Introduction to Building Construction

Functions and Performance of a Building: User-owner perspective

Enclose Space for the intended function and Transfer load on to the ground

Intended purpose: Protection and safety from weather (sun/Heat, cold, rain, flooding wind)

Transfer load: Both vertical and lateral loads: Self weight, Imposed load, wind, earthquake, water

Ease of maintenance and replacement (initial and life cycle cost); ability to recycle materials & components

Shelter-security, safety and comfort (visual, thermal, acoustical)- ease of use and operation

Desirable: An economical, safe, & timely completion using most appropriate resources available (materials/components/structural systems//skilled workers/equipment

Major stages in a Building project: Process perspective

Location/siting

Conceptualization and planning

Designing and detailing

Construction/execution

Operation and maintenance

Decommissioning and deconstruction.

Each stage - professionals across disciplines work together to achieve objectives

Multi-disciplinary team

Owner/Promoter: Individual/Govt/Local Authority/Private Company

Architect: Architectural Design- / aesthetics/ appearance- Elevation- internal arrangement of spaces- Planning permissions

Structural Engineer: Structural system; Materials/Specification; Analysis, Design,drawing

Geotechnical Engineer

Services Engineer/Specialists: Plumbing, HVAC, vertical transportation, Electrical

Interior and landscape designers

Health, safety, environmental/sustainability specialists

Multi-disciplinary team

Fire protection specialist

Lighting and Acoustics specialists

Security systems, BMS specialists

Estimation/Quantity surveyor: Costing/Budget

Contracts Eng: Methods statement/Tender Doc./Cond. of Contract/agreement

Construction Engineer: Drawing to a Building/Supervision/quality & Safety/Proj.Mgt

Contractor: Mobilizes materials, workforce and equipment and carries out construction

Grouping of Teams

- Design Team
- Construction Engineering & Management team
- Operation and Maintenance Team

Functions of Design team: Planning, design and Development

- Formalization of design brief in consultation with the owner
- Site survey and soil investigation
- Preparation of conceptual designs-highlighting both their positive and negative aspects
- Selection of a concept with the consent of the owner
- Selection of systems & Sizing the system
- Development of design:
  - Integration of architecture, structure and services,
  - Interaction among design team
  - Synthesis of requirements of each discipline
- Preparation of preliminary designs and drawings and obtaining the owners' approval
- Preparation of preliminary cost estimates for approval of owner.

Functions of Design team: Planning, design and Development

- Preparation of work-breakdown structure and programme for pre-construction activities
- Assisting client to obtain approvals of the Authority/authorities.
- Preparation of detailed design of each discipline for various services.
- Detailed specifications & construction working drawings with integration of all disciplines
- Peer review/proof checking of the drawings/designs in case of major/important projects
- Preparation of detailed cost estimate.
- Obtaining final approval of the client.
- Preparation of bill of quantities, specifications and tender documents.

Functions of Construction/Execution Team

- Specify criteria for selection of constructors
- Specify quality control, quality audit system and safety system
- Short-list constructors and organize Pre-bid meetings with the intending constructors
- Receive and evaluate tenders and select constructors
- Execution and supervision (Contract management and techno-legal aspects)
- Monitor for quality, safety, time and cost control through scientific project management
- Prepare/certify the completion (as-built) drawings for the building and services
- Assist in getting statutory approvals at various stages
- Completion, commissioning and trial run of installations/equipment and their operation
- Ensure availability of maintenance and operation manuals for future use.

Functions of Operation, maintenance, de-commissioning and De-construction

- Shall set up a system of periodic maintenance and upkeep of constructed buildings.
- Preparation of operation and maintenance manual
- Draws maintenance schedule/ frequencies and guidelines for maintenance personnel.
- Periodic validation through inspection for safety of structure, electrical and installations
- Ensuring that all fire safety equipment/systems are in proper working condition.
- Accessibility audits: universally accessible and barrier free for persons with disabilities.

Functions of Operation & maintenance, de-commissioning & Deconstructions

- Preparation of predictive/preventive maintenance schedules for all installations in the building and strictly following the same;

- Maintain record of the preventive maintenance

- Condition survey of structures and installations, identification of distress of various elements and initiating plans for rehabilitation/retrofitting well in time.

- Post-disaster investigations by competent engineer/specialist.

Location/Site-Plot/Type of building/Type of construction

Question:

- Owner has a plot – Is he/she having absolute freedom
- Are there any regulations which imposes restrictions/best practices

Offset (Refer to local authority regulations/National Building Code)

Floor Area Ratio (Refer to local authority regulations/National Building Code)

Type of Building

Type of Construction

Zoning of area where plot is located- distinct Fire zones

Classification of Buildings

Type of Construction

Distinct Fire zones

Classification of Buildings

Group	Buildings
A	Residential
B	Educational
C	Institutional
D	Assembly
E	Business
F	Mercantile
G	Industrial
H	Storage
J	Hazardous

Group-A: Residential

With sleeping accommodation	
With and without cooking or dining or both facilities	
Except buildings under Group-C	
A1-	Lodging or room homes
A2-	One- or two-family private dwelling
A3-	Dormitories
A4-	Apartments houses (flats)
A5-	Hotels (up to 4 stars)
A6-	Hotels (5 stars and above)

Group-B: Educational

School, college, day-care purposes involving assembly for instruction, education or recreation

B1- schools up to senior secondary level

B2- All other training Institutions

Which are not covered by Group-D

Group-C: Institutional

- Medical or other treatment
- Care of persons suffering from physical/mental illness/disease
- Care of infants
- Convalescents or aged persons
- Penal/correctional detention (movement restricted-Provided sleeping accommodation)

Subdivisions:

C1 -Hospital and sanitoria

C2- Custodial Institutional

C3- Penal or mental Institutional

Group-D: Assembly

Congregation for amusement, recreation, social, religious, Patriotic,
civil, travel or similar purposes

Ex: Theatres, Assembly halls, Auditorium, Gymnasiums, Exhibition hall, museums, skating rings, restaurants, places of worship, dance halls, passenger station, Air terminal, stadium

<u>Subdivisions</u>:

D1- Theatrical stage and fixed seats >1000 persons
D2 - Theatrical stage and fixed seats<1000 persons
D3- Without stage accommodation>300 persons no fixed seats
D4- Without stage accommodation<300 persons no fixed seats
D5- All others not covered under D1 to D4

Group-E: Business

Other than those covered under Group-F

Used for transaction of business

Ex: City halls, Town halls, Court houses, Libraries fall under this group

Subdivision:

E1- Office, banks, professional establishments like office of Architects, Doctors etc.

E2- Laboratories, Research Establishments, Test houses

E3- Computer installations

E4 – Telephone exchanges

E5 – Broadcasting stations and TV stations

Group-F: Mercantile

Shops, stores, market, for display and sale of merchandise either wholesale or retail

Subdivisions:

F1- Up to 500 sq.m area

F2- More than 500 sq.m area

F3- Underground shopping centres

Group-G: Industrial

Products or materials of all kinds of properties are fabricated, assembled, manufactured or processed

Ex: Assembly plants, laboratories, dry cleaning plants, power plants,
pumping stations, gas plants, refineries, saw-mills.

Subdivisions:

G1- Low hazard industries

G2- Moderate hazard Industries

G3- High Hazard Industries

(Based on relative danger of start and spread of fire, danger or smoke or gas generated the danger of explosion or other occurrence potentially endangering the lives and safety of occupants)

Light Hazard	Moderate Hazard	High Hazard
Abrasive Manufacturing Premises	Aluminium Factories	**SUB-CATEGORY (A)**
Aerated Water Factories	*Atta* and Cereal Grinding	Aircraft Hangers
Agarbatti Manufacturing	Bakeries and Biscuit Factories	Aluminium/Magnesium Powder Plants
Areca Nut Slicing and/or Betel nut Factories	*Beedi* Factories	Bituminised Paper and/or Hessian Cloth/Tar Felt Manufacturing
Analytical and/or Quality Control Laboratories	Bobbin Factories	Cotton Waste Factories
Asbestos Steam Packing and Lagging Manufacturing	Bookbinders, Envelopes and Paper Bag Manufacturing	Celluloid Goods Manufacturing
Battery Charging/Battery Service Stations	Cable Manufacturing	Chemical Manufacturing using raw materials having flash points below 23°C
Battery Manufacturing	Camphor Boiling	Cigarette Filter Manufacturing
Breweries	Candle Works	Cinema Films and T.V. Production Studios
Brick Works	Carbon Paper/Typewriter Ribbon Manufacturing	Coal and/or Coke and/or Charcoal Ball and Briquettes Manufacturing
Canning Factories	Cardboard Box Manufacturing	Collieries
Cardamom Factories	Carpenters, Wood Wool and Furniture Manufacturing	Cotton Seed Cleaning or De-linting Factories.
Cement Factories and/or Asbestos or Concrete Products Manufacturing	Carpet and Durries Factories	Distilleries
	Cashewnut Factories	
	Chemical Manufacturing using raw materials having flash points above 23°C	

Light Hazard	Moderate Hazard	High Hazard
Ceramic Factories and	points above 23°C	Duplicating/Stencil Paper Manufacturing
Crockery and Stoneware Pipe Manufacturing	Cigar and Cigarette Factories	Fire-works Manufacturing.
Clay Works	Coir Factories	Foam Plastics Manufacturing and/or Converting Plants.
Clock and Watch Manufacturing	Coir Carpets, Rugs, Tobacco, Hides and Skin Presses	Godowns and Warehouses (Storing Combustible/Flammable Goods).
Coffee Curing Roasting and Grinding Premises	Cold Storage Premises	Grass, Hay, Fodder and *Bhoosa* (chaff) Pressing Factories
Condensed Milk Factories, Milk Pasteurising Plant and Dairies	Cork Products Manufacturing	Industrial Gas Manufacturing (Other than Inert/Halogenated Hydrocarbon Gases)
Confectionery Manufacturing	Dry Cleaning, Dyeing and Laundries.	Jute Mills and Jute Presses
Electric Generating Houses (Hydro electric)	Electric Substations/Distribution Stations	Linoleum Factories
Electric Lamps (Incandescent and Fluorescent) and TV Picture Tube Manufacturing	Electric Generating Stations (Other than Underground Power houses)	LPG Bottling Plants (Mini)
Electro Plating Works	Enamelware Factories	Man Made Fibres (Acrylic Fibres/yarn Manufacturing)
Engineering Workshops	Filter and Wax Paper Manufacturing	Match Factories
	Flour Mills	

Light Hazard	Moderate Hazard	High Hazard
Fruits and Vegetables Dehydrating and Drying Factories	Garages	Mattress and Pillow Making
Fruit Products and Condiment Factories	Garment Makers	Metal or Tin Printers (where more than 50 Percent of floor area is occupied as Engineering Workshop; this may be taken as ordinary hazard risk)
Glass and Glass Fibre Manufacturing	Ghee Factories (Other than Vegetable)	Oil Mills
Godowns and Warehouses Storing Non-combustible Goods only	Godowns and Warehouses (Other than those Under Light and High Hazard A Categories)	Oil Extraction Plants
Green Houses	Grain and/or Seeds Disintegrating and/or Crushing Factories	Oil Terminals/Depots handling flammable Liquids having flash point of 23° C and Below
Gold Thread/Gilding Factories	Grease Manufacturing	Paints and Varnish Factories
Gum and/or Glue and Gelatine Manufacturing	Hosiery, Lace, Embroidery and Thread Factories	Paper and Cardboard Mills having raw material yards
Ice, Ice Candy and Ice-cream Manufacturing	Incandescent Gas Mantle Manufacturing	Piers, Wharves and Jetties – Handling Extra Hazardous Materials
Ink (Excluding Printing Ink) Factories	Industrial Gas Manufacturing (Inert/Halogenated hydrocarbon gases)	Printing Ink Manufacturing.
Mica Products Manufacturing	Man-made Yarn/Fibre Manufacturing (Other than Acrylic Fibres/Yarn Manufacturing)	Rosin Lamp-Black and Turpentine Factories
Pottery Works	Manure and Fertilizer Works (Blending, Mixing and granulating)	Saw Mills
Poultry Farms	[illegible]	Sponge Iron Steel Plants (Gas Based)
Salt Crushing Factories and Refineries		Surgical Cotton Manufacturing
		Tarpaulin and Canvas Proofing Factories

Light Hazard	Moderate Hazard	High Hazard
Stables	Mineral Oil Blending and Processing	Turpentine and Rosin Distilleries
Sugar Candy Manufacturing	Oil and Leather Cloth Factories	Tyre Retreading and Resoling Factories
Sugar Factories and Refineries	Oil Terminals/Depots Other than those Categorised under High Hazard A	
Tanneries/Leather Goods Manufacturers	Open storage of Flammable Liquids in Drums, Cans, etc	**SUB-CATEGORY (B)**
Umbrella Assembling Factories	Oxygen Plants	Ammonia and Urea Synthesis Plants
Vermicelli Factories	Paper and Cardboard Mills. without Raw Material Yards	CNG Compressing and Bottling Plants
Water Treatment/Filtration Plants and Water Pump Houses	Piers, Wharves, Jetties and Dockyards other than those Categorized Under High Hazard A	Coal Based Methane Plants
Zinc/Copper Factories	Plastic Goods Manufacturing	Explosive Factories
	Plywood/Wood Veneering Factories	NOTE — In case of complexes having separate plants having varying degrees of hazard, authority having jurisdiction shall be consulted to decide on level of protection to be provided.
	Printing Press Premises	

Group-H: Storage

Except those involve highly combustible or explosive products or materials

Ex:

- Warehouses,
- Cold storage, and transit sheds,
- Storehouse,
- Trucks and marine terminals,
- Garage hangers,
- Grain elevators, etc.

