@Seismicisolation

are firm. The distance between the pegs should be about 350 ft. The instrument is set up and levelled at a point exactly central between these pegs.

One staff is held on each peg and readings are taken. Assume that, in this particular case, the instrument is out of adjustment and that, when the spirit level is horizontal, the telescope is pointing down as shown by the full lines *gi* and *hi*. The dotted line *eif* is the true horizontal line through the instrument, and the line of sight of the telescope must be made to coincide with this. As the distances *AI* and *IB* are equal, the heights *eg* and *fh* will also be equal. Therefore, whether the instrument is correct or not, the difference in the staff readings will still give the true difference in levels between *A* and *B*.

The level is now moved to its second position at *D*, which is in line with pegs *A* and *B* and about 100 ft beyond *B*. Take readings on the two staves again and, the line of collimation being dipped (in this case the line *jkh*), the calculated difference in the levels of *A* and *B* will not be the same as before. This shows that the level is out of adjustment and must therefore be corrected.

This correction is quite a simple matter. The levelling screws on the dumpy level (or the screw under the telescope on the quick-set) are first adjusted until the difference in readings on the staves is the same as that obtained when the instrument was central between the pegs. This will bring the line of collimation horizontal and, at the same time, tilt the spirit level. Adjusting nuts are provided at one end of the spirit level and, by moving these one way or the other, the bubble can be brought central again. The adjusting screws should then be locked and the complete check carried out again. If the same results are not obtained from the two positions of the level, the spirit level has to be adjusted again and the check repeated. Once agreement is reached, it can be said that the adjustment is complete and that the line of collimation of the telescope is parallel to the axis of the spirit level.

USE OF THE THEODOLITE

The accurate positioning of the stanchions on the site will be the main work carried out with the theodolite. Many erection foremen prefer to use a piano wire or string-line for this work, but good results cannot be guaranteed with these methods except under conditions of dead calm. The string method also has the disadvantage that it compels the erector to use the profiles and setting-out pegs placed by the builder for his own use. The advantages obtained in checking the builder's work have already been pointed out, and a theodolite is essential for this. In any case, by the

time the erector arrives on the site, the pegs and profiles are almost certain to have been dislodged and cannot, therefore, be relied upon. Once the engineer or foreman has mastered the use of the theodolite, he will find all manner of work for it—such as lining crane tracks in the building, plumbing columns, and setting the track for the bogies carrying the scotch derrick cranes.

DESCRIPTION OF INSTRUMENT

Although more advanced models of theodolites are slowly coming into use, the vernier theodolite, illustrated in Plate 13.02, is still the most widely used pattern of instrument for constructional and civil engineering work. Our description relates only to that model.

The vernier theodolite consists basically of a telescope fitted with sighting diaphragms and mounted on trunnion bearings in such a manner that it is free to revolve in a vertical direction. These trunnion bearings are carried by A-shaped frames which are, in turn, set on a circular plate. Immediately below this is another and similar plate, and both plates are free to rotate on their common vertical axis but can be locked at will by the special clamping devices provided. The lower plate can be locked to the base of the instrument, and the upper plate can be locked to the lower.

Degrees are marked off on a scale set out along the outer edge of the lower plate. By locking this plate and swinging the upper one, which is also provided with a zero mark, lines can be set out at given horizontal angles to each other, with the instrument as the intersection point. A vertical scale is also fitted which enables vertical angles to be set out or measured. In the normal run of building and civil engineering work, however, this scale is seldom used. The clamping devices on the plates are fitted with fine-adjustment tangent screws which enable the plates to be moved slowly after they have been set approximately by hand. The vernier scales make it possible for angles to be set and read with great accuracy.

The whole instrument is mounted on a base which can be levelled by a three-screw system in the same manner as the dumpy level already described. In addition, however, special centring devices are usually fitted to theodolites to aid the accurate setting of the instrument. Models which have the centring device fitted above the levelling screws are much to be preferred, as adjustment in the horizontal direction can then be made without disturbing the level of the instrument. The tripods intended for use with theodolites are usually constructed so that the length of the legs can be adjusted to facilitate the setting of the instrument on uneven ground.

The placing and setting of the theodolite is similar to that of the dumpy level, with the exception that the theodolite has usually to

@Seismicisolation

be also set central over a given point. When a centring device is fitted, little difficulty need be expected. A plumb-bob slung from the centre of the instrument will be used to locate the instrument over the fixed point although some models have an optical centring sight that dispenses with the plumb-bob. In windy weather, the plumb-bob must be shielded, or reading will be impossible. A light wooden trough, about 9 in. deep, 9 in. wide and 3 ft long, with no

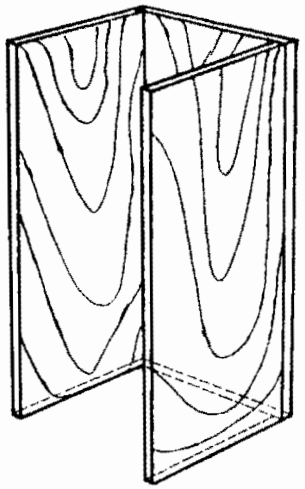


Fig. 13.09: Wind shield

ends, can soon be made. Stood on end, as shown in Fig. 13.09, so that it protects three sides of the plumb-line, this trough will be found very effective.

VERNIER SCALE

Most of the setting out for building work can be accomplished by merely using the theodolite in conjunction with the tape to offset measurements at true right angles. This makes the work extremely simple and the vernier scale of the instrument does not have to be used for most practical purposes. For the reader's information, this scale is used when reading angles other than right angles, and it is so constructed that the angle can be read accurately to a much finer degree than would be possible using the main scale only.

TO TURN A RIGHT ANGLE

Imagine that the theodolite is set up over peg *A* in Fig. 13.10 which is on the line *AB*, and that it is required that a further peg *C* be inserted so that the angle *BAC* is a right angle. The upper revolving plate which carries the telescope is swung on the lower

one until the zero on one of the vernier scales comes opposite the zero mark on the main scale. The two plates are locked together and the zero graduations are brought exactly opposite each other with the fine-adjustment screw. A small microscope is fitted above each vernier so that this can be done very accurately. Keeping the plates locked, the telescope is swung and sighted on peg *B*. The lower plate is now locked and, by using the other fine-adjustment screw which works this plate, the centre mark on the peg is brought exactly in line with the cross hairs on the diaphragm. Now release the upper plate and swing the instrument through 90° in the appropriate direction, making the final adjustment by locking

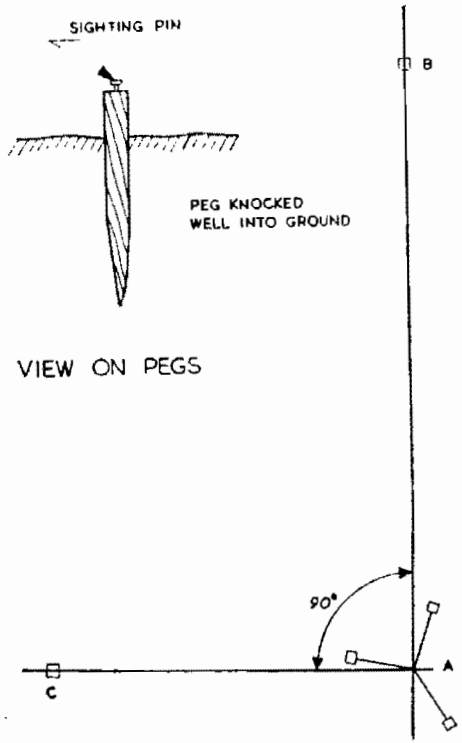


Fig. 13.10: Turning a right angle

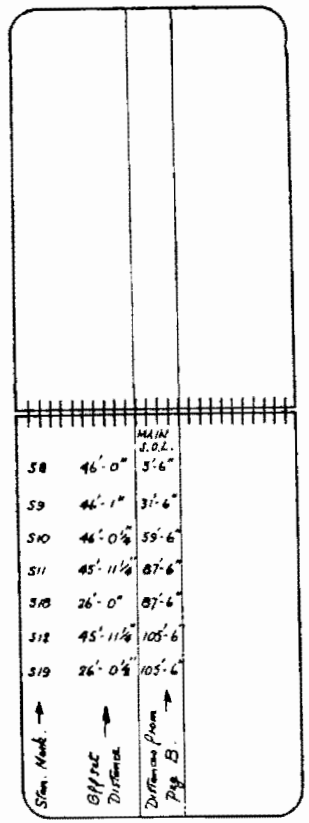


Fig. 13.11: Field book

the two plates together, again using the tangent screw and reading the microscope as before.

Peg *C* is now positioned by an assistant according to the surveyor's directions. When it has been driven firmly into the ground, a nail can be knocked into the top to mark the exact line.

@Seismicisolation

FIELD BOOK

Details of surveys carried out and measurements taken should always be made in the Field Book. Thus, by reference to this and the Level Book, a clear and accurate picture of the work done on any contract will be obtained. Fig. 13.11 illustrates a page from a typical Field Book. The double red lines down the centre of the page are useful, and offsets from a survey line can be indicated by placing the relevant figures either one side or the other of these lines, as the case may be. The survey shown in the illustration is a small section of one made to determine the accuracy of a number of bases on one site.

ADJUSTMENTS TO THE THEODOLITE

(*a*) *Adjustment for parallax*

This is made in exactly the same manner as to the surveyor's level. The knurled eyepiece is rotated until the lines on the diaphragm are brought into sharp relief. When the adjustment has been correctly made, these lines will not appear to move when the eye is moved slightly from side to side.

(*b*) *Adjustment to spirit levels on parallel plates*

The level is not adjusted correctly if both spirit levels are not at right angles to the vertical axis of the instrument. The procedure to check and correct this is as follows. The theodolite is set firmly on the ground with the top parallel plate in an approximately horizontal position. The telescope is locked with the vertical scale at zero—this operation is carried out accurately with the microscope and tangent screw. The top plate is now swung until the telescope is over an imaginary line joining two of the footscrews. These screws are rotated (one clockwise and the other anti-clockwise) to centre the bubble on the telescope. The telescope is then turned through 180° and, if the bubble is not central again, half the error is taken out by the footscrews and the remainder by adjusting the tangent screw on the vertical scale. The telescope is now turned through a right angle, and the same procedure is repeated, but only the third and remaining footscrew is used this time.

The whole procedure is now repeated until the level on the telescope shows central in all positions. All that remains is to adjust the levels on the upper plate until they register central, after which they are secured in position with the locking nuts. Should any other adjustments become necessary, it is recommended that the theodolite be returned to the makers for their attention.

LINING-IN THE STEELWORK

On most small buildings the lining-in work with the theodolite can often be limited to setting the stanchions on two sides, leaving the remainder to be positioned by using only the tape. This method is quite satisfactory and would suffice for buildings where the erection work has been completed.

A much better method, however, is to complete the survey work before erection begins. With this procedure the centre lines are marked on all the foundations, so that the stanchions, as they are being erected, can be placed very nearly on their final positions. This greatly simplifies the work for, after the steelwork has been erected, all the lines of sight on the stanchion centres are obscured and the use of offset lines becomes necessary. A setting-out operation that would take an hour to complete before erection commences thus often takes three or four hours if undertaken later.

It is not always possible to do the survey work before erection has begun; the engineer may be delayed on another job and be unable to make himself available at the right time for the new job. As it is too costly to stop the erection squad until he arrives on site, they should be allowed to proceed with their work. When the survey work has to be tackled at a later stage of the contract, this necessitates a deviation from the desirable procedure of setting all the stanchions with the theodolite. The method of offset lines in such a case would take too long, and it is much quicker to use the theodolite for setting as few lines as possible and to set the remainder of the stanchions from these lines with the tape.

When an offset line has to be used, the measurements are made to the face of the stanchions. These readings are taken best with the levelling staff held horizontally, and any foreman or engineer who is fully conversant with the normal use of the staff will have no difficulty in reading it when held in this manner. As only the bottom section of the staff is normally required for this work, the other two sections can be withdrawn temporarily. This would cause less fatigue to the assistant and enable him to hold the staff much steadier. Measurements obtained in this way will, of course, be the offset distance of the stanchion centres less half the width of the stanchions. Take care when reading the staff to see that the stanchion is not twisted, as such a twist could cause an error of up to $\frac{1}{2}$in. in bad cases.

Chapter 8 mentioned the lining-in difficulties encountered if a portal-framed structure is erected on loose foundation bolts and left to spread unrestricted. The engineer's work is lessened considerably if he follows the advice given in that chapter and arranges for all the bolts to be grouted solid in their final position. An

@Seismicisolation

accurately made template is used to ensure that no difficulty will be experienced with the stanchion erection. For setting a long row of identical stanchions, three or four such templates could be fabricated and they would be set and grouted early each day. By the following morning the cement grout should be sufficiently hard for the templates to be removed and the process to be repeated on further bases. This procedure will keep the engineer's work ahead of the erectors.

As it is difficult to fabricate structural steelwork to very fine limits, it may be found that the overall measurement of a long building is not equal to that given on the working drawings. More often than not, it will be slightly greater. This " growth " or " creep " of erected steelwork is always more noticeable on a line of stanchions where all the longitudinal beam connections are butt joints. When it can be foreseen that " creeping " will occur, it is not advisable to set the full line of stanchion foundation bolts to the drawing dimensions. Should this be done, the restraining action of the bolts would hold the foot of the stanchion in a fixed position and, as the top will have spread, the stanchion will not be plumb longitudinally. In such cases only the bolts for a section of the building should be set at one time. The plumbing error could then be remedied after erection of this portion and before proceeding with the setting of the bolts for the next section.

The checking of the plumb of a selected line of stanchions can be undertaken readily with the theodolite. The work is extremely simple if the instrument has already been set up on a line parallel to the stanchion centre lines. All that need be done in this case is to instruct the assistant to hold the staff against the bottom and tops of each stanchion. The set of readings obtained with the staff held against the tops is plotted against the set obtained with the staff held against the bottoms. A comparison of the two sets of readings brings to light any discrepancy in the plumb of individual stanchions. When using this method, do not forget that the cross-section of the stanchion may change at some point in its height. In this case due allowance has to be made when comparing the figures.

When the theodolite is used in this manner, it is always advisable to extend the parallel line some distance beyond the last stanchion and to set the theodolite well away from the nearest stanchion to be checked. This elementary precaution lessens the effect of any error that may be present in the vertical transiting of the telescope because, as shown in Fig. 13.12, the telescope is swung through a smaller arc. An additional advantage is that the readings can be taken much more easily. Twisting one's neck to take a reading through an almost vertical telescope can be very tiring and does not

lend itself to accurate work; the results are accurate only with a first-class instrument.