Group-J: Hazardous

- Storage, manufacture & handling of highly combustible or explosive material which may I burn with rapidity ii) produce poisonous fumes or explosions toxic chemicals
- Storage under pressure> 0.1 N/mm^2 in quantities exceeding 70m^3 of acetylene, hydrogen, illuminating and natural gases etc.
- Storage and handling of hazardous and highly flammable liquids, rockets propellants etc.
- Storage and handling of highly flammable or hazardous explosive materials other than liquids
- Manufacture of synthetic leather, ammunition, explosives and fire works

Type of Construction

Important factor in making buildings

- resistant to a complete burn-out and
- in preventing the rapid spread of fire smokes or fumes

Fire resistance

Fire resistance of a building or its structural elements expressed in hours against a specified test load which is expressed in K.Cal/m^2 and against a certain intensity of fire IS/ISO 834-1999 fire resistance test of structures

Types: 1, 2, 3, 4

(for buildings above 15m high- noncombustible materials shall be used for construction)

Fire separation (for purpose of preventing spread of fire): Distance (m) from any adjoining buildings or from opposite side of street, or other public space to the buildings

Table 1 Fire Resistance Ratings of Structural and Non-Structural Elements (minutes)
(*Clauses* 3.3.1 *and* 3.3.2)

Sl No.	Structural Element	Fire Resistance Ratings (min) for Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	Exterior walls:				
	a) Fire separation less than 3.7 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	120	90	60	60
	b) Fire separation of 3.7 m or more but less than 9 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	90	60	60	60
	c) Fire separation of 9 m or more:				
	1) Bearing	240	120	120	60
	2) Non-bearing	60	60	60	60
ii)	Fire separation assemblies (like fire check doors)	120	120	120	120
iii)	Fire enclosures of exits	120	120	120	120
iv)	Shafts for services, lift hoistway and refuse chutes	120	120	120	120
v)	Vertical separation between adjacent tenant spaces	60	60	60	60
vi)	Dwelling unit separation:				
	a) Load bearing	120	120	60	60
	b) Non-load bearing	60	60	30	30
vii)	Interior bearing walls, bearing partitions, columns, beams, girders, trusses (other than roof trusses) and framing:				
	a) Supporting more than one floor	240	120	120	120
	b) Supporting one floor only	180	90	60	60
	c) Supporting a roof only	180	90	60	60
viii)	Walls supporting structural members	180	90	60	60
ix)	Floor construction	120	90	60	60
x)	Roof construction:				
	a) 5 m or less in height to lowest member	120	90	60	60
	b) More than 5 m but less than 6.7 m in height to lowest member	60	60	60	60
	c) 6.7 m or more in height to lowest member	0	0	0	0

NOTES

1 The above fire resistance rating shall be required to achieve the respective type of construction unless otherwise specified in the respective clauses for different applications/use.

2 In case of lift bank, the partition wall, if any, need not be of fire rating specified in this table.

Table 2 Masonry Walls: Solid (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish for a Fire Resistance (Hours) of									
		Load Bearing					Non-load Bearing				
		1	1½	2	3	4	1	1½	2	3	4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	Reinforced[1] cement concrete	120 (25)[2]	140 (25)[2]	160 (25)[2]	200 (25)[2]	240 (25)[2]					
ii)	Unreinforced cement concrete	150	175	—	—	—					
iii)	No-fines concrete with :										
	a) 13 mm cement/sand or gypsum/sand	—	—	—	—	—	150	150	150	150	150
	b) 13 mm light weight aggregate gypsum plaster	—	—	—	—	—	150	150	150	150	150
iv)	Bricks of clay:										
	a) Without finish	90	100	100	170	170	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
v)	Bricks of sand lime:										
	a) Without finish	90	100	100	190	190	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
vi)	Blocks of concrete:										
	a) Without finish	90	100	100	—	—	75	90	100	140	150
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	75	75	90	100
	c) With 13 mm cement/sand or gypsum/ sand						75	90	90	100	140
vii)	Blocks of lightweight concrete:										
	a) Without finish	90	100	100	140	150	75	75	75	125	140
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	50	63	75	75	75
	c) With 13 mm cement/sand or gypsum/ sand	—	—	—	—	—	75	75	75	90	100
viii)	Blocks of aerated concrete:										
	a) Without finish	90	100	100	140	180	50	63	63	75	100
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	100	100	150					

[1] Walls containing at least 1 percent of vertical reinforcement.

[2] Minimum thickness of actual cover to reinforcement.

Table 3 Masonry Walls: Hollow (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish for a Fire Resistance (Hours) of										
		Load Bearing					Non-load Bearing					
		1	1½	2	3	4	½	1	1½	2	3	4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	Bricks of clay:											
	a) Without finish	170	170	170	200	200	75	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	100	100	170	170	170	75	75	90	90	90	100
ii)	Blocks of concrete:											
	a) Without finish						90	125	125	140	140	150
	b) With 13 mm cement/sand or gypsum/sand	190	200	200	—	—	90	125	125	140	140	140
	c) With 13 mm lightweight aggregate gypsum plaster						75	90	90	100	125	125
iii)	Blocks of lightweight concrete:											
	a) Without finish	100	100	100	—	—	75	90	90	100	140	150
	b) With 13 mm cement/sand or gypsum/sand	—	—	—	—	—	75	75	75	100	140	140
	c) With 13 mm lightweight aggregate gypsum plaster	—	—	—	—	—	63	63	63	75	90	100

Table 7 Framed External Walls Non-Load Bearing Required to Resist Fire only from Inside the Building (A)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance					
	½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Steel frame with an external cladding of non-combustible sheets (excluding sheet steel), with a steel supporting framework and internal lining of:						
1. Metal lath and plaster, thickness of plaster:						
a) Sanded gypsum plaster (metal lathing grade)	13	13				
b) Lightweight aggregate gypsum plaster	10	13	15	15	15	19
2. Two layer of plasterboard with joints staggered joints in outer layer taped and filled — Total thickness	21	32				
3. Plasterboard of thickness:						
a) With not less than 5 mm gypsum plaster finish	12.7					
b) With not less than 13 mm gypsum plaster finish	9.5					
c) With not less than 10 mm lightweight aggregate gypsum plaster	9.5					
4. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9	9	12	12	12	12
5. One layer of wood/wool slabs without finish		50				
6. One layer of compressed straw building slabs:						
a) Without finish	50					
b) With not less than 5 mm gypsum plaster finish		50				
7. Aerated concrete blocks	50	50	63	63	75	100
8. Bricks of clay:						
a) Without finish	75	75	90	90	100	100
b) With not less than 13 mm lightweight aggregate gypsum plaster			75	75	90	90

Table 8 Framed External Walls Non-Load Bearing Required to Resist Fire only from Inside the Building (B)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection to Provide Sufficient Insulation to Achieve a Modified Fire Resistance of Up to 4 h
(1)	(2)
Steel frame with an external cladding of sheet steel fully lapped, steel bolted and fixed to steel sheeting rails, with timber or steel supporting framework and internal lining of:	
1. Metal lath and plaster, thickness of plaster:	
a) Sanded gypsum plaster (metal lathing grade)	13
b) Lightweight aggregate gypsum plaster	10
2. One layer of plasterboard with joints taped and filled	12.7
3. Plasterboard of thickness with not less than 5 mm gypsum plaster finish	9.5
4. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9
5. One layer of wood/wool slabs	25
6. One layer of compressed straw building slabs	50
7. One layer of chipboard or of plywood	18
8. Aerated concrete blocks	50
9. Bricks of clay	75
10. Any internal decorative lining with a cavity fill independently supported and retained in position of mineral fibre insulating material (excluding glass) at a density of 48 kg/m^3	50

Table 9 Framed Walls Non-Load Bearing Required to Resist Fire only from Inside the Building (C)

(*Clause* 3.3.2)

Nature of Construction and Materials (1)	Minimum Thickness (mm) of Protection for a Fire Resistance of 1½ h (2)
Timber frame with external cladding of weather boarding or external plywood, 9.5 mm with an internal lining of:	
1. Plasterboard not less than 9.5 mm thick, finished with:	
a) Gypsum plaster	13
b) Lightweight aggregate gypsum plaster	10
2. Plasterboard not less than 12.7 mm thick, finished with:	
a) Gypsum plaster	10
b) Lightweight aggregate gypsum plaster	10
3. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9 12

Table 10 Reinforced Concrete Columns

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Fully exposed	Width	150	200	250	300	400	450
		Cover	40	40	40	40	40	40
ii)	50 percent exposed	Width	125	160	200	200	300	350
		Cover	40	40	40	40	40	40
iii)	One face exposed	Thickness	100	120	140	160	200	240
		Cover	40	40	40	40	40	40

Table 4 Framed Construction, Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials/Timber Studs at Centres not Exceeding 600 mm, Faced on Each Side with	Minimum Thickness (mm) of Protection for a Fire Resistance of 1h
(1)	(2)	(3)
i)	Plasterboard layers with joints staggered, joints in outer layer taped and filled — Total thickness for each face	25
ii)	One layer of 12.7 mm plasterboard with a finish of lightweight aggregate gypsum plaster	13
iii)	Metal lath and plaster, thickness of plaster:	
	a) Sanded gypsum plaster (metal lathing grade)	22
	b) Lightweight aggregate gypsum plaster	13

Table 5 Framed Construction, Non-Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Nature of Construction and Materials/Steel or Timber Frame at Centres not Exceeding 600 mm, Facings on Both Sides of	Stud Construction	Minimum Thickness (mm) of Protection for a Fire Resistance			
		½ h	1 h	1½ h	2 h
(1)	(2)	(3)	(4)	(5)	(6)
A) Dry lining with materials fixed direct to studs (without plaster finish)					
1. One layer of plasterboard with taped and filled joints	Timber or steel	12.7			
2. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled — Total thickness for each face	Timber or steel	19	25		
3. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	Timber or steel	9	12		
4. One layer of wood wool slabs	Timber	25			
5. One layer of chipboard or of plywood	Timber or steel	18			
B) Lining with materials fixed direct to suds, with plaster finish:					
Plasterboard of thickness:	Timber or steel				
a) With not less than 5 mm gypsum plaster finish		9.5			
b) With not less than 13 mm gypsum plaster finish			12.7		
C) Wet finish:					
Metal lath and plaster, thickness of plaster:					
a) Sanded gypsum plaster	Timber or steel	13			
b) Lightweight aggregate gypsum plaster	Timber		13	19	25
	Steel		13		

Table 6 Framed External Walls Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 1 h
(1)	(2)	(3)
	Timber studs at centers not exceeding 600 mm with internal linings of :	
i)	Plasterboard layers with joints in outer layer taped and filled, total thickness of plasterboard	25

Table 11 Concrete Beams

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	Width	200	200	200	200	240	280
		Cover	20	20	20	40	60[1)]	70[1)]
ii)	Reinforced concrete (continuous)	Width	200	200	200	200	240	280
		Cover	20	20	20	30	40	50[1)]
iii)	Prestressed concrete (simply supported)	Width	100	120	150	200	240	280
		Cover	25	40	55	70	80	90
iv)	Prestressed concrete (continuous)	Width	80	100	120	150	200	240
		Cover	20	30	40	55	70	80

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 12 Concrete Floors

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	Thickness	75	95	110	125	150	170
		Cover	20	20	25	35	45[1)]	55[1)]
ii)	Reinforced concrete (continuous)	Thickness	75	95	110	125	150	170
		Cover	20	20	20	25	35	45[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 13 Concrete Floors: Ribbed Open Soffit

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	Thickness of floor	75	95	110	125	150	170
		Rib width	125	125	125	125	150	175
		Cover	20	20	35	45	55	65
ii)	Reinforced concrete (continuous)	Thickness	75	95	110	125	150	170
		Width	125	125	125	125	150	175
		Cover	20	20	20	35	45	55

Table 14 Encased Steel Columns, 203 mm × 203 mm
(Protection Applied on Four Sides)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of				
	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)
A) Hollow protection (without an air cavity over the flanges):					
1. [1] Metal lathing with trowelled lightweight aggregate gypsum plaster	13	15	20	32	
2. Plasterboard with 1.6 mm wire binding at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:					
a) 9.5 mm plaster board	10	15			
b) 19 mm plaster board			10	13	20
3. Asbestos insulating boards, thickness of board:					
a) Single thickness of board, with 6 mm cover fillets at transverse joints		19	25		
b) Two layers, of total thickness				38	50
4. Solid bricks of clay, composition or sand lime, reinforced in every horizontal joint, unplastered	50	50	50	75	100
5. Aerated concrete blocks	60	60	60		
6. Solid blocks of lightweight concrete hollow protection (with an air cavity over the flanges)	50	50	50	60	75
B) Asbestos insulating board screwed to 25 mm asbestos battens	12	19			
C) Solid protections					
1. Concrete, not leaner than 1:2:4 mix (unplastered):					
a) Concrete not assumed to be load bearing, reinforced [2]	25	25	25	50	75
b) Concrete assumed to be load bearing	50	50	50	75	75
2. Lightweight concrete, not leaner than 1:2:4 mix (unplastered): concrete not assumed to be load bearing, reinforced [2]	25	25	25	40	60

[1] So fixed or designed, as to allow full penetration for mechanical bond.