Perusal of the collected readings will show doubtlessly that most stanchions have to be adjusted to bring them vertical within the allowable limits. A common method is to loosen any connections that may be making the structure rigid, and then to rock over the stanchions by adjusting the packings each side of the base and tightening the appropriate holding-down bolts. When the necessary adjustments have been made, the connections can be rebolted and

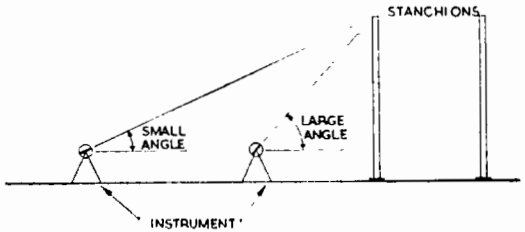


Fig. 13.12: The plumbing of columns

the building checked again. In bad cases, straining wires will have to be used on sections of the building to plumb it. This, however, should only be a last resort when other methods have failed.

It is difficult to state definite procedures for the work of plumbing a building as each individual job will vary greatly. Practice is the only way to success in this art, so the best the learner-engineer can do is to tackle each job with an open mind and use his common sense.

USE OF THE TAPE MEASURE

The most common error in the use of the tape is to allow it to sag without correction. If the taping is done at ground level, sag is easily eliminated by supporting the tape at frequent intervals throughout its length. To measure a distance across a gap at a height, as for example between overhead crane tracks, the following procedure should be adopted: First, take a tape reading between the tracks with a sagging tape held at one end by a spring balance recording some appropriate and definite pull. Then set out an equal distance at ground level, using the same sagging tape reading and the same pull. Then measure this distance in the normal way with the tape supported. The difference between the two readings will give the correction for sag.

Another common fault is that some users do not hold the tape horizontally. What happens in this case is seen from Fig. 13.13,

@Seismicisolation

which shows that the distance actually measured is the hypotenuse of the triangle *ABC*, and not the distance *AB* which is required. When it proves impossible to hold the tape horizontally and still make an accurate measurement, the plumb-bob is used, as shown, to transfer the tape reading to the peg.

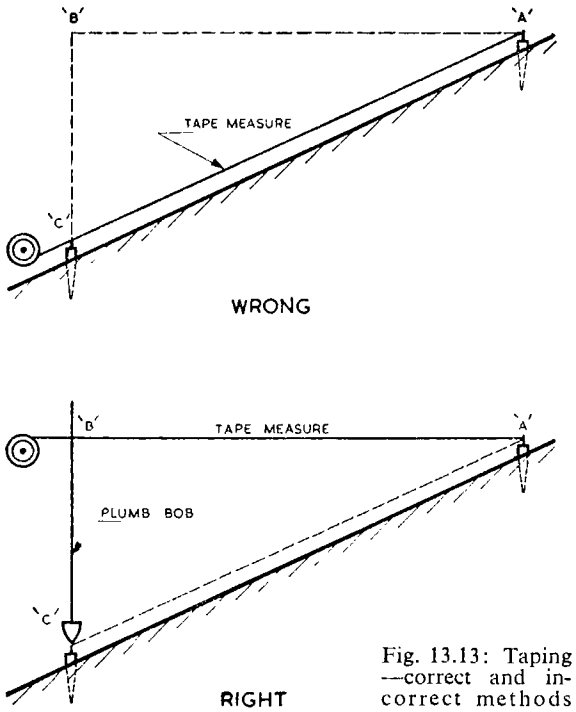


Fig. 13.13: Taping —correct and incorrect methods

It seems elementary to state that the ring on the steel tape is to be included in the length of the tape but the number of people who are ignorant of, or forget, this fact is surprising. All tape measurements must be made from the outside of the ring.

GENERAL ADVICE

1. Be methodical.
2. Book all measurements and angles in the Field Book and retain these books for possible future reference.
3. Do not be afraid to check and double-check all your work, remembering that the best check is one in which the work is undertaken in an entirely different way. This lessens the possibility of making the same error twice.

4. Do not use pegs when you are not sure of their accuracy, but instead work from the main setting-out points. Ensure that the value of the datum is agreed with the client's or contractor's surveyor and, if possible, refer the levels to an Ordnance Bench Mark. Beware of the Newlyn Datum.
5. Be sure that pegs you yourself insert are sufficiently solid. Place concrete round those you are not sure of remaining fast. Also, make certain that the person placing the concrete does not disturb the peg accidentally.

SUGGESTED ALLOWANCES IN LINE AND LEVEL OF BUILDINGS

No matter what is said to the contrary, it is impossible to set fabricated steelwork to very fine limits. Slight variations in the individual members do not always cancel themselves out. Before a structure is handed over, it is as well to state to within what limits it is set.

For buildings and structures which carry no mechanical plant the following figures are recommended by the author: (a) the levels of the bases are to be within plus or minus $\frac{1}{4}$ in. of the specified level, with never more than $\frac{1}{4}$ in. between adjacent column bases; (b) for columns, $\frac{1}{16}$ in. out of plumb for every 10 ft of height. For all other cases the limits specified above should be halved.

LIST OF SURVEYING EQUIPMENT FOR THE SITE

1	Theodolite with tripod and plumb-bob
1	Level with tripod
1	Surveyor's 14-ft staff
1	Wind shield
1	100-ft Steel tape
1	Spring balance reading up to 15 lb
1	4-ft Bricklayer's level and plumb rule
1	3-ft Folding rule
1	Level Book
1	Field Book
2	50-ft String lines
24	Timber pegs, 3 in. × 3 in. × 2 ft, pointed one end
1	7-lb Hammer
1	2-lb Hand hammer
7 lb	2-in. Round wire nails
1	Spare plumb-bob
1	Hand saw
1	200-ft Coil piano wire
2	Very light union screws (for tightening piano wire)
	Pencils
	Penknife
	French chalk
	Paint and marking brushes

@Seismicisolation

CHAPTER 14

ANCILLARY WORK

THE work described in this chapter is often part of the main steel-contract, but the actual supply and fixing at site is usually undertaken by specialist subcontractors. Dealing only in their particular class of work, these firms can handle the work very efficiently. The steelwork contractor, however, still remains responsible for the progress and quality of the work as a whole, and his foreman or site engineer will have to supervise the subcontractor's work.

PATENT GLAZING

The glazing is usually on the sides, ends, and roof of the building. To make the covering waterproof, the glass rests on a shelf angle at the top, with the sheets overlapping. At the bottom, the glass overlaps the sheeting. Lead flashings fitted at the top and bottom weatherproof the joints. The glazing bars are basically a T-shaped bar, used inverted with the table of the T at the bottom. Lead-sheathed bars, galvanized steel bars with cappings of lead or copper, and aluminium bars are most frequently used; but, in addition, the ordinary steel T with putty glazing is sometimes employed.

The actual fixing of the glass on the bars is the manufacturer's speciality and varies with the type of bar used. Asbestos or hemp string is used as a packing between the glass and the bar. With lead-sheathed bars, a leaf of lead is turned down on the glass to hold it in position but with most of the other types a capping is bolted or screwed down.

After checking that the connecting holes in the sheeting bars are correct, the subcontractor's men will handle the work in its entirety, although they may ask for an occasional lift with the erection crane if this is convenient.

When the bars are laid and bolted in position, the glass is slid in and the lead at the side turned down to lock the glass and make it weatherproof. A clip at the bottom prevents the glass from falling out. The main points to check with patent glazing are that the lead flashings are correctly placed and that no cracked panes of glass are inserted. Patching of cracked glass should never be permitted.

GUTTERS AND RAINWATER PIPES

These will be either of cast iron or steel. In the case of the latter the joints may be welded. Large gutters and pipes will have to be handled by the erection crane, and it is therefore essential that

they are on site to fit in with the erection programme. The larger gutters will possibly have snowboards and walkways over them and be provided with handrailing bolted to the sides.

The steelwork contractor is usually responsible for those rainwater goods which connect to his steelwork. All the remainder are fixed by the building contractor. Clipping to the stanchions, bottom purlins, or eaves beams is the usual method of holding the gutters and pipes in position. Some light gutters and pipes are clipped to the sheeting only.

Hessian dipped in red lead or a mastic made up of red lead and swarf is commonly used. This is inserted in the joints as the pieces of guttering are assembled. The red lead must be tacky to make a satisfactory joint. All the joints in the gutters must be carefully made and all bolts inserted and fully tightened. Attention must be given to the falls so that those specified are maintained. Joints in the downpipes are either welded or stemmed with red lead putty.

SHEETING

Sheeting has many advantages over other forms of covering for a factory-type building. Being mass-produced, it is readily available. It is also very adaptable and can be fashioned to cover all shapes and sizes of buildings. It provides a wide choice to meet the requirements of strength, durability, and price. Its chief superiority lies perhaps in the speed with which it can be erected, a factor of great importance if the completion of a building is a matter of urgency.

Sheets are manufactured in various materials—galvanized steel, asbestos, and aluminium. Special sheets with a metal core and various proprietary coverings are also obtainable. Corrugations give the sheets considerable strength: for a given thickness of sheet, the deeper the corrugations, the greater the strength.

DESCRIPTION OF GALVANIZED STEEL SHEETING

Steel sheets are available in thicknesses of 14, 16, 18, 20, 22, 24, and 26 B.W.G. The most common thicknesses used are 18g for roofwork and 20g for side sheeting, unless the presence of sea air or air laden with acid fumes dictates a heavier gauge to withstand the more rapid corrosion. Corrugations in frequent use are 8/3 in., 10/3 in., 6/5 in. and 5/5 in. The figure in inches denotes the size of the corrugation measured from ridge to ridge as in Fig. 14.01 (a), and the number in front of the oblique stroke gives the number of corrugations in the width of the sheet as in Fig. 14.01 (b).

Stock lengths of sheets range from 4 ft to 10 ft in 6-in steps. Other lengths can be obtained on special request; but, if the

@Seismicisolation

quantity is small, entails cutting from standard lengths. The available range, however, covers all practical requirements and special ordering is therefore seldom necessary. Gable sheets are occasionally supplied cut to the required rake. This work is, however, often left to the sheeter to be done on the site.

Three-inch corrugation sheets are usually fixed to the roof to provide a double-corrugation side lap and thus better weather

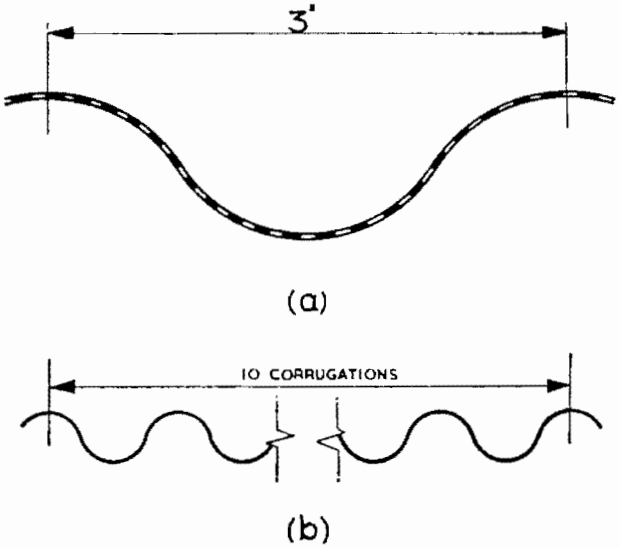


Fig. 14.01: Corrugations—how to measure

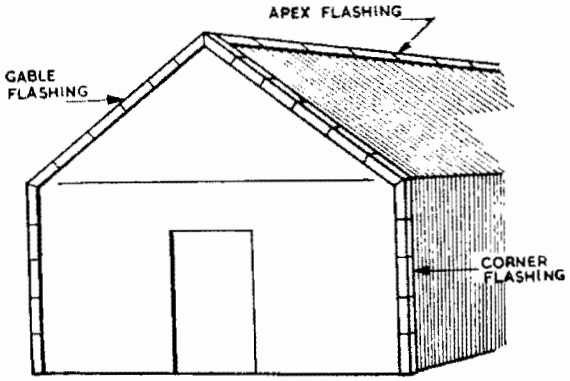
protection. Since side sheeting is vertical and not inclined, as is that on roofs, it is generally laid with only single-corrugation laps. In most of the other types of corrugations, the valley of the corrugation is deeper and only one-corrugation side laps are used. For all positions of sheeting a minimum end lap of 6 in. will be specified.

Flashings of the same material as the sheeting are also necessary to complete the weatherproofing of the building. These will have to be fixed at the roof apex, eaves, and gables; and also at all corners of the building. Window and door openings have to be flashed as well, unless the building is such that complete weatherproofing is not essential. The flashings are bent from material of the same gauge as that used for the main sheeting. The standard length is 6 ft. Fig. 14.02 shows the use of these flashings.

SHEETING FASTENERS

Galvanized bolts and screws are used to fasten the sheets to the purlins or side girts of the building, and also to fasten adjacent sheets

Fig. 14.02: The use of flashings



to each other. Hookbolts will be used where the purlins and side girts are steel sections, and shapes are available for angles and channels. Screws will be employed instead if the sheeting rails are timber. For each sheet width two bolts are used to each purlin or side rail as shown in Fig. 14.03. The length of the hookbolt depends upon the size of the angle or channel, the height of the corrugation, and the number of sheets fastened by the hookbolt in question. Table 14.01 lists the size of bookbolt necessary to fit the usual sizes of rails, as well as illustrating the method of measuring the size required for other cases. Note that $\frac{1}{4}$ in. has to be added to the lengths given in the table if the hookbolt passes through two or three thicknesses of sheets. In some cases it is impossible to fasten the sheet satisfactorily to a framing angle with a hookbolt, and specially made clips will have to be used. Seam bolts are generally used to fasten the sheets together. These bolts will be $\frac{1}{4}$ in. in diameter and $\frac{3}{4}$ in., 1 in., or more in length depending upon the individual thicknesses of the sheets and the number fastened.

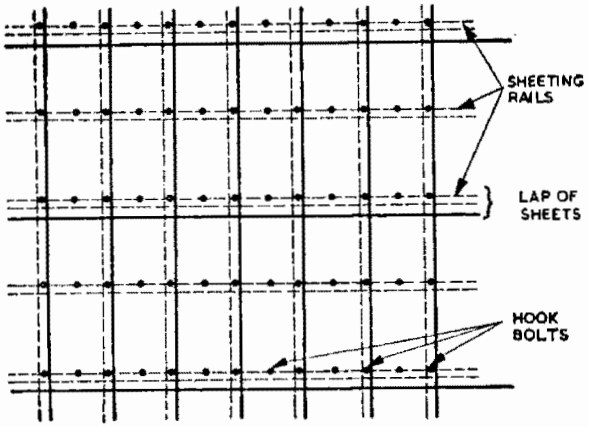


Fig. 14.03: Position-ing of hookbolts

@Seismicisolation

Unless the hole through which the hookbolt or seam bolt passes is water-proofed, rain will eventually seep through and cause trouble. To prevent this, lead or limpet washers are placed under the steel washer. Seam bolts on the roof must have a flat steel washer on the inside of the building and a lead or limpet washer under a steel washer on the outside of the roof. Water-proofing washers are not usually required on the side sheeting. Hookbolts on the roof have similar but larger washers.

ERECTION OF SHEETING

On receiving an order to begin the sheeting of a certain section of the building, the sheeter will assemble whatever tackle he requires for the work. He will be furnished with the requisite drawings and can then begin to collect the necessary sheets. On delivery to the site, these sheets will be graded into the different sizes and lengths, and stacked accordingly. If this rule is followed, the sheeter will have little trouble with this stage of his work.

A note is made later of the information which the drawing should contain about the size and length of the sheets. The sheeter must be instructed to take from the site stores only those sheets he requires for the particular drawing to which he is working at that time. If the drawing is found to be in error, the Drawing Office should be informed at once. They may then either authorize the use of sheets intended for another section of the building or order replacements. The sheeter must never be allowed to use those sheets which he thinks are correct without confirmation from the site office or serious trouble is almost certain to arise at the end of the contract because sufficient sheets of the correct sizes are not available.

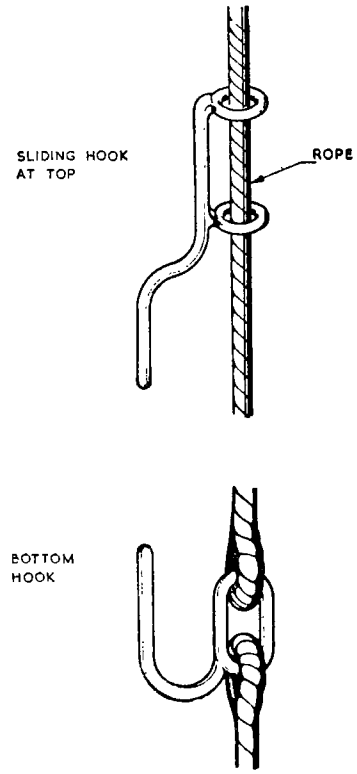
Table 14.01. SELECTION OF HOOKBOLTS*

Width of corrugation in inches	Height of corrugation in inches	Size of leg of angle						
		3 in.	3½ in.	4 in.	4½ in.	5 in.	5½ in.	6 in.
3	¾	4¼	4¾	5¼	5¾	6¼	6¾	7¼
5	1¼	4¾	5¼	5¾	6¼	6¾	7¼	7¾

* (i) Add ¼ in. additional length where hookbolt passes through 4-ply thickness.

(ii) For other sections than those listed in the table, length required is height of corrugation + length of leg of angle + ½ in. + additional ¼ in. if through 4-ply thickness.

Fig. 14.04: Clips for lifting sheets



If the site of the sheeting is only a short distance from the stocking ground, the sheets may be carried there as required. A trolley or bogie will have to be provided for longer distances. It is unlikely that the sheeter and his mate will ask for further assistance on the site since they are usually independent and prefer to work in their own manner. If a crane is available, it will always prove advisable to lift the sheets to the high roofs in bundles as required along the length of the building. If the sheeter can be assisted in this manner, the work can be done satisfactorily to both sides at a lower cost for sheeting. This saving will easily offset the extra cost for the use of the crane. When the sheets have to be hauled to the roof by hand, a block fitted with an endless rope is used and a clip is fastened into this rope, as shown in Fig. 14.04. The weight of the sheet is carried by the lower clip, and the other clip shown in the sketch slides down the rope to hold the top of the sheet in position.

Generally sheets are positioned and tacked into place individually, the exception being when riveting is specified as an alternative to

@Seismicisolation

seam bolting. In this case some sheeters prefer to rivet complete tiers of sheeting on the ground and lift as one. However, fixing will normally proceed with the sheets being tacked into position, with possibly only one bolt to each sheet, until one or two bays are covered. The sheets are then set parallel to the trusses by measuring to the corrugations, and any discrepancies are corrected by light blows on the corrugations with a hand hammer. After one tier of sheets has been located thus, the others are quickly set in line by sighting along the corrugations and adjusting if necessary. This check to ascertain that the sheets are parallel to the truss centre lines should be made at intervals of 15 or 20 ft because, if left longer, the discrepancy may grow to large proportions and spoil the appearance of the finished work. After the sheets are lined, the remaining hook and seam bolts are inserted as specified on the drawings, and the whole of the work is completely bolted.

Unless the gable sheets are supplied cut to the required shape, half or the whole of the gable sheeting may have to be laid out and the roof line marked. Steel sheets can be cut very quickly with a hammer and chisel.

It should be noted that all holes in sheets must be in the top of the corrugation so that any water running down the sheet will not penetrate into the building. One occasionally sees this rule ignored in cases where it is difficult to insert and tighten the bolt in the correct manner but this practice must not be allowed. The correct washers, galvanized lead or limpet must always be used to give a satisfactory finish to the work.

ASBESTOS SHEETING

This type of covering is fixed in very nearly the same manner as ordinary steel sheets, the main difference being the method of lapping. As asbestos sheets are much thicker than steel, they will not lay correctly if fixed in the way of steel sheets. To overcome this difficulty, two corners must be mitred as in Fig. 14.05, which shows sheets being laid from right to left. When working in the opposite direction, the other two corners will be cut instead. As can be seen in the diagram, the top and bottom sheets in each tier are mitred only at one corner. The size of the mitre is easily calculated from the amount of side and end lap specified. Asbestos sheets must always be sawn.

Until it has been firmly fixed in position, asbestos sheeting is very fragile and will not stand rough handling. Some sheeters can make a cut or a hole of good appearance using only hammer and punch or chisel. Cutting asbestos sheets in this manner can never

be recommended, as the vibration caused by the hammering tends to loosen the fibres near the cut and this ruins the lasting qualities of the material. A drill and saw should always be used for cutting.

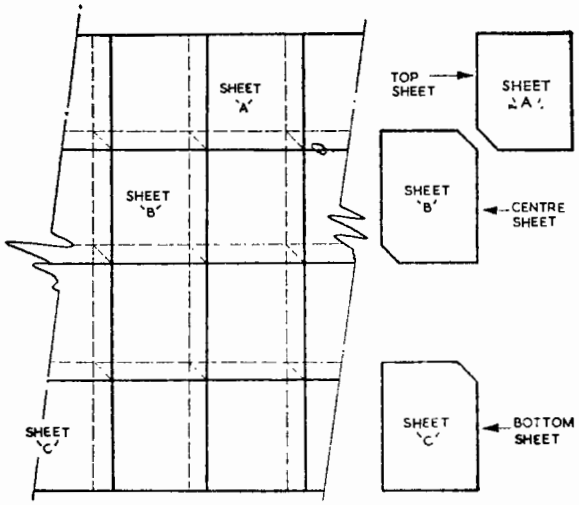


Fig. 14.05: Mitring asbestos sheets

SHEETING DRAWINGS

Sufficient information to enable the sheeting to be fixed to the satisfaction of the client must always be listed clearly on the drawings. Each drawing should also have a table showing the quantities and sizes necessary to complete the work shown, so that the sheeter can select the sheets he requires. Apart from the length, gauge, and corrugations any special cutting to individual sheets should also be noted. A specification giving end and side laps, number of hookbolts per sheet per purlin, distance between seam bolts, and the type of washers to be used should also be set out in full on each drawing to ensure that the sheeting is the fixed correctly.

NOTES

It should be impressed upon all sheeters that their last duty before leaving the site at night is to inspect their working area to ascertain that nothing has been left which may blow down. Damage can quickly be caused to the sheeting when high winds arise, but far more serious accidents can be caused to passers-by and other workmen if the wind moves loose material. It is common loosely to tack a large area of the building and to return later to complete

@Seismicisolation

the bolting. Too great an area must, however, never be left in this semi-finished condition. Once a strong wind succeeds in loosening a corner of the sheeting, the subsequent flapping extends this rapidly. Sheets that are to be left overnight on the roof should always be collected together and stacked in a neat pile which is suitably weighted or lashed down until required the following day.

When the sheeting of the building has been completed, the sheeter must be instructed to remove all surplus bolts and pieces of sheeting. This instruction applies particularly to the gutters which soon accumulate rubbish while the sheets are being fixed. If this is not attended to at once, the runaway for the rainwater is blocked quickly. It is advisable to make an inspection to check that the completed work has been left tidy before giving the sheeter a clearance for his work.

When corrugated sheets are stored at site prior to fixing, they must never be stacked in piles higher than about 18 in. Unless this is done, it will be found that, after even a short period of time, the weight of the top sheets will have tended to flatten those at the bottom of the pile. This pressure forces the corrugations out of shape and, when the sheets have to be fixed, it will be found impossible to match the work satisfactorily.

"Perspex" sheets of the same shape and corrugations as the main roof sheeting are now used widely in place of roof lights in standard glazing. These sheets can be inserted with ease in almost any desired location and are often dispersed over the roof to give a wide diffusion of light inside the building.

The sheeting specification will usually require that the laps be painted before the sheets are fixed. This can be checked very easily and there is no reason why it should ever be omitted.

Seam bolts may be inserted either upwards or downwards. Both methods have their advantages and disadvantages. When inserted downwards, only the heads of the bolts show and the exterior of the sheeting presents a better appearance. The thread of the bolt, which is more prone to attack by corrosion, is inside the building and is thus protected from the weather. Poor workmanship can, however, result in the bolts being pushed into the holes and left without nuts or washers. A close check should therefore be kept to ensure that the nuts and the correct washers are used and fully tightened—otherwise waterproofing problems will soon occur.

An advantage of inserting the bolts from inside the building is that the nuts can be put on and tightened easily by the man working on the outside. In addition, inspection of the completed work is easier. All nuts and washers are clearly visible, and it is only necessary to ensure that the nuts are tightened.

CHAPTER 15

ESTIMATING AND COSTING

ESTIMATING

METHODS OF OBTAINING TENDERS

After deciding to go ahead with a construction project the owner often places his requirements in the hands of an Architect or Consulting Engineer. These will prepare the plans and details and issue inquiries to ascertain the cost of the work. On the basis of the quotations received, a firm will be selected to carry out the work. There are four methods by which selection may be made:

1. Estimates may be invited from a large number of firms by advertisement in the Press.
2. Quotations may be obtained from a small number (say six) of selected firms.
3. A price may be negotiated with an individual firm.
4. One particular firm of repute may be asked to carry out the work on a cost-plus-profit basis.

Each of these methods will now be examined in detail.

ADVANTAGES AND DISADVANTAGES

1. There is much wasted effort when a large number of firms send in estimates as, naturally, the contract can only be awarded to one firm.
2. This is by far the best method as unnecessary tendering is cut to a minimum while the customer is still assured of a competitive price. As the ability of the firms is known, good work is assured.
3. This method has much to recommend it, where goodwill and mutual trust exist.
4. This method will usually be selected when it is necessary for the work to start before sufficient data have been obtained for accurate tendering, or where the work involves difficulties which cannot be foreseen or assessed. In this case co-operation and careful supervision are necessary to ensure the customer's satisfaction.

REQUIREMENTS FOR AN ESTIMATOR

A good estimator should be familiar with the practical issues involved in the erection of the work he is valuing. He must thus

@Seismicisolation

have a very wide experience of all classes of erection work. This grounding will enable him to understand, and so make due allowance for, the difficulties that may confront the erectors on site. Various methods of erection and an erection programme have to be visualized before estimating can begin.

GENERAL CONSIDERATIONS

The type of building is very important. Ton for ton, the cost of erection of light roof framing will prove much greater than that of a building of small area, constructed only of beams and stanchions. In the former case, all except the smaller trusses have to be assembled on the site which usually costs much more than the work of erection of the trusses. Also, since it covers a larger ground area, the erection of a trussed shed will involve more movements of the tackle, particularly if the erection is by derrick pole. A building of the same weight, composed mainly of beams and stanchions, will be erected in less time because there are fewer, but heavier, lifts.

As with all outside construction work, the weather has a large influence on the final costs of steel erection. This is especially evident in the case of small contracts of approximately two to three months' duration. If the estimate assumes average weather conditions, it will be found that, all other factors being equal, the work will be overspent or underspent, depending on whether it is carried out in the winter or the summer respectively. When it is known beforehand that a contract will be carried out during a certain period of the year, allowance can be made in the estimate for the anticipated weather. It is not safe to generalize about the British climate, but the estimator should assume that the costs of work in winter may be higher than that of similar work undertaken during the summer months. He should, therefore, make due allowance for this in his price build-up. In the summer months long hours can be worked and conditions are more amenable, promoting a definite quickening in the progress of erection. The opposite tendency applies in winter, as no man can be expected to give of his best when working in the open in a biting wind.

Particular attention should be paid to the height and weight of the heaviest lift that will be encountered during the construction of the building. The weight of the heaviest lift and the total weight of steelwork to be erected will be a guide to the selection of the appropriate lifting appliance, unless it so happens that these heavy lifts are few in number. In this case it will doubtlessly prove more economical to cater separately for the heavy lifts, and to erect the remainder of the structure with lighter tackle which will be quicker

in operation and more manœuvrable. Similar considerations will influence the selection of equipment to reach any sections of the structure that may project well above the general level.

The erection programme may have been decided by the client or his consultant. In this case the estimator is left with no alternative but to arrange for the erection sequence to follow this programme. If the choice of programme is left to the discretion of the contractor, then the estimator will have to select that tackle which he thinks will be available when the work has to commence. At the same time, he must not forget that he may not be the only contractor on the site and that the builder will often require one section completed ahead of the remainder to enable other building work to proceed at the earliest opportunity. If the estimator is in any doubt about selecting an acceptable programme and is unable to obtain confirmation, he should choose alternative programmes and make check estimates, finally comparing the results with his main estimate before completing the tender. It is of great assistance to the estimator to be provided with a clear and concise indication of his prospective client's wishes regarding the erection programme so that he can plan the erection to suit. With such indications from the client all firms will tender on the same basis and the prices tendered can be compared more easily.

Bearing in mind the remarks in the previous paragraph, the estimator should now be able to foresee the number of crane and other tackle movements and make due allowance for their cost. In some cases, the erection of a scotch derrick crane at the beginning of the contract and its dismantling at the end may be the only tackle movements. In another instance, on a building of about the same size and total weight, the site conditions or the requirements of the erection programme may be such that the same crane will have to be erected and dismantled several times. All this additional work adds to the final cost and accounts for the increased rate per ton on apparently similar buildings. It is difficult to generalize on the subject of the cost of erecting and dismantling tackle. Experienced men will complete the work in the minimum of time, but erectors unaccustomed to the handling of cranes and crane machinery may take longer. Again, site conditions and access to the area in which the tackle has to be erected will influence the cost to a large extent. The estimator must be guided by his experience and must rely upon his judgment of the site conditions likely to arise.

In important and intricate work it is always advisable to visit the site, as the estimator will then be better able to appreciate the conditions which are likely to hold during the erection of the structure. Access should be checked. Heavier plant may be transported

@Seismicisolation

to the site in larger assemblies than had originally been anticipated, thus saving time and money at the site. If the client's representative can be contacted during this site visit, agreement can possibly be reached on a definite erection programme if this has not already been laid down.