[2] Reinforcement shall consist of steel binding wire not less than 2.3 mm in thickness, or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.

Table 15 Encased Steel Beams, 406 mm × 176 mm (Protection Applied on Three Sides)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of					
	½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A) Hollow protection (without an air cavity beneath the lower flange):						
1. [1] Metal lathing with trowelled lightweight aggregate gypsum plaster	13	13	15	20	25	
2. Plasterboard with 1.6 mm wire binding[2] at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:						
a) 9.5 mm plaster board	10	10	15			
b) 19 mm plaster board	10	10		13	20	
3. Asbestos insulating boards, thickness of board:						
a) Single thickness of board, with 6 mm cover fillets at transverse joints			19	25		
b) Two layers, of total thickness					38	50
B) Hollow protection (with an air cavity below the lower flange):						
1. Asbestos insulating board screwed to 25 mm asbestos battens	9	12				
C) Solid protection:						
1. Concrete, not leaner than 1:2:4 mix (unplastered):						
a) Concrete not assumed to be load bearing, reinforced [3]	25	25	25	25	50	75
b) Concrete assumed to be load bearing	50	50	50	50	75	75
2. Lightweight concrete[4], not leaner than 1:2:4 (mix) unplastered	25	25	25	25	40	60

[1] So fixed or designed, as to allow full penetration for mechanical bond.

[2] Where wire binding cannot be used, expert advice should be sought regarding alternative methods of support to enable the lower edges of the plasterboard to be fixed together and to the lower flange, and for the top edge of the plasterboard to be held in position.

[3] Reinforcement shall consist of steel binding wire not less than 2.3 mm in thickness or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.

[4] Concrete not assumed to be load bearing, reinforced.

Table 16 Timber Floors — Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 21 mm Finished Thickness

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of		
	½ h	1 h	2 h
(1)	(2)	(3)	(4)
37 mm (minimum) timber joists with a ceiling of:			
1. Timber lathing and plaster, plaster of thickness	15		
2. Metal lathing and plaster, thickness of plaster:			
a) Sanded gypsum plaster (metal lathing grade)	15		
b) Lightweight aggregate gypsum plaster	13	13	25
3. One layer of plasterboard with taped and filled joints	12.7		
4. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	19	31	
5. One layer of plasterboard not less than 9.5 mm thick, finished with:			
a) Gypsum plaster	5		
b) Sanded gypsum plaster	13		
c) Lightweight aggregate gypsum plaster	13		
6. One layer of plasterboard not less than 12.7 mm thick, finished with:			
a) Gypsum plaster	5		
b) Lightweight aggregate gypsum plaster	10		
7. One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12	

Table 17 Timber Floors — Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 15 mm Finished Thickness

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of		
	1½ h	1 h	2 h
(1)	(2)	(3)	(4)
37 mm (minimum) timber joists with a ceiling of:			
1. Timber lathing and plaster, plaster of thickness	15		
2. Metal lathing and plaster, thickness of plaster for:			
a) Sanded gypsum plaster (metal lathing grade)	15		
b) Lightweight aggregate gypsum plaster	13	13	25
3. One layer of plasterboard with taped and filled joints	12.7		
4. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	22	31	
5. One layer of plasterboard not less than 9.5 mm thick, finish with:			
a) Gypsum plaster	5		
b) Sanded gypsum plaster	15		
c) Lightweight aggregate gypsum plaster	13		
6. One layer of plasterboard not less than 12.7 mm thick, finished with:			
a) Gypsum plaster	5		
b) Lightweight aggregate gypsum plaster	10		
7. One layer of asbestos insulating board, with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12[1)]	

[1)] Finished on top with 25 mm minimum thick glass fibre or mineral wool laid between joints.

Table 18 Timber Floors — Any Structurally Suitable Flooring of Timber or Lignocelluloses Boards

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of	
	½ h	1 h
(1)	(2)	(3)
37 mm (minimum) timber joists with a ceiling of:		
1. Timber lathing and plaster, plaster of thickness	15	
2. Metal lathing and plaster, thickness of plaster for:		
a) Sanded gypsum plaster (metal lathing grade)	15	
b) Lightweight aggregate gypsum plaster	13	19
3. One layer of plasterboard with joints taped and filled and backed by timber	12.7	
4. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	25	
5. Two layers of plasterboard, each not less than 9.5 mm thick, joints between boards staggered and outer layer finished with gypsum plaster	5	
6. One layer of plasterboard not less than 9.5 mm thick, finish with:		
a) Sanded gypsum plaster	13	
b) Lightweight aggregate gypsum plaster	15	
7. One layer of plasterboard not less than 12.7 mm thick, finished with:		
a) Sanded gypsum plaster	15	
b) Lightweight aggregate gypsum plaster	13	
8. One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	12	

FIRE ZONES

Demarcation: City or area are demarcated into <u>distinct "fire zones"</u> based on

i) fire hazard inherent in the building and

ii) structures according to occupancy called

Number and Designation of fire Zones depends on:

- Exiting layout
- Types of building construction
- Classification of existing building based on occupancy
- Expected future development
- Large Cities- 3 Zones (FZ1, FZ2, FZ3)
- Smaller Cities- 2 Zones

Fire Zone -1 Areas having

Residential (Group A)
Educational (Group-B)
Institutional (Group-C)
Assembly (Group-D)
Small business (Group-E1)
Mercantile (Group-F)

Fire Zones-2

Business (Subdivision E2 –E5)
Industrial (Group-G1&G2)
Except high hazardous
industrial buildings (Group-G3)

Fire Zone-3

High Hazard Industrial (Group-G3)
Storage (Group-H)
Hazardous storage (Group-J)

Permissible/Restrictions of Type of Construction

Fire zone-1: Types 1, 2, 3 & 4
Fire zone-2: Types 1, 2 & 3
Fire zone-3: Types 1 & 2

Overlapping fire-zones

If a building extends into more than one fire zone- classify it to be located in which major portion of the building is located

If it extends equally into two zones, classify it to be in fire zone having more hazardous occupancy

<u>Temporary buildings</u>:

Permitted in fire zones 1 and 2 (according to the purpose for which it is put up) by a special permit

To be removed on expiry of permit

Pre-construction Activities

- Application and Permits
- Permit and Inspection
- Application for Development / Building Permit
- Information to Accompany Notice
- Grant of Permit or Refusal
- Responsibilities and Duties of Owner
- Inspection, Occupancy permit and post occupancy inspection
- Unsafe Buildings
- Demolition of Building

Application and Permit

Responsibility of Building officials

- Enforce all the provisions of the Code and
- Receive applications (for erection and alteration)- examine the premises to enforce compliance with the approval/Code
- Act on query on mode of construction, addition, alteration, repair, removal, demolition, installation of service equipment, its location, use, occupancy and maintenance of all buildings
- Issue notices/orders to
  - remove illegal or unsafe conditions or to require the necessary safeguards during construction,
  - require adequate exit facilities in existing buildings and
  - to ensure compliance with all the requirements of safety, health and general welfare of the public.

Violations and Penalties

Construction Not According to Plan:

- Construction not according to the sanctioned plan- Owner notified- further construction stopped till correction effected and approved
- Authority will cancel the building permit issued - issue notice of such cancellation.
- No work shall be undertaken or permitted until a valid building permit is sought again.
- Provision for appeal by owner
- Non-response/Ignoring notice and Persistent violation- authorities order demolitions

Offences and Penalties

Modification:

- Difficulty faced during construction- on receipt request for modification – with spirit and intent of the Code/public welfare/safety be assured- approval will be considered

Occupancy Violations:

- Building officials may order such use discontinued – building to comply with the requirements of the Code within 10 days

Height Violations:

- Noncompliance will lead to demolition of excess height
- Architect/Engineer causing such violations of code provisions- penalty or recommend cancellation of license for practicing

Permit and Inspection: Development/Building Permit

- Prior approval required from the Authority for carrying out
  - development, erect, re-erect or
  - make alterations or
  - demolish any building

- Authority for Building permit
  - Town Planning Act
  - Development Act
  - Municipal Act

- Any other applicable statutes for
  - Layout, building plans
  - Water supply, sewerage, drainage
  - Electrification

- Large development shall include in the layout & building plans
  - landscape development plan
  - Provision for Rainwater harvesting.

Development/Building Permit

Specific approvals shall be obtained from

- Civil Aviation Authorities
- Fire Services Department (if building proposed is 15 m and above)
- Pollution Control Board
- Designated authorities under
  - Factories Act
  - Cinema Regulation Act
  - Urban Arts Commission
  - Coastal Regulation Zone Authority
  - Archeological Survey of India
  - Heritage Committee

Development/Building Permit

Single window clearance: Development/Building Permit Approval Committee with representative of the

- Team of building officials
- Representatives of all bodies/organizations from whom clearance for development/ building permit is required.

1st response/invalid notice/non-compliance intimation < 30 days

Application for Development / Building Permit

FORM FOR FIRST APPLICATION TO DEVELOP, ERECT, RE-ERECT OR TO MAKE ALTERATION IN ANY PLACE IN A BUILDING

To
....

Sir/madam,

I hereby give notice that I intend to develop, erect, re-erect or to make alteration in the building No.......... or to ....on/in Plot No. .... in Colony/Street*..................MOHALLA/BAZZAR/Road..........................*City ....and in accordance with the building code of ....Part-II, Clauses ....and I forward herewith the following plans and specifications in triplicate duly signed by me and ....the Architect/Engineer/ Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer, Registration No.................................... who will supervise its erection.
(Name in block letters)

1. Key plan 2. Site plans 3. Sub-division/layout plan 4. Building plans
5. Services plans 6. Specifications, general and detailed 7. Ownership title
8. Certificates for structural sufficiency 9. Certificate for engagement of builder/constructor(s)
10.Supervision

I request that the development/construction may be approved, and permission accorded to me to execute the work.

Signature of Owner ....
Name of the Owner ....
Address of Owner ....
....
....
Date: ....

Information to Accompany Notice

The notice shall be accompanied by the

- Key plan: 1 in 10,000 - Show boundary of site with respect to neighborhood landmarks
- Site plan
- Building plan
- Services plans
- Specifications
- Structural sufficiency certificate, and
- Certificate of supervision as prescribed

Table 2 Colouring of Plans
(*Clause* 12.2.1.2)

Sl No.	Item	Site Plan			Building Plan		
		White Plan	Blue Print	Ammonia Print	White Plan	Blue Print	Ammonia Print
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Plot lines	Thick black	Thick black	Thick black	Thick black	Thick black	Thick black
ii)	Existing street	Green	Green	Green	—	—	—
iii)	Future street, if any	Green dotted	Green dotted	Green dotted	—	—	—
iv)	Permissible building lines	Thick dotted black	Thick dotted black	Thick dotted black	—	—	—
v)	Open spaces	No colour	No colour	No colour	No colour	No colour	No colour
vi)	Existing work	Black (outline)	White	Blue	Black	White	Blue
vii)	Work proposed to be demolished	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched
viii)	Proposed work (*see* Note 1)	Red filled in	Red	Red	Red	Red	Red
ix)	Drainage and sewerage work	Red dotted	Red dotted	Red dotted	Red dotted	Red dotted	Red dotted
x)	Water supply work	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin

NOTES

1 For entirely new construction this need not be done; for extension of an existing work this shall apply.

2 For land development, subdivision, layout, suitable colouring notations shall be used which shall be indexed.

Site Plan

Scale > 1 in 500 for a site up to 1 hectare
Scale > 1 in 1000 for a site more than 1 hectare and shall show:

a) Boundaries of site

b) Position of the site in relation to neighboring street;

c) Name of the streets in which the building is proposed to be situated

d) Existing buildings standing on, over or under the site including service lines

e) Position of the building and of all other buildings (if any) which the applicant intends to erect upon his/her contiguous land referred to in (a) in relation to

Site Plan

f) Means of access from the street to the building, and to all other buildings (if any) which the applicant intends to erect upon his/her contiguous land referred to in (a);

g) Space to be left about the building to secure a free circulation of air, admission of light and access for scavenging purposes;

h) Width of street in front and of the street the side or near the buildings;

j) the direction of north point relative to the plan of the buildings;

k) any physical features, such as wells, drains, etc., and

Sub-Division/Layout Plan

In the case of development work, the notice shall be accompanied by the sub-division/layout plan which shall be drawn on a scale > 1 :500 containing:

a) Scale used and north point;

b) Location of all proposed and existing roads with their existing/proposed/ prescribed widths within the land;

c) Dimensions of plot along with building lines showing the setbacks with dimensions within each plot;

d) Location of drains, sewers, public facilities & services & electrical lines, etc.,

Sub-Division/Layout Plan

e) Table indicating size, area & use of all the plots in sub-division/layout plan

f) A statement indicating

- total area of site,
- area utilized under roads,
- open spaces for parks, playgrounds,
- and development plan reservations,
- schools, shopping and other public places
- along with their percentage with reference to the total area of site proposed to be subdivided

g) In case of plots which are subdivided in built up areas in addition to the above, the means of access to the sub-division from existing streets.

Building Plan and Details

Plan, elevations and sections of the building: scale of 1:100- should include

a) include floor plans of all floors together with the covered area clearly indicating the size and spacing of all framing members and sizes of rooms and the position of staircases, ramps and lift wells;

b) show the use or occupancy of all parts of the buildings;

c) show exact location of essential services, Ex: WC, sink, bath etc.

d) include at least one elevation from the front showing height of building and rooms and the height of parapet;

e) include at least one section through the staircase;

Building Plan and Details

f) include the structural arrangements with appropriate sections showing

- type/ arrangement of footings, foundations, basement walls;
- structural load bearing walls, columns and beams, and shear walls; and
- arrangement/spacing of frame, floor slabs and roof slabs with the material used

g) show all street elevations;

h) dimensions of the projected portions beyond the permissible building line;

j) include terrace plan indicating the drainage and the slope of the roof

k) give indications of the north point relative to the plan.

Building plan for multistorey/special Buildings

For MS buildings h≥ 15 m and special buildings - educational, assembly, institutional, industrial, storage and hazardous and mixed occupancies - having covered area more than 500 m^2, the building sanction shall be done in two stages.

***Stage 1*: First stage for planning clearance: Additional information required**

- Access to fire appliances/vehicles with details of vehicular turning circle and clear motorable accessway around the building;
- Size (width) of main and alternative staircases along with balcony approach, corridor, ventilated lobby approach;
- Location and details of lift enclosures; Location and size of fire lift;
- Smoke stop lobby door, where provided;
- Refuse chutes, refuse chamber, service duct, etc.,

Building plan for multistorey/ Special Buildings

- Vehicular parking spaces;
- Refuse area, if any;
- Details of building services: Air-conditioning system with position of fire dampers, mechanical ventilation system, electrical services, boilers, gas pipes, etc.,
- Details of exits including provision of ramps, etc, for hospitals and special risks;
- Location of generator, transformer and switchgear room;
- Smoke exhauster system, if any;

Building plan for multistorey/ Special Buildings

- Details of fire alarm system network;
- Location of centralized control, connecting all fire alarm systems, built-in-fire protection arrangements and public address system, etc.,
- Location and dimensions of static water storage tank and pump room along with fire service inlets for mobile pump and water storage tank;
- Location and details of fixed fire protection installations, such as, sprinklers, wet risers, hose-reels, drenchers, etc.,
- Location and details of first-aid fire fighting equipment/installations.

Building plan for multistorey/ Special Buildings

After obtaining the sanction for planning (Stage-1)

***Stage 2*:**

Structural plans, sections, details and design calculations duly signed by engineer/structural engineer along with the complete set of details duly approved in Stage-1 shall be submitted.

The building plans/details shall be deemed sanctioned for the commencement of construction only after obtaining the permit for Stage-2 from the Authority.

Services Plans and specifications

- Services plans:
  - plumbing services, and plans,
  - elevations and sections of private water supply,
  - sewage disposal system and
  - rainwater harvesting system, if any

- Specifications, both general and detailed, giving type and grade of materials to be used

- Duly signed by the registered architect, engineer, structural engineer or supervisor shall accompany the notice

Structural Sufficiency Certificate

- Documents/drawings to accompany structural sufficiency certificate

- Certified by structural engineer & owner that the building is safe against

  ✓ various loads, forces and effects including due to natural disasters, such as, earthquake, landslides, cyclones, floods, etc.

- Structural engineer shall also have the details to substantiate his/her design.

FORM FOR CERTIFICATE FOR STRUCTURAL DESIGN SUFFICIENCY

With respect to the building work of erection, re-erection or for making alteration in the building No.............or to............................on/in Plot No. ....Colony/Street*...............MOHALLA/BAZAR/Road*....................City.............
we certify that the structural plans and details of the building submitted for approval satisfy the structural safety requirements for all situations including natural disasters, as applicable, as stipulated under Part 6 Structural Design of the National Building Code of India and other relevant Codes; and the information given therein is factually correct to the best of our knowledge and understanding.

Signature of owner with date	Signature of the Registered Engineer/Structural Engineer with date and registration No.

Name: ....
Address: ....

Supervision

*N*otice should accompany by a certificate by the registered Architect/engineer/ Structural engineer/ supervisor undertaking the supervision

FORM FOR SUPERVISION

I hereby certify that the development, erection, re-erection or material alteration in/of building No.............or the............on/in Plot No..................in Colony/Street ....MOHALLA/BAAZAR Road.............. City ....shall be carried out under my supervision and I certify that all the materials (type and grade) and the workmanship of the work shall be generally in accordance with the general and detailed specifications' submitted along with, and that the work shall be carried out according to the sanctioned plans.

Signature of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/________________

Name of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/___________________

Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner_______________

Address of Architect/Engineer/Structural Engineer/Supervisor/Town Planner ______________________
Date: ....

Notice for Alteration only

Notice is only for an alteration of the building: Submit plans and statements Highlighting the changes to be submitted

Notice and building permit Not required: For activities which do not otherwise violate any provisions regarding i) general building requirements, ii) structural stability and iii) fire and health safety requirements of the Code

- Opening and closing of a window or door or ventilator
- Construction of sunshades on one's own land
- Providing intercommunication doors; Providing partitions
- Providing false ceiling
- Gardening
- Plastering and patch work; White washing; Painting
- Re-tiling and Re-roofing; Re-flooring

Fees

- Notice for seeking permission to construct/modify shall accompany payment of prescribed fee
- Non-issue of permit – fee will not be returned- while resubmission after complying to objections of authority if submitted within 1 year - fee need not be paid again

Duration of Sanction

- Sanction: valid for 3 years
- Permit shall be got revalidated before the expiration of this period
- Revalidation shall be subject to the rules then in force.

Deviations During Construction

- Any departure from sanctioned plan is intended to be made, sanction shall be obtained before the change is made
- Revised plan showing the deviations shall be submitted and the procedure laid down for the original plan heretofore shall apply to all such amended plans within three weeks.

Revocation of Permit

Authority may revoke any permit issued under the provisions of the Code, wherever there has been any

- false statement,
- misrepresentation of any material fact in the application on which the permit was based or
- violation of building permit

FORM FOR SANCTION OR REFUSAL OF DEVELOPMENT/BUILDING PERMIT

To ....

Sir,

With reference to your application...........................dated ....for grant of permit for the development, erection, re-erection or material alteration in the building No. ....or to ....on/in Plot No...............in Colony/*Street ....MOHALLA/BAZAR Road* ....City ....

I have to inform you that the sanction has been granted/ refused by the Authority on the following grounds:

1.
2.
3.
4.
5.

Office Stamp .... Office (Communication) No. ....
Date: ....
Signature of the Authority ....
Name, Designation and Address of the Autiotity ....

FORM FOR NOTICE FOR COMMENCEMENT

I hereby certify that the development, erection, re-erection or material alteration in/of building No......................or the.................on/in Plot No......................in Colony/Street ....MOHALLA/BAZAR/Road ....City ....will be commenced on as per your permission, vide No...............dated.............under the supervision of ....Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer, Registration No.....................................and in accordance with the plans sanctioned, vide No......................& dated ....

Signature of Owner ....
Name of Owner ....
Address of Owner ....

Date: ....

FORM FOR CERTIFICATE FOR EXECUTION OF WORK AS PER
STRUCTURAL SAFETY REQUIREMENTS

With respect to the building work of erection, re-erection or for making alteration in the building No...............or to................on/in Plot No...................Colony/street *..........................MOHALLA/BAZAR Road................*City.................... we certify:

a) that the building has been constructed according to the sanctioned plan and structural design (one set of drawings as executed enclosed), which incorporates the provisions of structural safety as specified in Part 6 'Structural Design' of the National Building Code of India and other relevant Codes; and

b) that the construction has been done under our supervision and guidance and adheres to the drawings and specifications submitted and records of supervision have been maintained. Any subsequent changes from the completion drawings shall be the responsibility of the owner.

Signature of owner with date	Signature of the Registered Engineer/Structural Engineer with date and registration No.

Name: ....
Address: ....

FORM FOR COMPLETION CERTIFICATE

I hereby certify that the development, erection, re-erection or material alteration in/of building No.............or the................ on/in Plot No............. in Colony/Street .... *MOHALLAIBAZA/*Road........................City ....has been supervised by me and has been completed on.......................... according to the plans sanctioned, vide No. .... dated ....

The work has been completed to my best satisfaction, the workmanship and all the materials (type and grade) have been used strictly in accordance with general and detailed specifications. No provisions of the Code, no requisitions made, conditions prescribed or orders issued there under have been transgressed in the course of the work. The land is fit for construction for which it has been developed or re-developed or the building is fit for use for which it has been erected, re-erected or altered, constructed and enlarged. I hereby also enclose the plan of the building completed in all aspects.

Signature of Architect/Engineer/Structural Engineer/Supervisor/Town Planner...............
Name of Architect/Engineer/Structural Engineer/Supervisor/Town Planner............
Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner..............
Address of Architect/Engineer/Structural Engineer/Supervisor/Town Planner.........................

Signature of the Owner Date: ………

ANNEX J

[*Clause* 13.2(h)]

FORM FOR OCCUPANCY PERMIT

The work of erection, re-erection or alteration in/of building No............................or the..............................on/ in Plot No............................in Colony/Street....................................*MOHALLA/BAZAR*/Road............................... City............................completed under the supervision of.....................................Architect/Engineer/Structural Engineer/Supervisor, Registration No............................has been inspected by me. The building can be permitted/ not permitted for occupation for ....occupancy subjected to the following:

1.
2.
3.

One set of completion plans duly certified is returned herewith.

Signature of the Authority ....

Office Stamp

Date: ....

Documents at Site

Materials test conformity certificates (with test data)

Site should display in a conspicuous place

a) a copy of the building permit; and

b) a copy of the approved drawings and specifications.

Reference: National Building code of India 2016: Bureau of Indian Standards, New Delhi

Activity

Locate the local Authority Building regulations pertaining to your State/City

(Search through relevant online portal of Stage Government)

Ex: (Tamil Nadu Combined Development and Building Rules, 2019, *G.O. Ms. No. 18, Municipal Administration and Water Supply (MA 1), 4th February 2019)*

http://www.cmdachennai.gov.in/

https://www.tn.gov.in/tcp/acts_rules.htm

What are the most important regulations to be satisfied for undertaking Building construction in a site (in not more than 2 to 3 pages)

This activity should be done by you without consulting anyone in your place. You can discuss with your classmates. In case of clarifications, send a mail to me.

Activity

Draw the Plot boundary with dimension, Plan and elevation of the House in which you are currently staying- comment whether the building conforms to current day local authority regulations if it must be construction new today (as per your interpretation of the regulations)

- The dimensions can be approximate. Drawings to be to scale.
- This activity should be done by you without consulting anyone in your place.
- You can discuss with your classmates. In case of clarifications, send a mail to me.