SUMMARY OF FACTORS AFFECTING THE COST OF ERECTION

Certain factors have to be considered when estimating the cost of erection on a cost per ton basis. These factors have been discussed generally in the preceding paragraphs and are summarized below.

1. The type of structure. Structures may be classed into the following types which are set out in an ascending order of cost.
   (a) Platform steelwork in plain material which is repetitive.
   (b) Heavy steelwork with repetition of units.
   (c) Other heavy steelwork, where no special tackle arrangements are necessary during erection.
   (d) Special items of a particular size and/or weight which require special arrangements for each operation.
   (e) Light framed structures of small total weight.
   (f) Light sections of varied types with scattered distribution—these can generally be reckoned to be the most costly.
2. The height of the structure—increased height usually means increased costs.
3. Remoteness of site. This usually means increased cost because of the difficulty of obtaining labour, the increased travelling and lodging expenses, and the increased cost of supervision.
4. A congested site means increased cost—whether the site is in a restricted area of a city or in a works.
5. A simple method of erection and the employment of simple tackle will usually tend to lower the cost of erection.

BUILD-UP OF AN ESTIMATE

In the first instance the estimator wil nave been provided with drawings of the proposed buildings, details of the total weight of steelwork involved, and an indication of the size of the sections as they will be delivered to the site. On completion of the tender, this information will doubtlessly have to be returned to the inquirer. It is suggested that a form such as shown in Fig. 15.01 be used as a record of the tender. As all the information is set down on one

sheet of paper, it can be filed readily with a copy of the tender itself to make a complete permanent record. Even if the firm is not successful in obtaining the contract, this information will serve as a useful guide for estimating for similar work in the future.

DETAILS OF ESTIMATE

ESTIMATE NO: _____
DATE: _____

ENQUIRY
RECEIVED FROM _____
DATE _____
DRAWINGS _____
SECTION OF WORK _____
TYPE OF STRUCTURE _____
UNUSUAL FEATURES _____
POSSIBLE COMMENCEMENT DATE _____
HIGHEST LIFT _____
SIZE AND WEIGHT OF LARGEST PIECE _____
TOTAL TONNAGES _____
SUGGESTED PLANT _____
ELECTRICAL POWER AVAILABLE ON SITE _____
WATER SUPPLIES _____
ACCESS TO SITE _____
SITE RIVETS (NO AND SIZES) _____
SITE BOLTING (DETAILS OF SPECIAL BOLTS) _____
SITE WELDING _____
TOTAL PRICE QUOTED _____
RATE PER TON _____

Fig. 15.01: Details of estimate

CHARGES TO BE CONSIDERED

Three types of charges, plus profits, have to be considered in the build-up of an estimate. These charges are:

Site Labour Charges
Charges Direct to the Contract
Indirect Costs

@Seismicisolation

(*a*) *Site labour charges*

This heading will cover the cost of all work carried out at the site by the erection squad. It will include the costs of the site supervisory staff, such as senior foremen, timekeepers and clerks. Sometimes the cost of the supervisory staff at site is allocated to the indirect costs, but in all cases where it can be seen that the cost of a man can be booked directly as a site labour charge, it is advisable to do so.

(*b*) *Charges direct to the contract*

These charges cover the cost per hour of all plant with the exception of small hand-tools, and also take care of the cost of transporting the plant and gear to and from the site of the contract. The cost per hour, inclusive of operator if necessary, of all plant owned by the firm will be set out in a schedule. By consulting this schedule the estimator can forecast the total cost of the plant for the duration of the contract. This hourly rate for the plant is evolved by considering the purchase cost of the plant, the interest on the capital outlay, depreciation, maintenance and repair costs, and the number of hours worked per year. The hourly cost calculated on this basis will be rechecked at the end of each year's working, and the rates adjusted as necessary.

It may happen that, due to unforeseen conditions, plant has to be hired to work a particular contract. As the firm hiring the plant requires to make a profit, it is certain that the rates charged will be above those allocated by the firm for similar plant of its own. In these cases the author recommends that excess hire charges are placed against the indirect charges for the whole of the erection work, so that they may be spread over all and thus not weigh heavily against the one contract.

(*c*) *Indirect costs*

Under this heading will come all the costs necessary for the successful running of the firm which cannot be charged directly to any individual contract. Indirect costs will cover Head Office costs, supervision costs, general expenses on the site, such as postages and telephones, insurances, car allowances for members of the staff, and excess plant hire charges as suggested in the previous paragraph. These charges will be calculated from the costs of the services in previous years or from a budget made out to cover the anticipated work for the year under consideration.

ESTIMATING WITHOUT REFERENCE TO PREVIOUS WORK

If costs of previous work are not available, the cost of the site labour can be estimated by the following method: a suitable

squad to carry out the work under consideration is selected, and the cost per hour or day of this squad decided. All the operations to be undertaken by this squad are then listed and the time each operation should take is set out. If the time for each of these operations has been correctly judged, the expected cost of the completed job will be obtained. With a certain amount of care this method is very accurate, and splitting the work into small operations makes it a lot easier to estimate accurately.

ESTIMATING FOR BRIDGE ERECTION

There are certain peculiarities regarding bridge work which must be given careful consideration. Work on certain sections of the bridge may be governed by the tides or it may be that traffic will have to be maintained during the day and the erection work carried out at night or week-ends only. Such conditions will raise the cost of the site labour considerably and must be thoroughly investigated before the erection price is finalized.

If the proposed bridge crosses or runs close to a public highway, the contractor is under an obligation to the general public to provide adequate safeguards against the risk of accidents. When the work involves replacement of an existing bridge structure, these safety precautions will be fairly comprehensive. The bridge site may have to be securely fenced off and day and night warning devices provided. Watchmen may also have to be supplied for the period when the erection squads are not on the site. Frequently, a temporary passageway for vehicles and pedestrians has to be provided.

An estimate for the erection of a bridge can be further split into the erection of the false-work, erection of the bridge structure proper, riveting or welding, and possibly the final painting of the completed bridge structure.

The false-work erection often involves a large proportion of the total erection costs and it therefore justifies careful examination in the estimating stage. The amount of false-work used will depend upon the erection method adopted. Further information on this will be found in Chapter 9. The only reliable guide for calculating the cost involved in the erection of this false-work is extensive practical experience and reference to the cost of similar work undertaken in the past.

Calculation of the bridge erection costs should follow a similar procedure to that laid down for steel-framed buildings. Riveting and weldings costs can often be deduced from costs of previous similar site work. Riveters and welders will require scaffolding before they can proceed with their work, and the cost of the erection

@Seismicisolation

and dismantling of this should not be forgotten. Painting of the completed structure may be sublet to specialists in this type of work and, if so, need not concern the estimator.

COSTING

Accurate day-to-day costing of erection contracts is necessary for three reasons:

1. As a check on the financial state of the work.
2. To show where money is being lost or made. This allows the estimator to adjust his figures for future work.
3. To enable remedies to be effected in good time if a contract is running at a loss.

Where there has been no system of cost keeping, its introduction will sometimes be viewed with suspicion by the foremen concerned. However, once they appreciate that the purpose of cost keeping is to check whether the assumptions made in the estimate were correct and to provide a suitable basis for future estimating work, they will readily give their co-operation.

It should be kept in mind that, whatever system of costing is adopted, the preliminary work has to be done by the site staff, as they alone know how much time is spent on each operation. Thus it is their responsibility to indicate the division of time. These cost and time figures from the site must be obtained with the minimum of effort, otherwise further cost is going to be created or inaccurate figures obtained. To this end the system put in operation must be as clear and simple as possible so that it can attain its object with the very minimum of work on the part of the site supervisory staff.

SITE LABOUR COSTS

In view of the comparatively short duration of most erection contracts it is essential that the costs of the work to date are examined week by week. If this procedure is not adopted, it may be found that a contract which is running at a loss has progressed too far for any remedies to be effective.

The amount of work completed each week must be accurately known so that a comparison with the estimate can be made. This tonnage figure should be given as " steel erected and completed for handing over " and " steel erected but not bolted or finally positioned ". The weight of steel involved should not be guessed but should be compiled from the Advice Notes and/or the Delivery Schedules. The amount of work done at site is not, of course, allocated to steel erection only but is split among the items, such

as tackle erection, steel erection proper, riveting, etc., which were estimated separately when the tender was built up.

The form illustrated in Fig. 15.02 enables this division to be speedily made. The form can be in duplicate and, from the copy sent into the Head Office, a cost sheet is compiled showing progressive amounts under each item. An up-to-date picture of the labour costs on site is thus given. This only needs comparison with the tonnage figures and the original estimate to show whether a profit or loss is being made.

BUILDING ERECTION

The total cost arrived at under this heading should be a reasonable representation of the erection costs for the steel frame of the building, excluding such items as tackle erection, men's travelling costs, etc. In itself this cost will be of great interest to the erection supervisor and estimator, both as a means of checking the expenditure on the work and as an aid to future estimating work.

Specific structures such as bridges, steel chimneys, tanks, and water towers should be kept entirely separate as, unless the firm specializes in this type of work, the erection of these structures is unlikely to be undertaken often enough to enable standard erection costs to be obtained.

In this method of cost keeping the cost of tackle erection has been separated from that of the erection of the structure itself.

- SITE COST ALLOCATION SHEET -

CONTRACT ..... WEEK ENDING .....
AT ..... CONTRACT NO .....

LABOUR

NAME	TRADE	Su	M	Tu	W	Th	F	Sa	TOTAL WAGES	T/T	T	E	R	B	W	P
TOTALS FOR WEEK																

WORK COMPLETED DURING WEEK.
TONS ERECTED .....
RIVETS DRIVEN .....
WELDING .....
BOLTS .....
% PLUMBED .....
% TACKLE ERECTED .....

NOTES: THE WORK ON WHICH EACH MAN IS ENGAGED EACH DAY IS INDICATED BY INSERTING THE APPROPRIATE SIGN THUS
TRAVELLING TIME T/T PIVETTING R
TACKLE ERECTION T BOLTING B
ERECTION E WELDING W
PLUMBING P

PLANT

MACHINE	OPERATION	Su	M	Tu	W	Th	F	Sa	TOTAL HRS. WORKED	TIME LOST DUE TO WEATHER	TIME LOST DUE TO BREAKDOWNS	FUEL USED	SUNDRY REPAIRS	REMARKS

Fig. 15.02: Site cost allocation sheet

@Seismicisolation

When this method is adopted, variations in the total weights of the structures will not affect the cost of erection per ton of any one class of structure. Therefore no sub-division need be made in each of the classifications as regards the comparative size of building under consideration.

SITE PREPARATION

Much time will be spent at the beginning of the work on certain

- SITE LABOUR COST SHEET -

CONTRACT AT — CONTRACT NO SHEET NO — OPERATION

WEEK ENDING	WEEKLY LABOUR COST	PROGRESSIVE TOTAL COST	WORK COMPLETED DURING WEEK	WORK COMPLETED TO DATE	VALUE AS TENDERED	PROFIT	LOSS

Fig. 15.03: Site labour cost sheet for Head Office use

large contracts in erecting site offices, stores, and other temporary buildings. As this is not actual erection work, the time should not be included with the erection costs. This site preparation work

will be negligible on small contracts, and separate costs will therefore not be necessary. On the larger works a well-planned office and main store is always advisable to enable work to be carried out efficiently. The estimate for a large contract will therefore include a sum of money for this purpose, deduced from the cost of similar work in the past.

ERECTION OF TACKLE

Costs of the erection and dismantling of tackle, particularly scotch derricks, will vary depending upon the skill of the erectors employed and upon site conditions. It is possible, however, to deduce a basic charge in man-hours for this work. This charge could be raised or lowered to suit conditions appertaining to the building under consideration. A further classification of this cost would indicate whether the tackle in question was erected with lifting appliances already to hand, or whether the whole operation was effected manually. For instance, the cost of erecting a 5-ton scotch derrick crane in a shipyard, where other cranes are available for help in lifting the sections, would not be a true basis for calculating the cost of erection of a similar crane on a " greenfield " site. In the latter case another and smaller crane or derrick pole would possibly have to be set up by hand before the erection of the chosen crane could commence. This could quite conceivably double the cost of erection.

ERECTION OF FALSE-WORK

False-work and trestling is seldom employed extensively in the erection of ordinary steel-framed buildings. It will rarely be necessary to separate the costs therefore, and, in fact, this would be extremely difficult. For bridge erection, however, it is vitally important to know the accurate costs of such work and a full segregation is essential. It will be seen from Fig. 15.02 that no space has been provided for listing the time spent on this work, but in cases where extensive false-work is employed a separate wages sheet could be specially prepared to cover time so spent.

EXTRA WORK

This term is understood to mean additional work which has been called for by the client since the original quotation for the main structure. It is often advisable for the contractor to quote such extras when they do occur on a lump sum basis, i.e., as with the main contract. This keeps the office work at a minimum.

Sometimes, however, this additional work has to be undertaken at short notice and without complete details being available. In

@Seismicisolation

such cases one of two methods of calculating the costs can be used. Either the client may be charged with the total cost of the site labour used on the job plus a percentage charge to cover the overheads and profit, or he may be charged the number of hours worked by the various classes of labour at a rate per hour agreed previously. When this method is employed there may be a further charge for the use of such plant as welding gear, burning gear, or cranes.

The full costs of all additional work must always be kept separate from the main bulk of the work or it will not be possible for a check to be made to find out whether the charges are sufficient to recover the money expended. If this is not the case, the agreed rates and charges should be adjusted until satisfactory.

PLANT COSTS

The plant charges will be assessed from the time sheet which will be compiled in respect of each item of plant. On this sheet will be shown day by day:

Working Time
Idling Time
Operator's Maintenance Time
Fuel Consumption
Repairs and Replacements made at the site

The cost of the plant will come under two headings at the office. One will be a weekly total of plant hours which will be allocated to the contract at the agreed rate for the plant. The second will be the plant cost sheet from which the actual cost of the plant per year will be deduced eventually. Dividing this figure by the average number of hours worked per year will give a check on the rate per hour charged. The cost per year of the plant will take into consideration the total cost of repairs, the annual depreciation, the cost of insurances, and possibly the interest on the capital outlay.

CHAPTER 16

THE PLANNING AND CONTROL OF ERECTION WORK

PROGRESS of erection work on the site always reflects the attention that has been given to it by the Erection Supervisor and his staff at the Head Office. It is ludicrous merely to send a squad of men and a load of tackle to a site and expect the work to proceed smoothly. Erection work is too involved to be controlled from the site alone. Deliveries of steel must arrive as necessary to fit in with the erection programme, the correct tackle must be made available and erected sufficiently in advance to dovetail into the erection scheme, and lastly, men must be found—riveters, welders, and crane drivers as well as erectors.