Site Organisation

- Site Clearance (new development or redevelopment)
- Site Planning
- Site Organisation
- Site Investigation
- Site Leveling and Grading

Site Clearance

- **Surface cleaning of grass, bushes, trees, anthills, hillocks**
- **Cleaning of obstructions above or below the ground level**
  - Old foundations, drainage works, septic tank, pit type latrines and soak pits.
- **Cleaning of obstructions belonging to other organizations**
  - Drainage or water supply lines, underground electric or telephone cables.
- **Demolition of Existing Buildings/Structures**

Fig: Site clearance

https://www.clarkkentservices.com/news/site-clearance-basics.html

Removal of Existing Services

- First step: Removal items which will affect site clearance: of Gas pipes, electric cables, water supply and sewage disposal pipes, telephone, television cables
- Request for removal of services/installations by concerned authority
- Service connections within building: Obtain release from utility servicer provider
- Seal/plug service connections in a safe manner
- Remove Appurtenant equipment such as meters/regulators
- Utility lines above ground level: proper protection, warning signs, relocation or removal as necessary

Removal of Bushes and Trees

- Clear Shrubs, weeds/grass – Fully remove the roots
- Dispose or buried in pits, with at least 300 mm depth of earth (should not be burnt at site)
- Trees to be preserved wherever possible- replantation at a convenient off-site location
- In other cases- cut down - remove root completely (Consult experts for large tress)
- Small trees - use bulldozers/extractor-cutters/manually
- For shallow excavation: stumps of diameters in excess of 500 mm may be removed by blasting – all safety measures to be taken
- For large scale excavation: mechanical shovels with buckets -stumps are uprooted as the excavation is dug.

Rear side of Dean Students Office

In front of NCCRD Building

In front of Center for Innovation building

Demolition of Existing Building/Structure

- Obtain Permit from the authority
- Approval to be displayed at site (Information to neighbours)
- Analyze the design and drawings and look for alterations, if any
- Make a detailed study of the structure and its surroundings
- Understand the structural system and its behaviour
- Finalise method and sequence of demolition

Demolition of Existing Structure: Precautions

- Very Important: Safety of adjacent structures– relationship & condition of adjoining properties may be affected
- Check to be done if any shoring /underpinning required to adjacent buildings
- Understand the liability for their condition.
- Take Photo of any existing defects on adjacent properties, witnessed & store safely
- Remove flammable or explosive material (oil drums/gas cylinders)

Demolition of Existing Structure: Precautions

- Entrust to specialist contractor (demolition sequence & precautions)
- Prominent danger signs shall be posted all round the property
- Barricade all access/openings to the site/structure
- Main roads shall be kept clear and unobstructed all times. Sidewalk or road adjacent to the work shall be closed/protected/diversion planned
- Provide at least 2 independent exits for escape of workmen during any emergency.

Demolition of Existing Structure: Precautions

- During nights, place warning lights on or above the barricades.
- Issue safety appliances to workers. Safety precautions for fire shall be provided.
- Fragile materials like glass to be removed prior to commencement of work
- Dust shall be controlled by spraying water to prevent harm to workmen/neighborhood
- Adequate natural or artificial lighting and ventilation shall be provided to workmen.

Choice of Method of Demolition

- Structural form (RCC, steel, plain concrete, structural masonry)
- Scale of construction (small or large),
- Location of site (urban centre or suburb)
- Detached building on
  - ✓ an isolated site (Min. dist. to boundary> 2h building) or
  - ✓ a confined site not all the boundaries are at a distance> 2 h of building)
- Partial demolition:
  - Requires knowledge of building design
  - Identify Load bearing members/wall and support by struts, props & suitable shoring
  - Most partial demolition carried out manually using hand tools such as picks and hammers
  - Relative cost of demolition by different methods.

Methods of Demolition

- Top down or controlled complete demolition
- Top-Down Methods
  - Manual Method: Stone Chisel: Manual method of demolition- used for light construction (masonry)
  - Top-Down by Machines: Machines attached with bucket, rock shovel bucket, rubble shovel bucket, heavy duty bucket, demolition boom
- Mechanical Method by Hydraulic Crusher with long boom arm
- Wrecking Ball method
- Implosion

Top-Down Methods: Manual Method

- For RCC buildings - jack hammers – Gradual breaking down of Structural elements
- Oxy-acetylene torch: to cut the reinforcements
- Reinforcements remains until all the concrete connecting to or supported by the reinforcement is broken away.
- If rope or tie wires are used to pull down the structural elements- Should be at least 4 time stronger than the anticipated pulling force.

Top-Down Methods: Demolition sequence

- Cantilevered slabs, canopies, verandahs & features attached to the external walls - prior to main building and its internal structures on each floor.
- Lift machine rooms & water tanks be demolished to the main roof level
- Demolition of floor slabs shall begin at mid span and work towards supporting beams.
- Non-load bearing walls -prior to demolition of load bearing walls
- Demolition of Floor beams : Cantilever beams/secondary beams/main beams
- When structural stability of beams are affected, due to loss of restraints, beams shall be propped prior to loss of support or restraint.
- Columns and load bearing walls shall be demolished after removal of beams on top.

Top-Down Methods

Cantilever Structures and Balconies & Canopies

- May project out of the building over the pedestrian footpath or in some cases over a portion of the traffic lane.
- Please Temp. supporting structures and/or catch platform underneath the cantilever balcony

Sequence of dismantling Cantilever slabs and beams

- First: Demolish Exterior walls
- Any structure or dead load supported by the cantilever system shall be removed prior to demolishing the cantilever slabs and beams.
- Concrete shall be broken down gradually starting from the exterior edge of the cantilever floor, working inwards and toward its supporting beams.

Top-Down Methods

- Cantilever beam shall be demolished after the demolition of the connecting floor slab.
- Slab shall be cut into a manageable size and lifted away.
- Demolition of cantilever beam shall not advance further than the floor slab - to ensure support for the slab
- Saw cut and lift may be used to dismantle the cantilever features.

Top-Down Methods

Exterior Wall; Brick in-fill Wall

- Brick in-fill to be removed before dismantling RC frame
- Start removing Brick/block from the top layer downwards
- Push Brick-In-fill inward- to avoid hazard of bricks falling out of the building,
- Use working platforms outside the building for removal of brick in-fill walls.

RC frame

i) taking down the individual beams and columns separately and/or

ii) taking down the frame of a bay between two columns.

Top-Down Methods: Exterior Beam

- Use Wire and winch to secure cross beam to other structural members .
- Break Concrete first at both ends near its column supports to expose the reinforcement .
- Cut Reinforcement at one end to allow the beam to partially drop.
- Winch the beam to the floor in controlled manner through the wire
- Cut reinforcement at the second end-beam will be lowered fully in a controlled manner.

Top-Down Methods: Exterior Column

- Secure top of the column to a structural member by wire and winch.
- Pre-weaken the column at its bottom to reduce the pulling force – ensures break occurs at the desired location.
- First Remove concrete cover of the reinforcement
- Reinforcement at the interior face shall remain.
- Cut the Reinforcement at exterior face before the pulling of the column
- After pre-weakening, Pull down the column by the wire and winch towards the interior in a controlled manner.

Top-Down Methods: Exterior RCC Frame

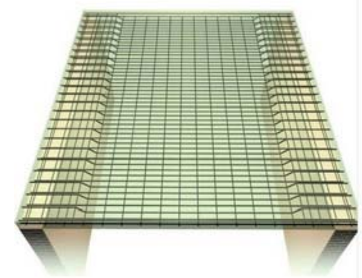
<u>Manual Demolition</u>

- Optimum section of the frame to be demolished: Bay between the two adjacent columns- but shall not be > 3 m.
- Secure Frame section to other structural members with wire and winch before disconnecting the framing from the remaining structure.
- Pre-weaken at the bottom of the two columns.
- Cut off reinforcing bars connecting the beams after pre-weakening.
- Pull down the frame by exerting force through winch and pulley system.

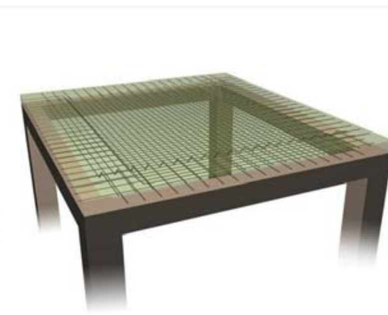
Top-Down Methods: Reinforced Concrete Wall: Load Bearing Wall

- Demolition by cutting down the wall into manageable sections of width < 2 m.
- Secure the wall using wire and winch systems.
- Pre-weaken at the bottom of the wall
- Using hand tools- Break concrete along the cut line of the interior face of the wall section
- Care should be taken to minimize debris from falling out from the building .
- Remove concrete along the cut line, separate reinforcement along the vertical cut line
- Pull the wall down into the building by exerting force through the wire and winch systems

Top-Down Methods



One Way Slab



Two Way Slab

Floor Slabs

- Demolish RC floor slab by gradually breaking the concrete.
- Reinforcement is cut off after the concrete is broken.

Two-way slab

- Supported by beams or structural members on all four sides.
- Start from middle of the slab and advance towards the sides in all 4 directions.

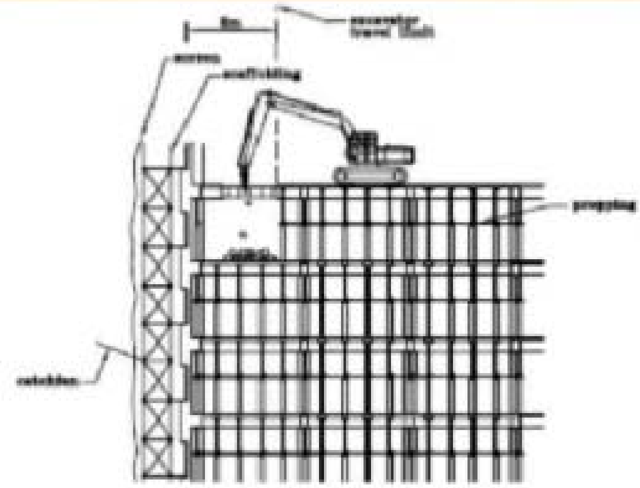
One-way slab

- Begin at unsupported end and proceed in strips perpendicular to the supporting beam/wall
- Strips shall be demolished from their centre towards the supports in both directions.

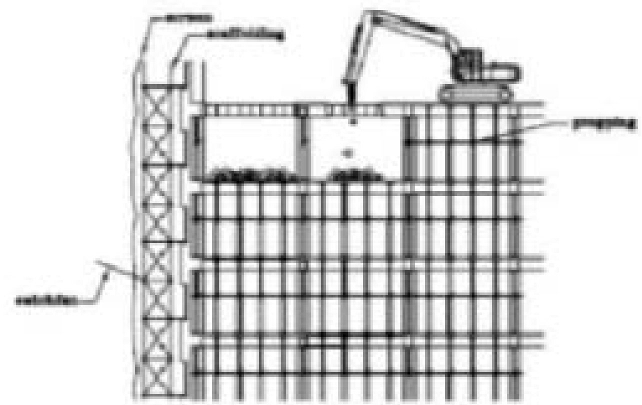
Top-Down By Machines

Supports for Machines

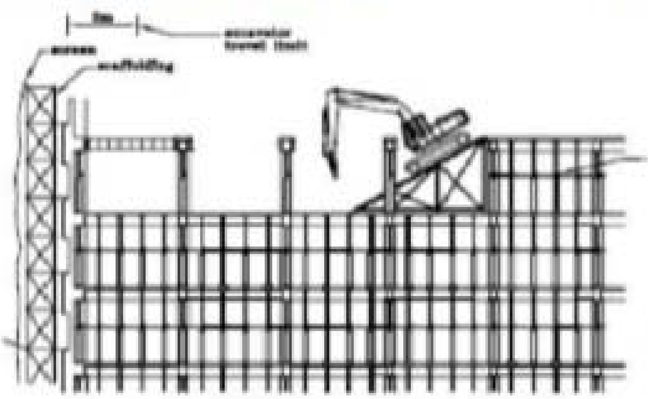
- Check load imposed on floors by mechanical plant before lifting it to the topmost floor
- Install props at floor below the working floor to safely support the machine operation
- Lift Mechanical plant onto the roof using of Mobile crane
- Restrict movement of the mechanical plant
    - within 2 m of the building edge
    - 1 m of any floor opening
    - any Cantilever structures
    - beyond the propped area
- When rope/tie wire used for pulling- protect workers /Move them away from the area
- Strength of wire ~ 4 times the anticipated load- Check integrity of rope/tie wire 2 times /day



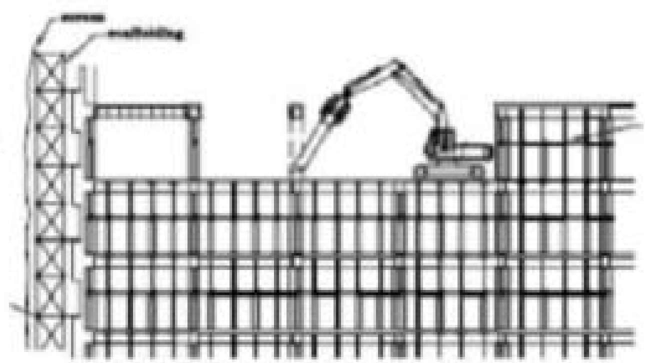
1. Demolish slab & beam



2. Continue demolishing slab & beam



2. Access ramp to lower floor



4. Demolition of interior column

Top-Down By Machines

Temporary Ramp Construction

- For movement of machine to the next floor

- Ramp Slope: not be steeper than 1.75 to 1 or as per machine manufacturer

- Demolish first all cantilever slabs and beams, canopies and verandahs

- Structural elements, in general should be demolished in sequence
    - Slab
    - Secondary beams
    - Main beams


NORTHEAST
JCB

Methods of Demolition: Pusher arm demolition

- Method of progressive demolition
- Machine with a steel pusher arm is used to exert a horizontal thrust on the building fabric.
- Operated from outside the Building
- Operation of Machine: Firm level base with a clear operating base of at least 6 m
- Operator's cabin: to withstand Impact of flying debris-shatter-proof glass cab windows.
- Hand demolition to reduce height of the building; height above pusher arm< 600mm
- Attached buildings, if any, - detach by hand demolition.

Grapples

Hammer

Shear

Multiprocessor

Pulverizes

Buckets

ATTACHMENTS

Mechanical method by Hydraulic Crusher with Long Boom Arm

- Crusher attachment breaks the concrete and the reinforcement by the hydraulic thrust through the long boom arm system.
- Operated from the ground outside the building.
- Suitable: dangerous buildings, silos and other industrial facilities.

Methods of Demolition: Hitting/wrecking ball

Steel ball:

- 0.5 to 2.0 tonne Steel ball is suspended by a crawler type crane.
- Repeated hitting by a steel ball can demolish concrete and masonry.
- Produces noise, dust and vibration.

Process:

- Method of progressive demolition
- By swinging a weight or demolition ball, suspended from a lifting appliance such as a crane, against the fabric of the structure.
- Three techniques can be used, viz., vertical drop, swinging in line with the jib, and slewing jib.

Methods of Demolition: Hitting /wrecking ball

Methods of Demolition: Hitting /wrecking ball

- Swing angle shall be restricted to less than 60^0 based on safety considerations.
- Normal duty mobile crane: Demolition ball-confined to the vertical drop technique
- Heavy duty machine: For other techniques- install anti-spin device to the hoist rope.
- With progress of demolition- Reduce length of crane Jib- jib head >3.0 m above the part of the building being demolished.

Methods of Demolition

Jack up

- Machine uses hydraulic jack to demolish RCC buildings.

Ex: Floor slabs: Designed for downward DL+IL -demolished easily through application of point load in the upward direction from the bottom of the slab

Deliberate collapse demolition

- Removal of key structural members causing complete collapse of whole/part of building
- Experts' advice needed
- For safety- Used for detached/isolated buildings on reasonably level sites

Methods of Demolition:

Wire-rope pulling demolition

- Adequate size steel wire ropes but in not less than 38 mm circumference.
- Rope should be firmly attached at both ends and the pulling tension gradually applied.
- No person should be forward of the winch or on either side of the rope between winch and the building/component being demolished.

Methods of Demolition: Breaking by hydraulic pressure

Hydraulic Breaker

- Can break concrete using hydraulic pressure to hold and crush the section in a solid C-shaped frame or strong jaws.
- C-shaped breaker is suspended by a crawler crane.
- Jaw-type breakers are mounted on top of the arm of the crawler machine.

Pile crusher

Pile crusher can break a concrete pile having a longitudinal hole in the centre.

A strong band combined with hydraulic jack is set up to hold the pile and the jack-force breaks the concrete pile by crushing across the diameter in various directions.

Methods of Demolition: Abrasion

Hand Hammer Drill: Used for boring into concrete. The drill bit hits the concrete over 1000 times and turns about 300 times per minute, thereby powders concrete by abrasion.

Methods of Demolition: Abrasion

<u>Large size hammer drill</u>: Drill is mounted on a self-propelled machine- used to bore massive or mat concrete.

Process:

- Involves progressing of demolition of a structure by operatives using hand-held tools.
- Debris allowed to fall freely (where distance to highway or an adjoining property > 6 m)

Methods of Demolition: Abrasion

<u>Diamond boring Machine</u>: Used to bore holes of 100 to 150 mm dia. Holes are drilled side by side and then the concrete can be cut. Mounted on a self-propelled machine.

<u>Diamond disc cutter</u>: Appropriate for cutting reinforced concrete.

<u>Diamond wire saw</u>: A loop wire saw with a diamond can cut around the circumference of the concrete section. Suitable for demolishing massive concrete and foundations.

<u>High pressure Water jet</u> 250-300 MPa from a nozzle about 0.3 to 0.5 mm in dia., used for cutting plain concrete.

<u>Abrasive water jet</u>: Contains garnet or steel particles can cut reinforced concrete

Methods of Demolition: Blasting/Bursting

- Alternate method- blasting/ bursting
- Concrete and rock can be split by bursting force in a hole, through either

  i) static bursting (using wedge or chemical expansive demolition agents) or

  ii) dynamic bursting (water gun, gas cylinder, liquid CO_2, explosives).
- Utmost safety to be followed when expansive material or gas used

Methods of Demolition: Blasting/Bursting

<u>Gas expansion burster</u>:

- Steel cylinder containing a liquefied gas, which expands with great force when subjected to an electric charge, is inserted into a prepared cavity in the fabric to be demolished.
- On being fired the expansion of the cylinder causes the fabric mass to be broken into fragments.

<u>Hydraulic burster</u>: Consists of a steel cylinder with several pistons which are forced out radially under hydraulic pressure.

Methods of Demolition: Blasting/Bursting

Thermal reaction:

- Steel member to be cut out/removed by creating a thermal reaction
- Results in a liberation of a large quantity of heat causing the steel to become plastic.
- A small force such as a wire rope attached to a winch will be sufficient to cause collapse of the member.

Methods of Demolition

Thermic lance

- A steel tube, sometimes packed with steel rods, through which oxygen is passed.
- The tip of the lance is preheated by conventional means to melting point (approx. 1000^0C) when the supply of oxygen is introduced.
- Sets up a thermo-chemical reaction giving a temperature of around 3500^0C at the reaction end which will melt all the materials encountered causing very little damage to surrounding materials.

Implosion

- Tall and heavy structures – controlled explosive demolition
- **Implosion -** Collapse down into its **footprint-** suitable with surrounding buildings
- **Implosion:** collapses inward-
- Atmospheric pressure doesn't pull or push the structure inward, gravity makes it collapse.


PACIFIC


©Implosionworld.com

Principle of Implosion

- Removal of support structure of a building at a certain point, section of the building above that point will fall down on the part of the building below

- Upper section is heavy enough, it will collide with the lower part with sufficient force to cause significant damage.

- Explosives are trigger for the demolition. - gravity that brings the building down

- Blasters set explosives so that "tower" falls toward the center of the building.

- More than one tower: explosives detonated in the right order, the toppling towers crash against each other- rubble collects at the center of the building.

- Option: Detonate columns at the center of the building before the other columns so that the building's sides fall inward

Preparing the building for Demolition

- Clear all services, partitions, door, windows and debris out of the building.
- This makes for a cleaner break at each floor.
- May take up weakening of columns with sledgehammers/ steel-cutters
- Loading of columns with explosives

Types of Explosives

Concrete Columns

- Traditional dynamite - absorbent stuffing soaked in a highly combustible chemical or mixture of chemicals.

- Blasters cram this explosive material into narrow **bore holes** drilled in the concrete columns

- On ignition - chemical burns quickly- produces a large volume of hot gas in a short time.

- Gas expands rapidly- applies immense outward pressure (up to 600 tons per square inch sends a powerful shock wave busting through the column at supersonic speed, shattering the concrete into tiny chunks.

Types of Explosives

Steel Columns

- Specialized explosive material, called **RDX**
- RDX-based explosive compounds expand at a very high rate of speed, up to 8,000 m/sec.
- Instead of disintegrating the entire column, the concentrated, high-velocity pressure slices right through the steel, splitting it in half.
- Additionally, blasters may ignite dynamite on one side of the column to push it over in a particular direction.

Concrete columns are blown apart with conventional dynamite or a similar sort of explosive

Steel columns are sliced in half using a high-velocity explosive called RDX.

Ignition of RDX and dynamite

- Traditional fuse design: ignite one end of the cord, explosive material inside it burns at a steady pace, and the flame travels down the cord to the detonator on the other end- sets off the **primary charge**.

Blasting caps are used as a catalyst to set off the explosives loaded in support columns.

Apply a severe shock with a **blasting cap,** a small amount of explosive material (called the **primer charge**) connected to some sort of fuse.

Ignition of RDX and dynamite

- Electrical detonator : long electrical wire.
- Wire is surrounded by a layer of explosive material at the detonator end
- Detonator is attached directly to the primer charge affixed to the main explosives.
- Pass current through the wire (battery powered) wire heats up due to electrical resistance
- Heat ignites the flammable substance on the detonator end- in turn sets off the primer charge- triggers explosion.

Columns are fully loaded with explosives and hooked up to blasting caps and fuses.

How to Control Explosion?

- Configure the blast caps with simple **delay** mechanisms/timing devices, the blasters precisely dictate the order of the explosions.

i. Sections of slow-burning material positioned between the fuse and the primer charge.

ii. Use longer or shorter length of delay material, the blasters can adjust how long it takes each explosive to go off.

iii. Length of the fuse -it will take longer for the charge to move down a longer fuse than a shorter one.

Test Blast

- Quantity of explosives based on experience
- Test blasts to ensure overloading/ under-loading the support structure
- Number of trials with different amount of explosive charges.
- Use of necessary amount of explosive material- minimize flying debris, reduces damage to nearby structures.

Test blast performed on a concrete column

Final Steps before demolition

- Calculations on safety perimeter based on the size of the building and the amount of explosives used.
- Prepare neighboring building/people /local authority/ about care taken
- Measure ground vibrations and air-blasts during an implosion - Portable field seismographs
- Videotape from multiple angles – to create of record of what actually happened.

Blasting

- Blasting done with detonator controller with two buttons, one labeled "charge" and one labeled "fire."
- A blaster presses and holds the "charge" button until an indicator light comes on. This builds up the intense electrical charge needed to activate the detonators
- After the detonator-control machine is charged, and the countdown is completed
- The blaster presses the "fire" button (while still holding down the charge button), releasing the charge into the wires so it can set off the blasting caps.

Two types of blasting machines, a traditional rack-bar and a modern electronic control box

Post- Demolition

- Cloud of dust billows out around the wreckage, enveloping nearby areas

- After the cloud has cleared- survey and crucial to confirm that all of the explosives were detonated and to remove any explosives that did not go off.

The Frank Leux Building in Birmingham, AL, was demolished by Engineered Demolition, Inc. in the spring of 1997.


©Protec

View for learning on demolition equipment/methods

- https://www.youtube.com/watch?v=tRJz0PePXZ8
- https://www.youtube.com/watch?v=4wd2HdE8Ze4
- https://www.youtube.com/watch?v=5PM4V6JAWZI
- https://www.youtube.com/watch?v=j_gJPXmWaoE
- https://www.youtube.com/watch?v=IEO42qEAlrY
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- https://www.youtube.com/watch?v=VP8KjbXuP8Y
- https://www.youtube.com/watch?v=4rYudtAnHZI
- https://www.youtube.com/watch?v=BGbVn72eVYY