To assist him in the successful co-ordination of all branches of work under his control, the Erection Supervisor should continually have a clear picture in his mind of contracts that are to start as well as of those already in progress. Few contracts will run as scheduled; weather conditions, steel deliveries, and unforeseeable obstacles on the site have a habit of interfering with the best of plans. No matter what difficulties present themselves, the Supervisor must strive to produce the finished building at the appointed time. This will entail the continual adjustment of the overall erection programme as additional men and/or plant are moved to the contract in an effort to complete the work at the scheduled time.

Considered in the light of the above, each contract may appear to be only a minute section of the whole plan. This view must never be taken, however, because in reality the individual contract is equally as important as the whole scheme. The Erection Supervisor may be well pleased if he knows that, taken as a whole, his erection work is proceeding satisfactorily, but the client whose work is behind schedule is hardly likely to be content if informed that his is the only building to be delayed. He will not be in the least interested that other contracts are ahead of their target dates by some weeks. The only building that concerns him is, of course, his own. Therefore, when considering erection work, the maxim should always be that each contract makes the plan and not the plan each contract.

Problems affecting progress on a particular site are identical with those that have to be overcome generally. The site engineer and foreman between them will be responsible for maintaining the anticipated progress on the site and they should be given all facilities

@Seismicisolation

possible by the Head Office staff. The efforts of the site engineer and foreman on a large contract can make or mar the progress. The general erection programme on the site may have been laid down by the client when the job was sent out for tender or, if this was not done, the Erection Supervisor will have arranged this during his preliminary site discussions with the client's representatives. When the decisions on programme and tackle have been made and the contract work commenced, the site staff assume the responsibility for progress. They are intimately concerned and they will have a minute-by-minute picture of the site work and the progress of other contractors. If they have paid careful attention to their work, they should be able to foresee any difficulties almost before they arise and take the necessary steps to overcome them without delay.

CONTROLLING A NUMBER OF CONTRACTS

Every contract, no matter how small or insignificant it may seem, should be given full consideration when the overall picture of erection operations is being studied. A small contract falling behind programme may have to be given assistance by the transfer of labour, and possibly tackle, from another site which may well interrupt the flow of work there. This trouble can be, and usually is, avoided by careful planning and a strict check on the work as it proceeds. Interruption to work on another contract should not be countenanced if there are other alternatives.

One secret of successful progressing of erection work is to make constant site visits. The position of the work is seen more vividly at first hand than from the mere reading of reports. This constant assessing of the situation is always helpful and has a beneficial effect on the site staff for they appreciate that their work is being constantly inspected and progress noted. This instinctively moves them to give more attention to their work with consequent advantages to the final results. If a contract is not visited over a period of weeks, the impression quickly forms in the minds of the site supervisory staff that their superiors are no longer interested in the contract with the result that their own interest slackens and progress inevitably falls behind schedule. Even if the site visit by the Erection Supervisor has no visible gain, it does at least prevent the spread of this despondency.

Erection work can never be scheduled or progress results forecast with the same accuracy as in factory production. At times unforesecable events make it imperative that additional tackle be sent to a particular site If this tackle or a practicable substitute is not available from stock, it must be obtained elsewhere. This

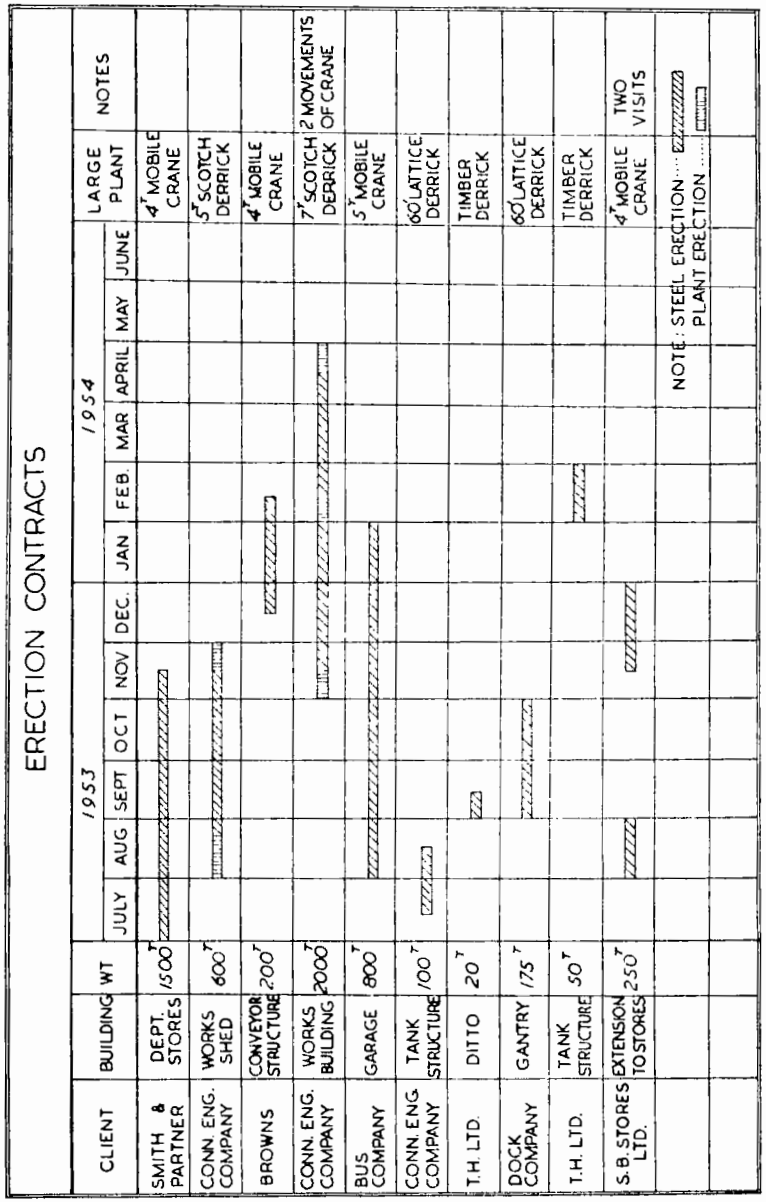


Fig. 16.01: Chart illustrating anticipated progress on a number of erection contracts

@Seismicisolation

often presents the Erection Supervisor with a difficult problem which he must solve with the least possible delay. Can he use alternative tackle for the job in question and, if not, can he use tackle from another contract, or possibly use tackle which has been allocated to some future work and substitute other tackle in its place? All these alternatives may prove impossible or not acceptable, and the only solution left is to employ hired tackle. Whatever the problems that arise, the completion of all contracts within the stipulated time should be the aim which the Erection Supervisor has continually before him.

A suitably prepared chart offers an excellent method of visibly and forcibly presenting the necessary information on present and future work. Such a chart should indicate at a glance the size of each contract, time allocated for both tackle and steel erection, plant required, movements of tackle from site to site, and senior foremen in charge. Fig. 16.01 illustrates such a chart covering an entire erection programme for one year and clearly showing all the essential information. The programme will, of course, have to be amended as the year progresses but revisions can easily be made. As the work proceeds at each site, it will be noted on the chart.

CONTROL OF INDIVIDUAL CONTRACTS

The initial planning and subsequent control of a medium-sized erection contract will now be dealt with in detail. Efficient planning of every contract is absolutely essential if the work is to be completed expeditiously and at the minimum cost. The method of planning and controlling described in the following pages can easily be adapted to suit the requirements of any individual contract or firm.

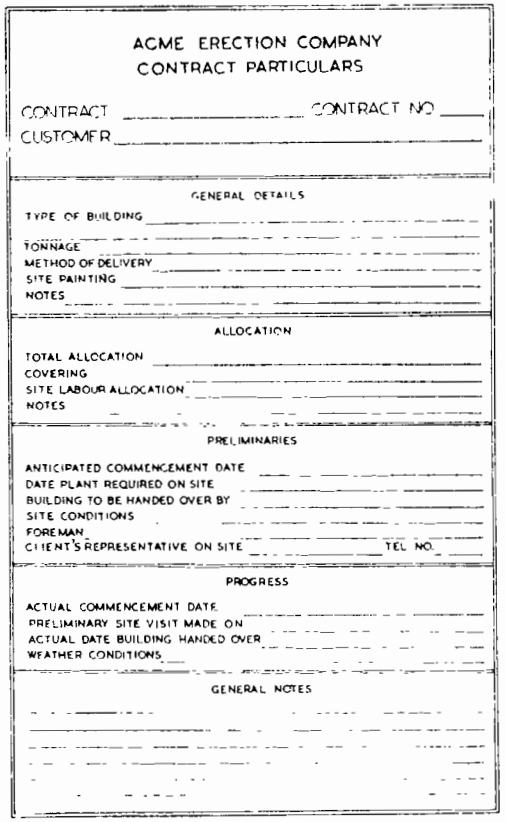
When the work of other contractors has to be dovetailed into the programme for the steelwork erection, the responsibility for the planning of the contract as a whole should rest upon the Resident Engineer, or should be shared between him and the main contractor. Planning in this manner should result in a schedule agreeable to all concerned. It should also ensure that each individual contractor works smoothly with the others. Overall planning of this nature does not in any way relieve the erection contractor of the necessity for planning his own section of the work so that, even when a master plan has been settled, the erection of steelwork should still be carefully scheduled, progressed and controlled, so that it will maintain its proper place in the overall programme.

COMPARISON WITH ESTIMATE

When the Erection Supervisor is informed that his company has secured a particular contract he should first assemble all the

available data and drawings for the work. All information appertaining to each contract should be kept in one file for easy future reference. A digest of the most important information can be made on a form similar to that shown in Fig. 16.02, and this often saves reference to the main file when information and facts are required at short notice.

If the estimate has been prepared as suggested in Chapter 15, a perusal of the estimate make-up sheet will yield valuable information


ACME ERECTION COMPANY
CONTRACT PARTICULARS

CONTRACT _____ CONTRACT NO. _____
CUSTOMER _____

GENERAL DETAILS
TYPE OF BUILDING _____
TONNAGE _____
METHOD OF DELIVERY _____
SITE PAINTING _____
NOTES _____

ALLOCATION
TOTAL ALLOCATION _____
COVERING _____
SITE LABOUR ALLOCATION _____
NOTES _____

PRELIMINARIES
ANTICIPATED COMMENCEMENT DATE _____
DATE PLANT REQUIRED ON SITE _____
BUILDING TO BE HANDED OVER BY _____
SITE CONDITIONS _____
FOREMAN _____
CLIENT'S REPRESENTATIVE ON SITE _____ TEL. NO. _____

PROGRESS
ACTUAL COMMENCEMENT DATE _____
PRELIMINARY SITE VISIT MADE ON _____
ACTUAL DATE BUILDING HANDED OVER _____
WEATHER CONDITIONS _____

GENERAL NOTES

Fig. 16.02: Digest of information from the estimate

for the preliminary planning. Comparison with the form of the original estimate readily shows whether the work in its present form agrees with that estimated originally. Since the estimate was drafted, a number of the conditions affecting the erection programme may have changed; the design of the building may have been

@Seismicisolation

amended, site conditions may not be as anticipated, or the tackle it was proposed to use may have been detained on another contract. There can be no doubt that before a final decision is made, a representative of the erection firm must visit the site to assess all matters relating to the structure erection.

INFORMATION FROM DRAWING OFFICE

To enable the erection engineer to consider his erection plans further, he will require the following information from the Drawing Office:

- Arrangement drawings
- Details of any site riveting and welding
- Notes of any special connections
- Details of the weights and dimensions of the main sections as fabricated
- Heights of lift
- Note of any lifting lugs provided

PRELIMINARY CONSIDERATIONS

If the client has a representative on the site, either a Resident Engineer or Clerk of Works, this representative should be contacted. It may happen that another contractor is the erector's client and in this case it will be necessary to contact his representative.

This preliminary meeting may well be the first personal contact between the client or his representative and the erection contractor. It falls upon the contractor's representative to create a favourable impression which will be helpful to the smooth running of the contract and to his company. This first meeting is likely to be an important one on all counts, and therefore should never be treated lightly.

The whole development of the contract will be discussed at this meeting and there are many points which will occupy the attention of the erection engineer. Under a carefully drawn-up contract many of the conditions under which the work is to be done will already have been agreed. These conditions must be verified, and the engineer must make certain that the other parties to the agreement appreciate their side of the bargain. If no such conditions exist in the contract, then the representative of the erection firm must say what he requires and make sure that, whatever is agreed, he will be ready for the start of the erection.

If a general programme for the work has to be threshed out at this stage, it is always advisable that a meeting of all interested contractors be arranged to discuss this. Most subcontractors are

specialists in some trade and have the common fault of being somewhat reluctant to see the point of view of the other workers on the site. The erection contractor is no exception to this. A full meeting held in this manner enables all revelant matters to be discussed and any alternative proposals will have a fair hearing.

The engineer should draft a detailed report immediately after the meeting. No time should be lost in doing this, and if the engineer is not returning to his office after the meeting, then he should mail his report so that it may be typed for his return. Any important decisions reached at the meeting should always be confirmed by letter to those concerned so that there is no possibility of any misunderstanding. When the proceedings of the meeting affect any of the other departments of the firm, a copy of the report should be circulated to the departmental heads. The foreman who is to have charge of the contract will require a copy of this report. At the same time, it should be arranged that he receives a copy of all future correspondence regarding site arrangements.

In the midst of these consultations the Erection Supervisor will also be concerned with a number of purely domestic, but no less important, matters. Accommodation for the workmen may have to be found at the site and, in the case of isolated sites, transport to and from the site may be required as well. The men must be paid weekly, and suitable arrangements for this must be made before they are sent to the job. If the wage bill is expected to be large, the local bank could be asked to help to relieve the foreman of the responsibility of handling large sums of ready cash. Transport of tackle to the site has also to be considered at this stage and, if large shipments of either tackle or structural steelwork are to be made by rail, the facilities of the local station should be checked to see that the traffic can be handled. Other arrangements will have to be made if the local station cannot cope.

When electrically driven cranes are to be used on the site, arrangements will have to be made with the electricity supply authority concerned. The majority of these authorities bring their cables only to an agreed point on the site and leave the customer responsible for the remainder of the wiring. Unless the erection firm employ their own electrician, someone will have to be found to handle this work. If there is an electrical contractor on the site, he may be only too pleased to help and he will possibly only charge a reasonable sum for the work as he will already have tools on the site.

Erection plant should be used to its full capacity and should never be retained unnecessarily in the Tackle Yard but should as far as possible be in use on one of the sites. Subject to any necessary

@Seismicisolation

maintenance, it will not be recovering the initial capital outlay unless it is moved to another site and recommences work there as soon as it has completed work on the first. An excessively long period of inclement weather can throw the best of schedules out of gear and may cause plant to be retained on a contract longer than anticipated.