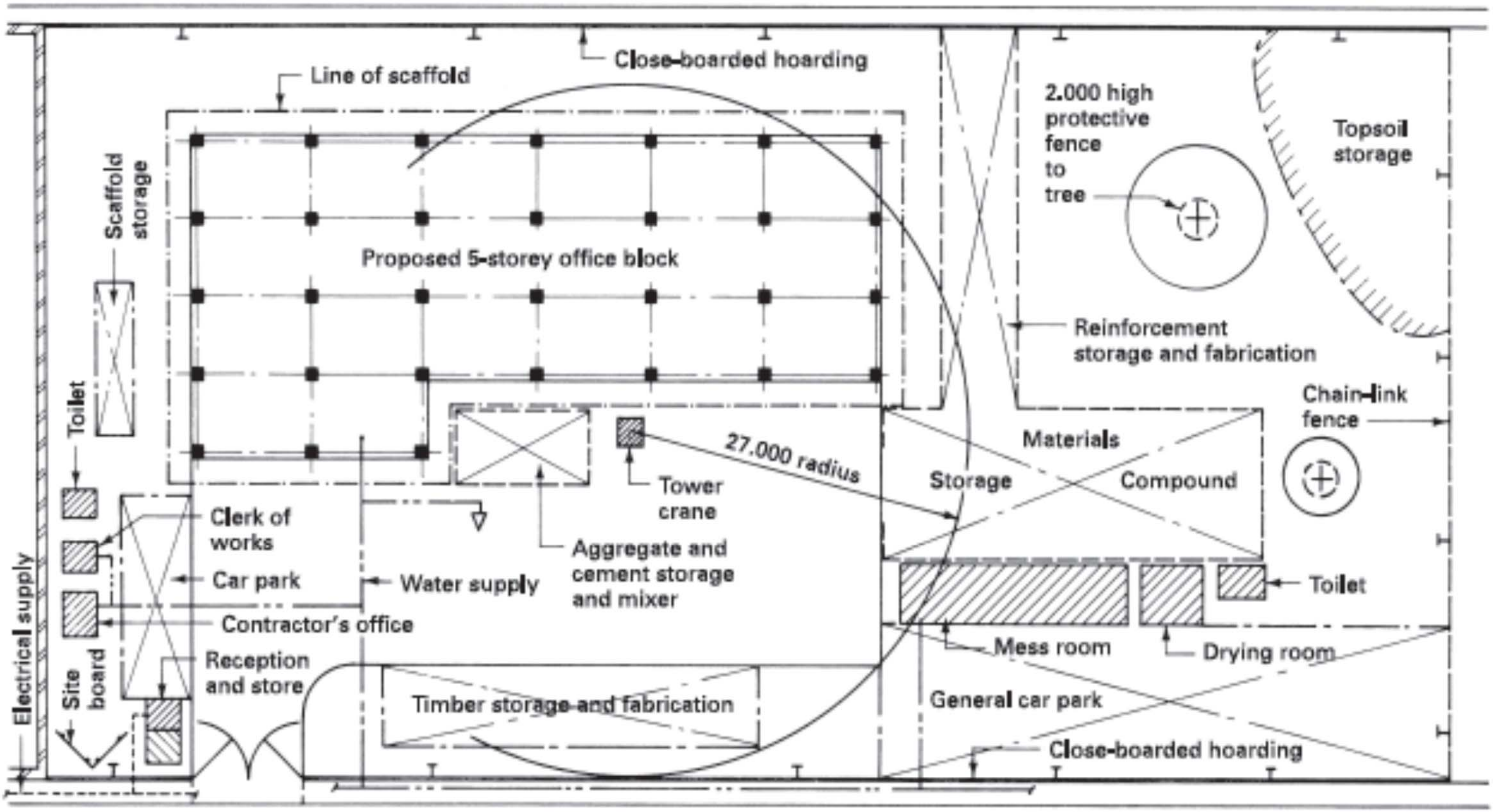
Site Organisation

Site Organisation

- Aim: to produce a layout that is logical, orderly and above all practical.
- Essential for efficient construction- safe, time, resource utilization and cost
- No two sites are the same - many variables involved- No perfect single solution
- Site layout plan indicates
  - locations construction
  - all facilities, accommodation and plant to secure optimum economy, efficiency, and safety during
  - Access to site including site construction, roads inside site for movement
  - Site accommodation: office, personnel and labor,
  - Storage of materials, plants and movement of plant,
  - Site electricity, lighting, and protection.
- Tidy site is the outward symbol of an efficient organization

Site Organisation topics

- Access to Site and Site Roads
- Site Drainage
- Site Accommodation
- Storage for Materials
- Storage for Equipment and Tools
- Plant Requirements and Movement of Plants
- Site Electricity
- Site Lighting
- Water for Construction
- Site Protection



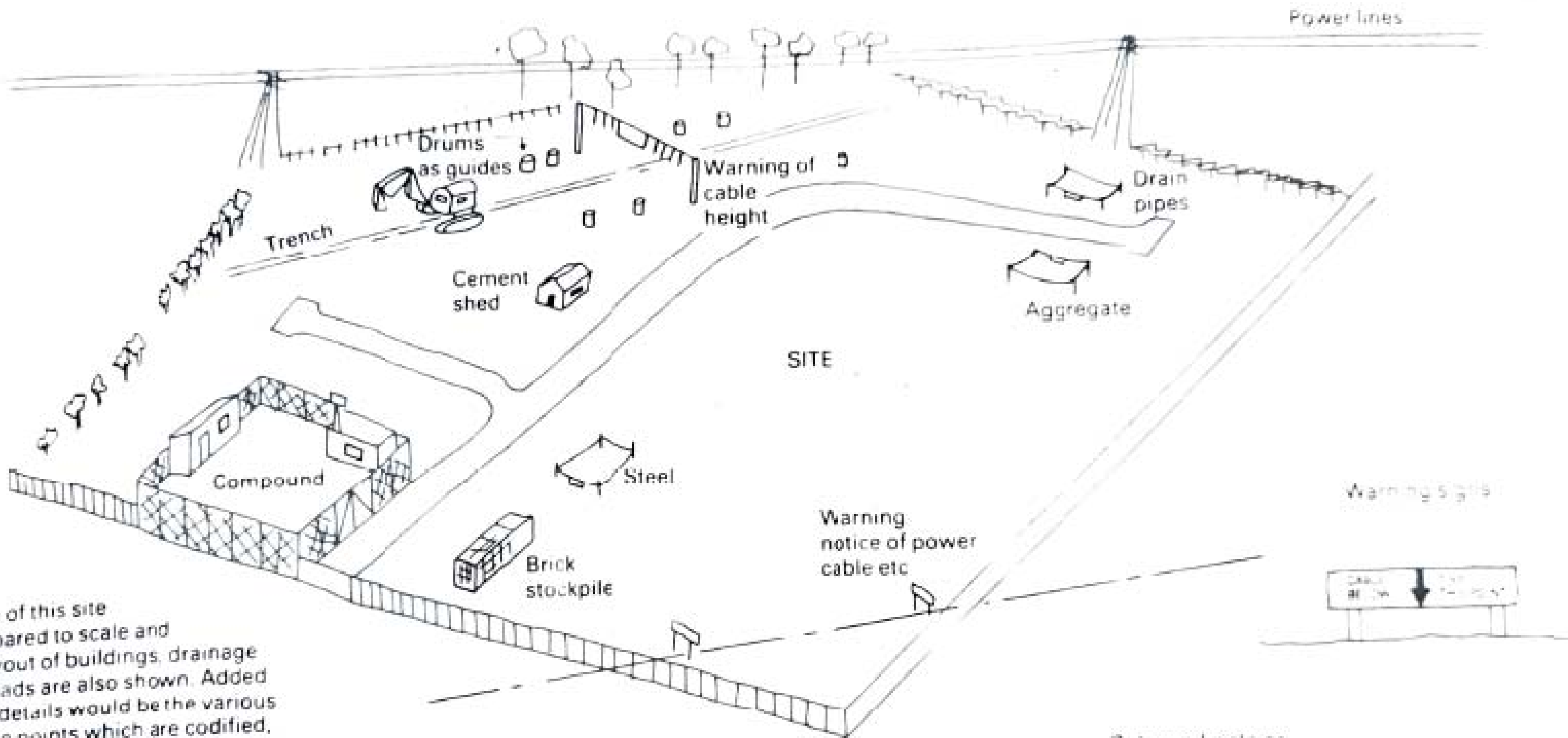
Close-boarded hoarding
Line of scaffold
2.000 high protective fence to tree
Topsoil storage
Scaffold storage
Proposed 5-storey office block
Reinforcement storage and fabrication
Toilet
Chain-link fence
27.000 radius
Materials
Storage
Compound
Tower crane
Clerk of works
Aggregate and cement storage and mixer
Car park
Water supply
Toilet
Electrical supply
Contractor's office
Mess room
Drying room
Reception and store
Site board
Timber storage and fabrication
General car park
Close-boarded hoarding

Access to site

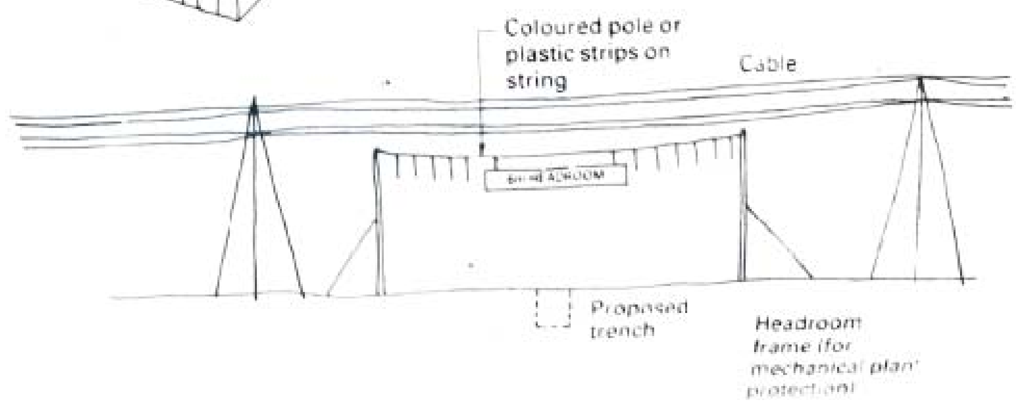
- Access to site – to be described in the contract.
- Site having more than one access:
  - Each entrance should be identified by either a letter or number
  - Instructions to be displayed- visitors/materials/equipment gates
  - Preferable to identify exit/entry only gates
- Access to fire-fighting equipment vehicles (from beginning to completion)
- Free access from the street to fire hydrant/static water tanks (fire fighting)
- Do not store construction materials within 3 m of hydrant/static water tanks.
- Free access to permanent and portable first aid and fire-fighting equipment.

Site Roads

- Identify early equipment/plants and its locations for efficient and economic operation
- Decision on type of roads is to be used (Ex: rough access, water bound or bitumen sprayed) – depend on i) type of plant, ii) ground conditions, iii) cost-effectiveness.
- Ex-1: Tracked vehicles fitted with grips cannot pass continuously over water bound or bitumen sprayed roads, as the grips on the tracks will destroy the surface.
- Ex-2: Heavy plant on flat tracks, such as diggers, cannot pass over soft or hard ground without seriously damaging the surface.
- Rough access roads: on-site traffic; water-bound or bitumen sprayed roads: on-off site traffic.
- Maintenance of Roads: Avoid breaking up of haunches/ditches/potholes-damage to vehicle
- Warning signs, speed limit and supervision - wherever vehicles cross over locations



A plan of this site is prepared to scale and the layout of buildings, drainage and roads are also shown. Added to the details would be the various storage points which are codified, to enable directions for off-loading to be given to lorry drivers and staff.



Site drainage: Surface Drainage

- Controlling storm runoff is a major factor in preparing a grading plan.

- To prevent erosion/flooding, principle of positive drainage is used- divert storm away from a building or area and carry it away from a site in a storm drainage system.

- Spot elevations are set at critical points adjacent to a building to provide drainage.

- Choose location of catch basins, and their connection to existing drainage channels in the area or to an existing storm drainage line

- Surface drain lines are called storm sewers and are constructed with tight /closed joints.

- Surface drainage: Adjust ground slopes to allow runoff of storm water and its interception at various intervals at catch basins.

Site drainage: Surface Drainage

- Drainage systems: High-cost items in site organization
- Design: based on the amount of rainfall to be carried away at a given time.
- Runoff: Portion of precipitation which finds its way into natural/artificial channels either

  i) as surface flow during the storm period or

  ii) as subsurface flow after the storm has subsided.
- Runoff: volume of water discharged from a given watershed area in m^3/sec
- Factors affecting Runoff:

  i) intensity of storm, amount of rainfall, and its duration, and

  ii) watershed characteristics- porosity of soil, gradient or slope, and vegetative cover.

Site Drainage: Sub-surface drainage

- Involves the control and removal of soil moisture.
- Carries water away from impervious soils, clay, and rock
- Prevents seepage of water through foundation walls
- Powers water tables for low flat land
- Prevents unstable subgrade or frost heaving, and
- Removing surface runoff in combination with underground drainage.
- <u>Design</u>: Provide horizontal passage in subsoil–to collect gravitational water-direct to outlets
- Drain lines be either open joints or employ perforated pipe.

Site Drainage: Sub-surface drainage

Factors affecting Flow into subsurface drains

i) soil permeability,

ii) depth of drain below soil surface,

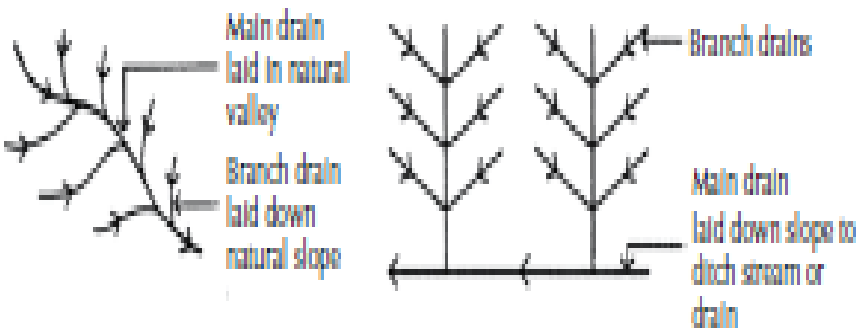
iii) size and number of openings into the drain,

iv) drain spacing, and diameter.