The availability of plant can quite well have a large effect on the erection methods chosen. There is always a number of different erection methods for any given site conditions, but no work should ever be carried out, or even considered, with insufficient tackle. When all the correct tackle is not available at the required time, then the balance must be procured by some means. The alternatives are usually to have it specially made or to obtain it from one of the numerous hiring firms. Making or buying tackle for a particular contract may prove a justifiable expense, but it is quite likely that plant bought for one contract can easily be adapted for use on another at a later date. If plant will be on hand for a while after the contract it was bought for initially is completed, then there is always the possibility to hire it out in its turn.

No matter how small the structure under consideration, all feasible methods for its erection should be examined and any suggestions by others should be studied carefully. It is never advisable to rush a decision on erection procedure. Time saved in reaching a decision can easily cause weeks of extra work for the erection squads if the wrong decision is reached.

CLIENT AND ERECTION PROGRAMME

The client will exert his influence either directly or, more usually, through his representative who may be the architect or consulting engineer. As the client bears heavy expenditure during the period of construction and will have no return until the building is in commission, he will require the structure to be completed as soon as possible. He may therefore arrange for one section of the building to be completed in advance of the remainder, and have this section put into production while work still proceeds on the remainder. Alternatively, if the contract is the rebuilding of an existing factory, then the work may have to be done in stages. In this case, the old building is kept in production as long as possible, and the machines and fitments are transferred according to a strict schedule to maintain the output at a certain level. There have been cases where complete new frameworks have been assembled around an existing building and have been covered before the dismantling of the old buildings commenced.

ERECTION CONTRACTOR'S PROBLEMS

To enable the erection contractor to arrange his programme and to plan his work well in advance, the client should state his requirements as early as possible. If the erection contractor is brought into the discussions at an early stage, he may possibly suggest from his past experience some improvements to the scheme.

When an erection scheme has been agreed, any amendments should be avoided if at all possible. Alterations disrupt the smooth flow of work and can cause extra expense to both parties. Amendments which alter the amount or order of the work may mean that the erection contractor has to bring additional plant and labour to the site which, in turn, may affect other contracts.

Finally, should the engineer foresee any quick erection methods which will save his client money, then he should not hesitate to point these out. One highly satisfied client is worth a dozen dissatisfied ones. When the client knows of an efficient and straightforward contractor, he is not afraid to recommend him to his business associates.

SUBDIVISION OF WORK

With the arrangement drawings and client's requirements in front of him, the Erection Supervisor can divide the work into sections and arrive at an overall length of time for each section and also for the complete job. If the client has not stipulated a definite programme, then the erector has an advantage in that he can arrange a programme to suit the plant and labour he has available. He is thus in a position to carry out the work more efficiently. The division of the work into sections, or deliveries as they are sometimes called, will be made after giving due consideration to the capacity and reach of the cranes to be used. In the case of a shed building, each delivery will usually contain a complete bay of the building; but in multi-storey building construction, with a crane mounted on the structure, each delivery will include the steelwork of one or more floors throughout the area of the building covered by the crane.

To enable the steelwork members in each delivery to be consigned to site in the correct sequence for handling by the erection cranes, a Delivery Schedule, of which a typical example is shown in Fig. 16.03, should be prepared. This form, which will be used both by the despatchers and the staff at site, lists all individual pieces in the required order of delivery, gives a brief description of them, and also contains a section which, when completed on the site, gives a permanent and detailed record of all delivery information. The approximate weight given is of great value to the

@Seismicisolation

ACME ERECTION COMPANY

DELIVERY SCHEDULE

CONTRACT *NEW GARAGE* CONTRACT NO. *1189*

CUSTOMER *BUS COMPANY*

MARK	ITEM	SIZE	APPROX. WT	DRG	DESPATCH DATE	RECEIVED DATE	RECEIVED AD. NO.
S9	STAN	8 x 6 x 20'-0"	8 CWTS	86	10.8.53	15.8.53	62
S10	DO	DO.	DO	86		16.8.53	64
S11	DO	8 x 8 x 20'-0"	11 CWTS	87		15.8.53	62
S12	DO.	DO	DO.	87		DO.	62
EG13	LATTICE GIRDER	30'-0" x 5'-0" x 8"	15 CWTS	41A	DITTO	12.8.53	59
EG14	DO	DO.	DO.	DO.		DO.	59
EG15	DO.	32'-6" x 5'-3" x 8"	DO.	DO.		DO.	59
EG16	DO	DO.	DO.	DO.			
8/SG1	ANGLES	15'-0"	8 CWTS	53	12.8.53	17.8.53	66
8/SG4	DO.	DO.	DO.	DO		DO.	66
14/FP	FISH PLATES	1'-0" x 3" x 1/4"	1 CWT.	DO		DO	66
SB1	BRACING	16'-0"	1½ CWT	59		16.8.53	64
SB2	DO.	DO	DO.	DO.		DO.	64
SB3	DO.	DO.	DO.	DO.	DITTO	DO.	64
SB4	DO.	DO.	DO.	DO.		DO.	64
4/T4	TRUSSES	30' 0' x 9'-0" x 14"	15 CWTS	32		15.8.53	62
2/T3	DO.	DO.	12 CWTS	DO.		16.8.53	63
					SCHEDULE NUMBER	3	

Fig. 16.03: Typical Delivery Schedule

foreman erector when he selects his tackle for lifting, and the details of size enable the piece to be quickly traced and identified if the painted mark becomes obliterated. All separate pieces of steelwork, irrespective of size, must be listed on this Delivery Schedule.

PROGRAMME CHART

The Erection Supervisor is now at the stage where he can make a detailed programme chart for the complete contract. Charts are preferable to other methods of illustrating times, as they show the set progress visibly and clearly. The procedure to adopt to compile this chart is as follows:

1. Decide on the work entailed by the erection of each individual delivery and reduce this work to small operations. Here the work can be subdivided into off-loading, ground assembly, riveting, erection of main pieces, filling-in work, and the final lining and levelling. When compiling this chart, the time likely to be occupied by bolting-up should not be forgotten as it often amounts to a greater period of time than that taken by the erection. When bolting-up operations are extensive, as for instance on bunker work, they should be shown separately on the programme chart which will reduce the possibility of error. Time must also be allocated to cover crane erections and movements.

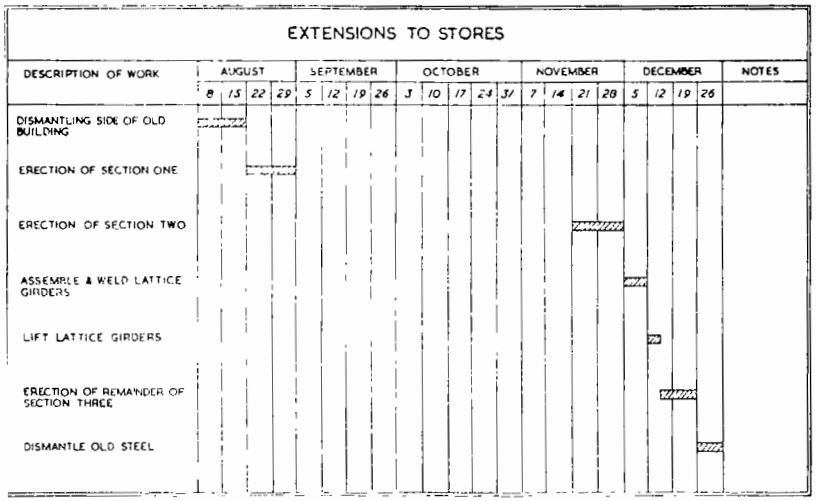


Fig. 16.04: Erection progress chart for a single contract

@Seismicisolation

2. A rough draft of the complete programme is made next.
3. The client's requirements for the completion of all or part of the work will now be fitted into the programme, and from these data suitable starting dates are deduced.
4. The whole chart is now re-drafted in its final form. A typical example is shown in Fig. 16.04. Copies of this chart are made for office and site use.

CONSULTATION WITH FOREMAN

It is desirable that the foreman who is to have control of the site work is brought into these preliminary discussions. If this can be arranged, definite advantages accrue to each side. The foreman will travel to the site with a fairly comprehensive knowledge of the contract. It will also often be found that he can offer suggestions which prove beneficial to the conduct of the work and which can be incorporated easily during the planning stage but may prove difficult or even impossible to work later.

INFORMATION FOR DRAWING OFFICE

At this stage the Drawing Office will require details of the erection plans so that they can prepare the Delivery Schedules and Charts. This information is wanted now so that the construction shops can be aware of the sequence in which to fabricate the material. A set of the arrangement drawings is marked-up to indicate the order in which the various sections of the building are required. For any major work, a Programme Chart illustrating the erection times is also prepared. Sometimes certain pieces are required on site in advance of the other material in that particular section so that they can be site-jointed ready for erection at the correct time. Special note must be made of these items.

FORMATION OF SITE CONTROL

The cabins and workshops forming the administrative unit on the site should be despatched well ahead of the target date for the commencement of steel erection operations. This will give the site supervisory staff sufficient time to erect them with the nucleus of erectors who will go to the site in the first place. A well-planned administrative centre on the site of a large contract pays dividends during the latter stages of the work.

During this period the foreman or site engineer can collect together all the steelwork drawings and delivery schedules, bolt lists, rivet lists, and similar data, and arrange and index them so that they are readily available when required later. The indexing

of the steelwork drawings on the site is most important, and it is absolutely essential that the method of recording progress will give all the necessary information in the minimum of time without creating too much work for the site administration.

CHECKING DELIVERIES OF STEELWORK

At this stage of the contract, and indeed throughout the whole of the work, a strict check should be kept on the steelwork deliveries. All material received at site should be checked against the appropriate Advice Notes and discrepancies given immediate attention. Early each morning the charge-hand off-loader should present a list of steelwork received and off-loaded the previous day. This list should contain the following information:

(a) Date
(b) Wagon or lorry number
(c) Mark of each item together with a brief description
(d) Position off-loaded.

This information will enable the Advice Notes to be checked rapidly and the Delivery Schedules to be brought up to date. Inspection of the Delivery Schedules will then show which materials and items, if any, are overdue, and steps can be taken immediately to ascertain the reason and expedite the delivery. Thus from the Schedule shown in Fig. 16.03 it can be readily seen that Eaves Girder E.G.16 has not yet been delivered and is therefore overdue. Unless steps are taken to have this girder delivered at once, erection will be held up with subsequent delays to the programme, as well as additional costs if there is no alternative work for the erection squad.

A useful check on the deliveries can be made with the aid of an additional set of arrangement drawings. As each individual member is marked off the Delivery Schedule, it can also be underlined on these drawings. A coloured pencil is ideal for this work. The same set of arrangement drawings, marked in a different colour, can be used to show erection progress. Regular comparison of these two sets of colour shows the amount of steel delivered in advance of the erection work and quickly brings to light any errors should they have occurred.

PROGRESS OF ERECTION

The initial delivery of steelwork will have been made before the date specified for the commencement, and the erection work should be in a position to begin. The main concern of both the Head Office and site staffs will be to maintain the scheduled progress. The Erection Supervisor should visit the site periodically to check that satisfactory progress has been made but, notwithstanding these

@Seismicisolation

ACME ERECTION COMPANY

WEEKLY ERECTION REPORT

CONTRACT _____ CONTRACT NO _____

CUSTOMER _____

LOSS OF TIME DUE TO	MEN	HOURS	MAN HOURS	SITE LABOUR
(a) ERRORS				
(b) NON DELIVERY OF STEEL				
(c) ADDITIONAL WORK				
(d) INCLEMENT WEATHER				LARGE PLANT ON SITE
(e) OTHER CAUSES				
TOTAL				THIS WEEK / TO DATE
				STEEL DELIVERED
GIVE FULL DETAILS BELOW				STEEL ERECTED

GENERAL REPORT FOR WEEK

SIGNED _____

Fig. 16.05: Weekly Report Form

visits, a Weekly Report should be mailed to the Head Office. This report should contain the following information:

(a) Name of contract and the number
(b) Tonnage of steel delivered to site during the week
(c) Tonnage of steel erected during the week
(d) Total tonnage delivered to date
(e) Total tonnage erected to date
(f) Details of large plant on site
(g) Man-hours lost during the week due to inclement weather, errors in fabrication, etc.
(h) A detailed report of the progress of erection during the week.

Fig. 16.05 illustrates a suitable form which could be used to record weekly progress. The use of this, together with the Cost Allocation Sheet described in Chapter 15, should suffice for the Head Office to ascertain progress and costs. If urgent matters

should arise during the week, these should be dealt with immediately by letter, telephone, or telegram.

For important erection work, when it is absolutely essential that the erection progress be followed carefully, the main arrangement drawings for the work could be reproduced as photostat copies. These drawings would be sent to the site each week and returned at the end of the week, marked to indicate the progress to date together with the Weekly Report. After the arrangement drawings at Head Office had been marked to correspond, the photostat copies would be returned to the site so that they could be used to record the progress of the following week.

@Seismicisolation

CHAPTER 17

THE BUILDING REGULATIONS

THE safeness of any particular operation can be largely a matter of opinion, and opinions can vary. To give some standard of safety for building work, Parliament has passed regulations which establish safety standards as well as conditions of employment for the workmen. It is the duty of every employer to see that these requirements are fulfilled.

The Building (Safety, Health and Welfare) Regulations, 1948, govern the following classes of work:

(a) Construction, alteration or maintenance of a building
(b) Demolition of a building
(c) Foundation work for a new building.

Most steel erection operations are covered by the regulations although certain classes of structures, such as gasholders and bridges, are not considered to be buildings. The various regulations are fully set out in Statutory Instrument 1948 No. 1145, and a copy of this, together with the publications "Guide to the Building (Safety, Health and Welfare) Regulations, 1948—Form 105" and "The Supervisor's Guide to the Building Regulations", issued by the Royal Society for the Prevention of Accidents, should be in the hands of all employers, engineers, foremen, and other responsible persons. Copies can be obtained through any bookseller and the price is only a few pence each.

The Building (Safety, Health and Welfare) Regulations empower H.M. Inspector of Factories to visit and inspect building sites to satisfy himself on the conditions there. So that he is able to do this, he must be informed of the commencement of any work; a special form is set aside for this purpose. Inspections and tests will have to be carried out throughout the contract, and records kept of the results. At the end of this chapter will be found a list of all the necessary registers and forms, together with a description of their uses.

Readers must bear in mind that this chapter does not cover all the requirements of the Act, but gives merely an idea of the extent of the regulations and how they apply to steel erection work in particular. No attempt has been made to refer the reader to any individual regulation, as it is hoped that after reading this chapter a copy of the actual regulations will be obtained and will be carefully studied in detail.

No unusual stipulations will be found in the Act. Yet, however carefully the employer may provide suitable tackle and facilities for the safety of his men, the responsibility for seeing that full use is made of these will fall upon the employer's site representatives and the men themselves. All need careful instruction and warning in these matters.

On a large contract the engineer or foreman may have so much work and responsibility in other directions that he is unable to give full attention to the refinements of these regulations. In this case another person should be nominated "Safety Officer" for the contract and should make regular inspections to ascertain that everything is satisfactory. When more than 50 persons are employed on the site at any one time the appointment of a Safety Officer is compulsory. The Safety Officer's other duties must be such that they do not interfere with this work.

SCAFFOLDING

Great attention should be paid to the strength of all scaffolding and gangways. The erection of scaffolding should be carried out by skilled labour under the supervision of a competent man. Scaffolders must be provided with sufficient materials to enable the scaffold to be erected without skimping. Naturally, they should not be permitted to use materials that are in any way faulty. If timber is used for scaffolding, the bark should be stripped off so that any faulty parts can be seen easily. The minimum of paint should be used on timber poles and battens for the same reason.

Scaffolding will have to be inspected and certified as safe before use by a competent person. Inspections must also be made at intervals of not more than seven days while the scaffolding is up. The results of these inspections should be inserted in the appropriate register and signed by the person making the inspection. Any necessary action should be taken at once. When a scaffold is dismantled or altered substantially, the work should be carried out only by the same class of labour as was used to erect it originally. Warning notices will have to be displayed in prominent places when a scaffold is partially dismantled. Care must be taken to see that no person can use the scaffold without due warning of the alterations.

Often it will be found that access is constantly required to certain parts of the structure. In this case gangways and suitable staircases or ladders must be provided. Handrailing is necessary on the stairs and gangways, and toeboards must be fixed to the latter. Minimum sizes and heights for this handrailing are stipulated in the regulations. If a ladder is to be used as a means of access to a scaffold or gangway, an adequate handhold should be provided to enable persons

@Seismicisolation

using the ladder to leave or gain the platform in safety. One method of ensuring this is to use a ladder of sufficient length for it to project above the platform—the regulations specify that the minimum projection should not be less than 42 in. When possible, the permanent stairs and platforms of the structure should be erected along with the main steel skeleton. Special provisions for access may not be necessary in that case.

Temporary platforms erected solely for the purpose of bolting-up, riveting or welding, need not be constructed to the same standards as those mentioned above, provided that it is known that these platforms will only be required for a short period of time. In these cases no handrailing or toeboards will have to be fixed provided that adequate handhold is available and that the platform is not less than 34 in. wide. A receptacle for small tools must also be supplied.

Ladders should be stayed or tied so as to prevent undue sway during use or when a high wind is blowing. If the ladder, or run of ladders, rises more than 30 ft vertically, provision will have to be made for intermediate landing places. These must not be more than 30 ft apart vertically and, depending upon the actual circumstances, it may be necessary to provide railing and toeboards at such locations.

It may occasionally be convenient to use a scaffold that has already been erected by another contractor on the site. Even when the permission of this other contractor has been obtained, it is still necessary to examine the scaffold carefully as any accidents will be the responsibility of the employers of the person or persons involved, and not necessarily that of the scaffold owners. This point should, therefore, be noted carefully.

CRANES

Current building regulations require that any derrick crane manufactured after 30 September 1931 shall conform to the specification laid down in B.S. 327: Part 1: 1951 (Power-driven derrick cranes) and B.S. 327: Part 2: 1954 (Derrick cranes, hand-operated). Cranes with any structural parts made of timber are very much out of date, and their use is banned by the regulations. When a crane conforms to the latest edition of this B.S. specification, there need be no worry as to its strength and safety provided it is used for the work specified. Copies of B.S. 327: Parts 1 and 2 should be obtained for reference, as they contain much useful information.

The stability of most scotch derrick cranes used on construction work depends upon removable ballast. Before attempting to use the crane, the person in charge should be satisfied that the legs have

been loaded with the appropriate weight of ballast and that this is stacked securely. It seems elementary to state that care must be taken to load the leg in such a manner that the ballast can function as intended and restrain the leg from rising. The Building Regulations require that the amount of ballast necessary to load each leg be clearly indicated by a notice fastened to the leg. This notice should be fastened at such a height that it will still be visible when the full weight of ballast has been stacked.

Unless the crane is fitted with a separate motor for derricking (which is very unusual), it is stipulated that a special interlocking device be used between the derricking clutch and derricking pawl. This interlocking device must be so constructed that it prevents the pawl from being released accidentally before the clutch is fully engaged. All the levers, handles and controls on the crane must be clearly labelled with their functions, and locking devices should be fitted where possible so that accidental misuse is prevented.

Every power-driven crane has to be provided with a suitable cabin to protect the driver from the weather but this cabin must not in any way restrict his vision. If the driver does not have an unrestricted view of the load and the area around it, he must be provided with one or more banksmen who will signal him the movements required for the operation of the crane. Verbal signals are very seldom any use on construction sites, and before operations are commenced, driver and banksmen should therefore agree on a definite set of signals. No person under the age of 18 years is permitted to drive a crane or to give any signals for its operation.

Another requirement of the regulations is that two types of safe working load indicator should be fitted to the crane. Both of these should be clearly visible to the driver, and one must show the safe working load at the radius at which the crane is working at that time. This indicator will usually be gravity-operated. The other indicator must be automatic and should give audible and visible warning when the load being carried at any given radius approaches the safe working load for that radius. Simple and efficient indicators are on the market which fulfil these conditions. An automatic indicator is not necessary on the following:

(a) Guy derrick cranes
(b) A hand crane which is being used solely to erect or dismantle another crane
(c) Any crane with a safe working load of 1 ton or less.

After the crane has been erected and before use, it must be tested and proved capable of handling a load 25 per cent in excess of that which it will be expected to lift. This test and its result have to be entered in the appropriate register and signed by the person

@Seismicisolation

making the test. A weekly inspection has to be carried out during use and a report on the condition of the crane made and signed. The driver may perform this task. A thorough examination of the crane must be made every 14 months, and also before the crane is put into use after any substantial alteration and repair. The safe working loads for the various radii at which the crane may be worked should be entered on the report. A further and more thorough examination is to be made every four years.

WINCHES

As in the case of derrick cranes, timber is not permitted in the construction of erection winches. All winches should be tested at least once every 14 months and after every substantial alteration or repair; a more thorough examination has to be made every four years. Each winch should be clearly marked with the applicable safe working load and, naturally, no load greater than this should be lifted.

CHAINS, ROPES, AND OTHER LIFTING GEAR

Hooks, rings and shackles, as well as chain and wire slings, are covered by the term "lifting gear". These items form a very important part of erection tackle, and sound materials must be used for their construction. All of them must be tested before use and the manufacturer will supply particulars of these tests on purchase of the gear. The regulations do not require that fibre rope, fibre rope slings, or wire ropes in use before the commencement of the regulations be tested. All tackle should be given an identification mark after testing, and the safe working load must be clearly shown. Ropes or rope slings need not be marked with the safe working load provided that this information is inserted in the register alongside the identification mark.

Faulty wire rope is not to be used for raising, lowering, or suspending any load whatsoever. The regulations class as faulty any rope in which, in a length of ten diameters, the number of broken wires visible exceeds one-twentieth of the total number of wires in the rope. Never use knotted chains or wires as this practice, even when it does not cause a fracture immediately, throws a severe strain on the material and trouble is bound to occur later.

An examination must be carried out every six months by a competent person, and all wrought iron items have to be annealed or given other approved heat treatment every 14 months. If the diameter of the bar of the chain or shackle is $\frac{1}{2}$ in. or less, this annealing must be carried out at intervals of not more than six months. Tackle not in regular use may be annealed when required.

Unless due care is taken when a load is lifted by brother chains, the safe working load in the individual legs may be exceeded because the angle between the legs is too great. The load in each leg increases very rapidly as the angle between them is increased. The extent to which the safe working load in brother slings diminishes can be seen clearly from Tables 5.04 and 5.05 in Chapter 5, where the permissible loads for different angles are given.

WELFARE OF EMPLOYEES

At one time steel erectors and building workers generally were expected to work and take their meals on the site under rough conditions. The Building Regulations make certain stipulations which will make the work far pleasanter for the men. Accommodation must be provided on the site for the men to take shelter when the weather is bad. This should include racks on which the men can hang their clothes to dry. The shelter should also provide facilities for boiling water for hot beverages, and a place for the men to wash their hands. Drinking water must also be supplied.

FIRST AID FACILITIES

It is unlikely that more than 100 men will be employed at any one time on a normal steel erection contract, but if this does happen, fairly elaborate precautions must be taken to attend to any injuries that may be sustained. Unless a hospital or proper first aid station is within reasonable reach, an ambulance and stretchers must be made readily available. A first aid box, clearly marked as such, must be kept in an accessible place if more than ten persons are likely to be employed at any one time. If the number of men on the site exceeds 25, a person who is capable of giving treatment should be placed in charge of this box.

When work is handled on a bridge, jetty, or riverside building, or any site where there is a danger of workmen falling into the water and possibly drowning, efficient rescue equipment will have to be provided. This should include a boat, or boats, and lifebuoys. These must be kept in an accessible place so as to be ready for instant use.

WELDING AND GAS-CUTTING

There is no danger attached to either electric welding or gas-cutting operations, provided sensible precautions are taken when the equipment is used. Electricity has certain peculiarities which must be recognized. The most important of these is that the electric current will always take the shortest and easiest route back to its source. In normal welding operations the work will be grounded

@Seismicisolation

and, unless proper protection is afforded, no welding should be done in snow or rain. Under these weather conditions the current may travel back through the operator and cause shock.

The rays emitted during the welding process are harmful to the eyes. Helmets, handshields, and goggles equipped with suitable filter lenses must therefore be provided. The site supervisor should make sure that this protective equipment is always used. People working near welders will also have to be protected from the rays, which can be dangerous at an appreciable distance from their source.

When welding is done on a steel structure, the earth is usually connected to the structure for the return circuit. Before operations are commenced, this return path should be examined to ascertain that there will be no danger of fire. The risk of fire should always be borne in mind when the oxy-acetylene cutting torch is used. If this tool is employed on a high structure, the users should not forget that the sparks and pieces of molten metal will travel a considerable distance before they cool sufficiently not to be dangerous.

DISPLAY OF REGULATIONS

Certain forms and notices have to be kept or displayed on the site. These are listed below:

Factories Acts Form 36—General Register
Factories Acts Form 3—Abstract of the Acts for display on the site notice board
Factories Acts Form 92—Register of Persons Employed in Painting Buildings
Factories Acts Form 91—(Part I)—Prescribed Register for reports on :
- Inspection of Scaffolding
- Weekly Inspection of Lifting Appliances
- Weekly Examinations of Excavations and Earthworks
- Anchorage Tests for Derrick Cranes
- Tests and Examinations of Passenger Hoists

Workmen's Compensation Act, 1925—Accident Book
Lead Paint Regulations, 1927—Form 996 (for display)

It is also recommended that the following are kept at the site for study by the engineers and foremen:

The Construction (General Provisions) Regulations, 1961, No. 1580
The Construction (Lifting Operations) Regulations, 1961, No. 1581
The Building (Safety, Health and Welfare) Regulations ,1948, No. 1145
Accidents—How They Happen and How to Prevent Them
The Supervisor's Guide to the Building Regulations—from the Royal Society for the Prevention of Accidents, Terminal House, 52 Grosvenor Gardens, London, S.W.1.
Accident Prevention—published at intervals by The Iron Trades Employers' Insurance Association Ltd., Iron Trades Mutual Insurance Co. Ltd., Iron Trades House, 21-24 Grosvenor Place, London, S.W.1.

BIBLIOGRAPHY

Factories Acts, 1937 and 1948
Part II Section 22—Hoists and Lifts
Section 23—Chains, Ropes and Lifting Tackle
Section 24—Cranes and Other Lifting Machinery
Section 29—Steam Boilers
Section 31—Air Receivers
Part VIII Section 107—Building Operations
Section 108—Works and Engineering Construction
British Standards for Lifting Tackle—B.S. Handbook No. 4 which covers Fibre and Wire Ropes, Terminal Attachments for Wire Ropes, Chains and Terminal Attachments
B.S. 482: 1950 Wrought Iron and Mild Steel Hooks
B.S. 825: 1949 Mild Steel Shackles
B.S. 327: Part 1: 1951 Derrick Cranes (Power-driven)
B.S. 327: Part 2: 1954 Derrick Cranes (Hand-operated)
B.S. 638: 1954 Arc Welding Plant and Equipment
B.S. 499: 1952 Glossary of Terms relating to the Welding and Cutting of Metals
B.S. 449: 1948 The Use of Structural Steel in Building
B.S. 499: Section 7: 1952 Scheme of Symbols for Welding
B.S. 1757: 1951 Power-driven Mobile Cranes
B.S. 357: 1930 Travelling Jib Cranes (Contractor's Type)
BEAMA Guide to British Electrodes—The British Electrical and Allied Manufacturers' Association (Inc.), London.

@Seismicisolation

INDEX

Access to site 88, 91, 96, 97, 107, 115
  to tackle stores 4
Adjustment for parallax 185, 190
Adjustments to level 185–86
  to theodolite 190
Advice-note for tackle 8–9
A-frames 20, 119
Air, compressed 40
  compressors 144–46
  consumption of winches 28
  hose and connections 149–50
Allowances in levelling steelwork 195
  in setting of steelwork 195
Alternating current 156
Anchorage, deadman 72–73
Anchorages. *See also* Staking
  guys and winches 71–73, 81
  scotch derrick cranes 74, 99
  testing 71, 234–36
Annealing 69, 236
Arch bridges 130–34
Arch roofed buildings, erection of 112–13
Area representatives 3
Asbestos sheeting 202–03
Availability of electrical power on site 39, 222

Ballasting of scotch derrick cranes 75–77, 99, 100, 234
  of winches 27
Bar, pinch 49
Beams, clamps for 48
Bench mark 177
  temporary 177, 183–85
Bend, double sheet 58
  fisherman's 58
'Birdcage' packing 128
Blackwall hitch 58
Blocks 28–34
  chain 37
  efficiency of 32–34
  length of rope for sets of 32
  reeving 31
  rope 29
Blocks *continued*
  snatch 30
  wire rope 30
Bolting 136–41
  advantages over riveting 136
  checking procedure 141
  correct procedure for 141
  for scaffolding 234
  high strength 137–40
  lining connections for 137
  site difficulties 137
  'turn of nut' method 141
  use of hand torque spanner 140
  use of impact wrench 41, 140
  use of torque multiplying spanner 140
  washer dimensions and tension and torque values 139
Bolts, black 136
  high strength 137–40
  high strength friction grip 136
  high strength, testing 141
  hook 199, 200
  seam 200
  turned 136
  turned and fitted 137
Book, field 190
  level 181–82
Booking levels, collimation system of 181–82, 183–85
Bowline 56
Bridge girders, cantilevering 120–22
Bridges, arch 130–34
  cantilever 134–35
  erection of 115–35
  plate girder 117
  suspension 128–30
  truss girder 117–18
British Standard Specifications 239
Brother slings 66
Building erection, cost of 213
  Regulations 7, 55, 232–38
Buildings, erection of 87–114
Bulldog grips 44
'Bullring' 16

Cable, welding 156
Camber 103, 118

@Seismicisolation

Cantilever bridges 134–35
Cantilevering bridge girders 120–22
Cast iron, cutting of 172
C-clamps 48
Chain blocks 37
  slings 69
Change point 184
Charges, direct to contract 210
  indirect 210
  site labour 210
  to be considered when estimating 209–10
Chemical testing of welds 163
Clamps, C-type 48
  for beams 48
Cleaning nozzles in oxy-acetylene cutting 174
  welding tools 156
Clove hitch 59
Collimation level 183
  line of 185
  system of booking levels 181–82, 183–85
Comparison with estimate 220–22
Compressed air 40
  see also Air
Compressors 144–46
Construction of wire ropes 50–52
Control of erection work 217–31
  site 228–29
Corrosion of wire ropes 53
Corrugations 197–98
Cost of building erection 213
  of erection of falsework 215
  of extra work 215–16
  of plant 216
  of site preparation 214–15
  of tackle erection 215
Costing 212–16
Costs, site labour 212
Cranes, goliath 21, 119
  guy derrick 15, 91–97, 235
    erection of 80–81, 94–95
  hand-operated scotch derrick 13–15, 234
  headroom and reach 14
  inspection of 53–54, 234–36
  interlocking devices on gearing 13, 235
  locomotive, outriggers on 21, 22
  mobile, description of 22–23
    erection by 89–100, 102–04
    outriggers on 23
Cranes *continued*
  power-driven scotch derrick 11–13, 97–100, 234
  rail-mounted 24
  safe working load indicator 235
  scotch derrick 25
    ballasting of 75–77, 99, 100, 234
    erection by 97–100
    erection of 73–79
  sizes and capacities of scotch derrick 11, 13–14
  testing 53–54, 71, 234–36
  tower 24–25
  wire ropes for use on 50–56
'Creep' 192
Creeper frame 131
Crosshead 17
Current, alternating 156
  direct 156
  for welding 156–57
Cutting of cast iron 172
  of wire ropes 56, 172
  oxy-acetylene 166–75

Datum, levelling 177
Deadman anchorage 72–73
Derrick poles 16
  steel 17–18, 70–71
  timber 16–17, 70–71
Derricks, erection of steel 70–71
  erection of timber 70–71
Destructive methods of inspecting welds 162–63
Direct charges 210
Direct current 156
Dogs, timber 46
Dolly bars 147
Double sheet bend 58
Drawing office 1
  information from 222
  information from, for sheeters 203
  information required by 228
  notes for 113–14
Drift pins 143
Drifts 43
Drilling equipment 38–41
Drills, square shank 38
Drums, minimum sizes 52

Efficiency of blocks 32–34
Electrical power, availability on site 39, 223

Electricity, precautions in welding 164, 237–38
Electrode holders 155–56
Employee's welfare 237
Engineer, site 4, 217
Equipment, drilling 38–41
  levelling 195
  oxy-acetylene cutting 167, 175
  riveting 142–51
  surveying 195
Erection, by scotch derrick crane 97–100
  checking progress 229–31
  cost of tackle 215
  gear, loads on structure from 104, 116
  of arch roof buildings 112–13
  of bridges 115–35
    estimating for 211–12
  of buildings 87–114
  of falsework 81–83, 215
  of guy derrick crane 80–81, 93–95
  of office buildings 88–100
  of portal framed buildings 107–10
  of scotch derrick crane 73–79
  of shed-type buildings 100–14
  of sheeting 200–02
  of steel and timber derricks 70–71
  of truss-span building 104–07
  of water tank towers 110
  progress, checking 229–31
  work, planning and control of 217–31
    supervision of 3–4, 217–31
Estimate, comparison with 220–22
Estimating 205–12
  department 2
Examination of tackle 233–37
  of welds 159–63
Extra work, cost of 215–16
Eye splice 62

Factories Acts 7, 232–38
Falsework, erection of 81–83, 215
Fasteners, sheeting 198–200
  timber 46
Faulty welds, removal of 163–64
  wire ropes, definition of 236
Field book 190
Figure of eight knot 58
First Aid facilities 237
Fisherman's bend 58
Flame-cleaning 174
Footblock for guy derrick crane 80
  for lattice steel derrick 19
Foreman 217, 228
  junior 4
  senior 3
Frame, creeper 131
Frames, A- 20, 119
  space 111–12

Galvanized steel sheeting 197–202
Gearing, interlocking devices on crane 13, 235
Girders, 'launching' of 119–21
Glazing, patent 196
Goliath crane 21, 119
Grinding machines 41–42
Grips, bulldog 44
'Growth' of steelwork 192
Gutters 196–97
Guy derrick cranes 15, 91–97, 235
  erection of 80–81, 94–95
  footblock 80
  'jumping' 94–95
Guys, anchorages for 71–73, 81

Hammers 43
  riveting 147
Hand-operated scotch derrick crane 13–15, 234
Hand winches 26
Headroom and reach of cranes 14
Heating fires for rivets 149
Hiring of plant 10, 210, 224
Hitch, blackwall 58
  clove 59
  rolling 59
  stopper 59
Holders, electrode 155–56
Holders-on 147–48
Hook-bolts 199, 200
Hose, air, and connections 149–50
Hydraulic jacks 36

Impact wrenches 41, 140
Indicator, safe working load 235
Indirect charges 210
Information from drawing office 222
  required by drawing office 228
  required by sheeters from drawing office 203

@Seismicisolation

Inspection of cranes 53–54, 234–36
of welds by chemical testing 163
by destructive methods 162–63
by magnetic particle 160–61
by mechanical testing 162–63
by metallographic testing 163
by non-destructive methods 159–60
by penetrating oil 161
by radiography 161–62
by supersonic methods 162
of winches 236
Interlocking devices on crane gearing 13, 235
Intermediate levels 185

Jacking 126–28
Jacks 34–36
hydraulic 36
ratchet 35
screw 35
ship 36
toe 35, 36, 127
trip 35
use of 36, 126–28
Jam riveter 148
Joists, safe loads on rolled steel 79, 82
'Jumping' a guy derrick crane 94–95
Junior foreman 4

'Kicker' 18, 19
Knots 56–61

Labour charges, site 210
Labour costs, site 212
Ladders 233, 234
Lang's lay 52
Lattice steel derrick, footblock 19
'Launching' of girders 119–21
'Lay' of ropes 51–52
Legs, sheer 19–20, 111
Level, adjustments to 185–86
book 181–82
collimation 183
description of 178–79
use of 182–85
Levelling 177–86
datum 177
equipment 195
of steelwork 105, 109
staff 179–81
steelwork, allowances 195
Levels, intermediate 185
Lifting of trusses 106–07
Line of collimation 185
Lines, offset 191
Lining-in steelwork 191–93
Loads on structure from erection gear 104, 116
safe, on rolled steel joists 79, 82
wind 82, 116
Locomotive cranes 21
outriggers on 22
Long splice 62–65

Machines, grinding 41–42
Magnetic particle inspection of welds 160–61
Measure, tape 193–94
Measuring of wire ropes 52
Mechanical testing of welds 162–63
Metal arc welding 153–54
Metallographic testing of welds 163
Mobile cranes, description of 22–23
erection by 89–100, 102–04
outriggers on 23
use of restrictor ring 23

Non-destructive methods of inspecting welds 159–60
Nozzles, cleaning in oxy-acetylene cutting 174
Nut runners 41

Office 1
Office buildings, erection of 88–100
Off-loading of steelwork 91, 97, 105, 229
Offset lines 191
Order department 2
Ordering spares 10
Outriggers on locomotive cranes 22
on mobile cranes 23
Oxy-acetylene cutting 166–75
cleaning of nozzles 174
equipment 167, 175
of cast iron 172
of stainless steel 173–74
of wire ropes 172
operation 169–70
theory of 168
uses of 166

Packing, 'birdcage' 128
Packings, timber 128
Parallax, adjustment for 185, 190
Patent glazing 196
Penetrating oil, use in testing welds 161
Piling, use of 118
Pinch bar 49
Pipes, rainwater 196–97
Pit-prop remover 37
Planning of erection work, 217–31
problems 225
Plant, costs 216
hiring of 10, 210, 224
Plate girder bridges 117
Plumbing of steelwork 192, 195
Pneumatic riveting hammers 147
Point, change 184
Poles, derrick 16
steel derrick 17–18, 70–71
timber derrick 16–17, 70–71
Portal-framed buildings, erection of 107–10
Power-driven scotch derrick cranes 11–13, 97–100, 234
Power for welding, source of 155
Powered winches 27
Preparation for welding 157–59
site, cost of 214–15
Progress, checking erection 229–31
Pulleys, minimum sizes 52

Radiographic methods of testing welds 161–62
Rail-mounted crane 24
Rainwater pipes 196–97
Ratchet jacks 35
Reach and headroom, cranes 14
Records, tackle 7
Reeving of blocks 31
Regulations, Building 7, 55, 232, 238
Removal of faulty welds 163–64
Remover, pit-prop 37
Report, weekly 230
Restrictor ring, use on mobile cranes 23
Rivet heads, shape of 143
signs for 144
Rivet heating 143
fires 149
Rivet snaps 148
Riveter, jam 148
squeeze 148
Riveter, jam *continued*
yoke 148
Riveting 116–17, 142–51
advantages of bolting over 136
air hose and connections 149–50
care of equipment 150
compressors for 146
dolly bars 147
drift pins for 143
equipment for 144
hammers 147
hand 142
heating procedure 143
holders-on 147–48
inspection 144
list of gear 151
procedure 143
scaffolding for 142, 234
squad 142
use of service bolts 142
Rolled steel joists, safe loads 79, 82
Rollers 47
Rolling hitch 59
'Rolling-in' 122–25
Rope blocks 29
safe loads 34
Ropes 50–65
knots and splices 56
lay of 51–52
length required for set of blocks 32
minimum sizes of drums and pulleys 52
seizing 65
whipping 55, 56, 60
wire 50–65
care of 52–55
causes of wear 30, 53, 54
construction of 50–52
corrosion of 53
cutting 56, 172
faulty, definition of 236
for cranes 50–56
handling 54
measuring of 52
ordering 56
storage 55
Round turn 58
Runners, nut 41

Safe bearing loads for timber packings and props 129
Safe loads on rolled steel joists 79, 82
on rope blocks 34

@Seismicisolation

Safe working load indicator for cranes 235
Safety during welding operations 164, 174, 237–38
of sheeting operations 203–04
officer 233
Scaffold wires 67
Scaffolding 108, 233–34
erected by other contractors 234
for riveting 142, 234
for welding 234
Scale, vernier 188
Scotch derrick cranes 25
ballasting of 75–77, 99, 100, 234
erection by 97–100
erection of 73–79
hand-operated 13–15, 234
power-driven 11–13, 97–100, 234
sizes and capacities 11, 13–14
Screw jacks 35
Seam bolts 200
Senior foreman 3
Setting allowances for steelwork 195
Shackles 44
Shed-type building, erection of 101–14
Sheer legs 19–20, 111
Sheet bend, double 58
single 58
Sheeting, asbestos 202–03
erection of 200–02
fasteners 198–200
galvanized steel 197–202
operations, safety of 203–04
Ship jacks 36
Short splice 61–62
Single sheet bend 58
Site, access to 88, 91, 96, 97, 107, 115
control 228–29
engineer 4, 217
labour charges 210
labour costs 212
preparation, cost of 214–15
visits 218, 222
Sizes and capacities of scotch derrick cranes 11, 13–14
Slings, brother 66
chain 69
wire rope 65
care of 67
Snatch blocks 30
Space frames 111–12
Spanners 42
hand torque 140
torque multiplying 140
Spares, ordering 10
Splices 61–65
eye 62
long 62–65
short 61–62
Square shank drills 38
Squeeze riveter 148
Staff, levelling 179–81
Stainless steel-cutting by oxy-acetylene process 173–74
Staking 45, 71
Steel derrick poles 17–18, 70–71
Steel derricks, erection of 70–71
Steelwork, checking delivery of 229
'growth' of 192
levelling allowances 195
levelling of 105, 109
lining-in 191–93
off-loading of 91, 97, 105, 229
plumbing of 192, 195
setting allowances 195
transport to site 88, 104, 107, 115, 223
Stopper hitch 59
Storage of wire ropes 55
Stores, tackle 4
Supervision of erection work 3–4, 217–31
Surveying 176–95
equipment 195
Surveyor's level 178
tripod for 179
Suspension bridges 128–30
Sylvester 37

Tackle, advice note 8–9
cost of erection 215
examination of 233–37
lists 83–85
records 7
stores 4
Tape measure 193–94
Temporary bench mark 177, 183–85
Testing of anchorages 71
of cranes 53–54, 71, 234, 236
Theodolite, adjustments to, 186, 190
description of 187–88
uses 186–87

Thimbles 56
Timber derrick poles 16–17, 70–71
derricks, erection of 70–71
dogs 46
fasteners 46
packings 128, 129
Toe jacks 35, 36, 127
Tools, cleaning of welding 156
Tower cranes 24–25
Transport of steelwork to site 88, 104, 107, 115, 223
Trestling. *See* Falsework
Trip jacks 35
Tripod for surveyor's level 179
Truss girder bridges 117–18
Trusses, lifting of 106–07
Truss-span building, erection of 104–07
Turn, round 58

Utrasonic methods of testing welds, 162

Vernier scale 188
Vernier theodolite. *See* Theodolite

Wages department 2
Water tank towers, erection of 110
Wedges 47
Weekly report 230
Welding 152
cable 156
current for 156–57
list of gear 165
metal arc 153–54
precautions 164, 237–38
preparation for 157–59
safety during 164, 174, 237–38
scaffolding for 234
source of power 155
tools, cleaning of 156
Welds, chemical testing of 163
Welds, chemical testing of *continued*
destructive methods of inspecting 162–63
examination of 159–63
inspection by magnetic particles 160–61
by mechanical testing 162–63
by metallographic testing 163
by non-destructive methods 159–60
by penetrating oil 161
by radiography 161–62
by ultrasonic methods 162
removal of faulty 163–64
Welfare of employees 237
Whipping a rope 55, 56, 60
Winches 26–28, 236
air consumption of 28
anchorages for 71–73, 81
ballasting of 27
hand 26
inspection of 236
powered 27
Wind loads 82, 116
Wind pressure 82, 116
Wire rope blocks 30
slings 65, 67
Wire ropes 50–65
care of 52–55
causes of wear 30, 53, 54
construction of 50–52
corrosion of 53
cutting 56, 172
faulty, definition of 236
for cranes 50–56
handling of 54
measuring of 52
ordering 56
storage 55
Wires, scaffold 67
Wrenches, impact 41, 140

Yoke riveter 148

@Seismicisolation