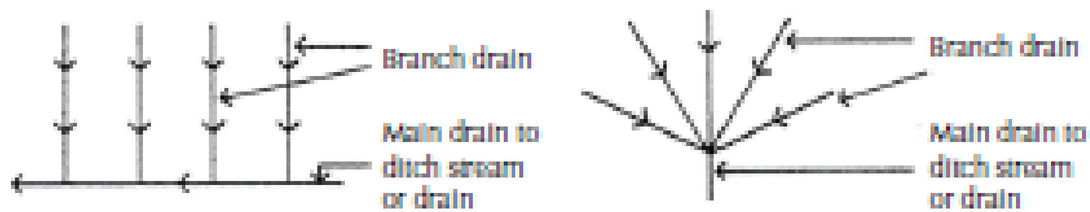
Site Drainage: Sub-surface drainage

Different systems of subsurface drainage:

1) Natural: For areas that do not require complete drainage.
2) Herringbone: In areas of land with a concave surface with land sloping in either direction. This system should not have angles over 45.
3) Grid: Used where laterals enter the main from one side- intersect at $<90^0$.
4) Fan-Shaped: Short branches drain to spine pipe – lead to drain/ditch



(a) Natural system of drains (b) Herringbone system of drains

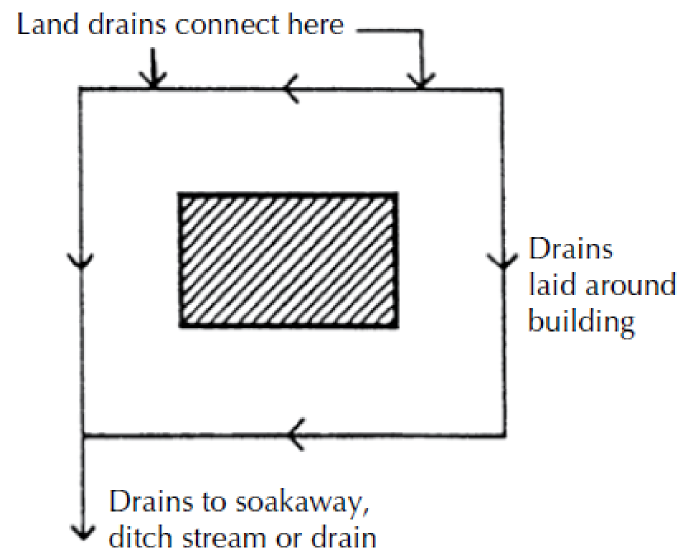


(a) Grid system of drains (b) Fan-shaped system of drains

Site Drainage: Sub-surface drainage

5) Moat or Cut off system:

- Laid some distance from and around the new building
- Drain the ground between it and the new building,
- Carry water from diverted land drains down the slope of the site.
- Should be clear of paved areas around the building



Moat or cut-off system.

Site accommodation

Site Accommodation: Need

- Administrative offices for contractor/ Engineer-in-charge/ Third party PMC
- Retiring rooms for workers
- Temporary housing accommodation for workers at remote sites
- Rest rooms/washrooms

Construction- temporary activity: do not justify the provision of permanent buildings

Why and How accommodation Help:

- Promotes good relationship between management and staff,
- Reduces the loss of materials due to theft, accidental damage and vandalism.
- Increases productivity through better facilities and amenities on a site for staff
- Compliance to statutory regulations- worker welfare

Site Accommodation: Siting of Administrative Office

- Site office: Varies with site/nature of work
- Estimate: Site office 150 m^2 for ~ 300 workers; 200-300 m^2 for ~ 1,000-1,500
- Locate Office & general storage for equipment & storekeeper room near the main entrance
- Avoid obstructing the entrance to the other vehicles while checking is carried out.
- Position offices to allow overall view of entrance and site
- Resident Engineers' & sub-contractor's office to be close to contractor's office
- Reduces driving down through construction area to reach office

Site Accommodation: Type of construction

Offices: Artificial lighting, desks, tables/ chairs, cash chests, toilet, meals room etc.

Alternate Materials of construction:

- Masonry walls (Constructed with mud mortar/lean lime mortar- easy dismantling) with thatched roof/GI-FRP sheets
- Timber huts (prefabricated to allow for ease of dismantling and assembly to facilitate the reuse on other sites)
- Mobile caravans or cabins

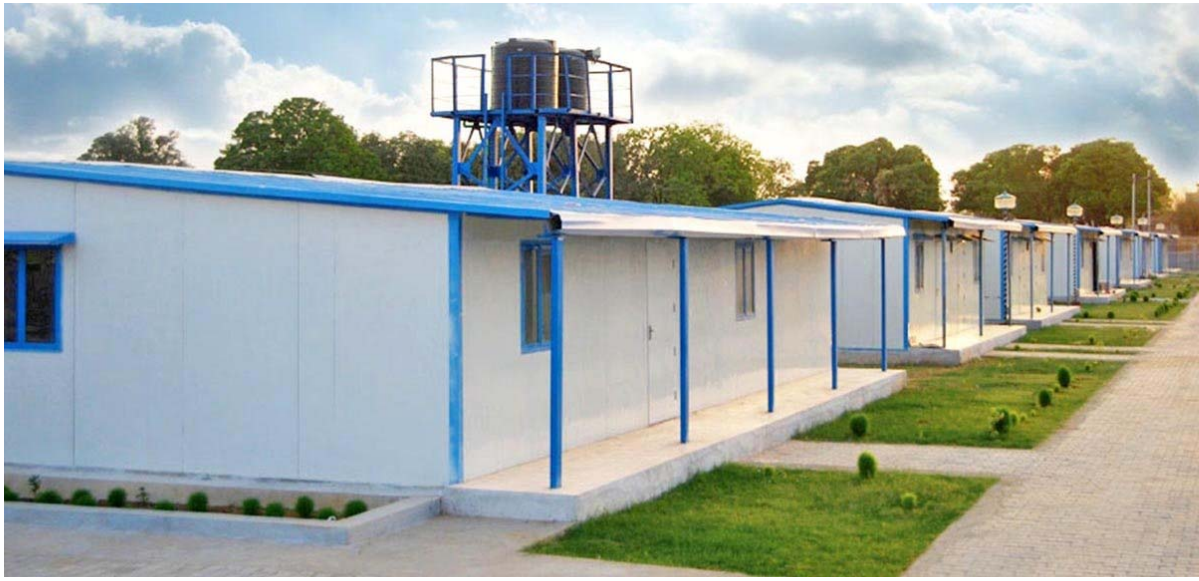
  Ply clad timber frame - insulated and decorated - equipped with all necessary furniture, light, HVAC units, sanitary fittings- connected to site service lines.

  Caravans can be towed; Cabins require special transporter trailers. High initial cost- Installtion faster- 100% reuse


PROJECT OFFICE

Site Accommodation: Temporary Housing for workers

- Migrant Labourers & remote sites:
  - Remote site accommodation
  - Transport to reach the site if they can not reach by walk
  - increases the cost and
  - May also generate administrative and social problems.
- Positive aspect: Encouraging migrant labourers to bring their families improves social relations between the camp and the neighbouring area during the construction work.
- Negative point: may make the migrant labourers to settle in the project area after the construction work is completed.
- Unless the project location contributes continuous construction activities, permanent settlement of the migrant workers could create conflicts with the local population.



Site Accommodation: Temporary Housing for workers

Points for setting up labor camps:

- Located on high, well drained ground.
- Within walking distance of the site - but separated (Min 200 m)
- For longer distance- provide vehicles for to and fro to site
- Size: Floor area of 5 sq. m per person
- Locate away from villages – to avoid clashes with local people.

Site accommodation: Essential facilities

- First-aid: Location of First aid boxes to be marked- Trai. Train persons in first aid procedures.
- Provide with meals room, sanitary and washing facilities.
- Provide Rest room and clothing room in large construction sites.
- Fire precaution/protection/prevention:
  - Locate Temporary site buildings/accommodation/storage - to cause the min. fire hazard
  - Shall be constructed from non-combustible materials as far as possible.
  - Training on use of portable fire extinguishers/water
- Temporary services: Telephones, electricity, water supply and sanitation.

Time-Temperature Curve for Fire Development

Complete process of fire development inside a typical room
assuming no fire suppression by sprinklers or fire fighters

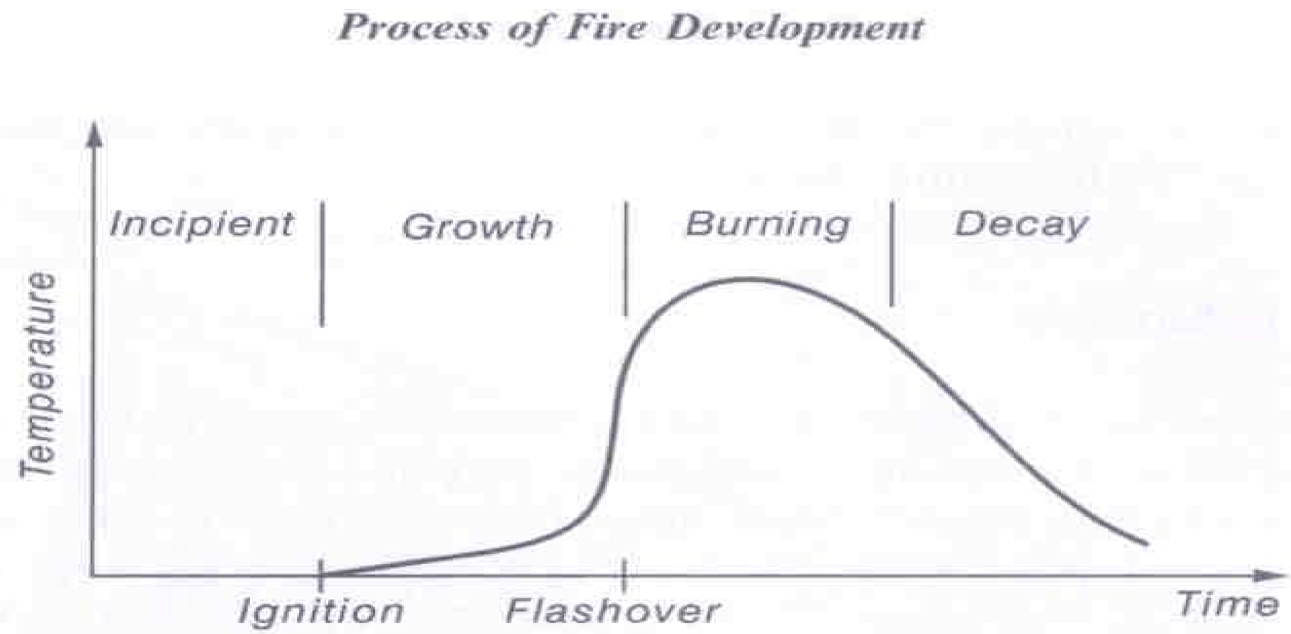


Figure 2.2 Time–temperature curve for full process of fire development

Some fires go out prematurely – others do not reach flashover
(fuel is small- isolated- not enough air) (large opening- heat flows out)

Fire Behaviour

Incipient period: heating of potential fuel

Ignition: start of flaming combustion

Growth period: fire spread slowly at first on combustible surfaces-then more rapidly as fire grows- provides radiant feedback from flames and hot gases to other fuel items

Flash over: Transition to the *burning period* - occurs when the upper layer temperature reach about 600°C

Fire Behaviour

- Rate of burning in growth period- controlled by nature of burning fuel surfaces

- <u>Burning period</u>: temp. and radiant heat flux within the room are so great that all exposed surfaces are burning and the rate of heat release is governed by available ventilation

- It is the burning period of fire that impacts on structural elements and compartment boundaries.

- <u>*Decay Period*</u>*:* Eventually the fuel burns out and temperature falls in the *decay period.*

SUMMARY OF PERIODS OF TYPICAL FIRE DEVELOPMENT

Table 2.1 Summary of periods of typical fire development

	Incipient period	Growth period	Burning period	Decay period
Fire behaviour	Heating of fuel	Fuel controlled burning	Ventilation controlled burning	Fuel controlled burning
Human behaviour	Prevent ignition	Extinguish by hand, escape	Death	
Detection	Smoke detectors	Smoke detectors, heat detectors	External smoke and flame	
Active control	Prevent ignition	Extinguish by sprinklers or fire fighters; control smoke	Control by fire-fighters	
Passive control		Select materials with resistance to flame spread	Provide fire resistance; contain fire, prevent collapse	

Human behaviour

- *Incipient period*: people sense the potential fire during this period
- Many fires are averted by occupants who remove the fuel or eliminate the ignition source.
- *Ignition period*: Fire is more obvious and can be extinguished when small.
- If the fire has grown to involve a whole item of furniture or more, it cannot be extinguished by hand but the occupants have the opportunity to escape.
- *Growth period* : conditions in the room become life threatening
- After *flashover* survival is not possible (extreme conditions of heat, and toxic gases)

Fire detection

Incipient period : human detection possible by sight or smell.

Automatic sensing before ignition is possible if a very sensitive aspirating smoke detector has been installed .

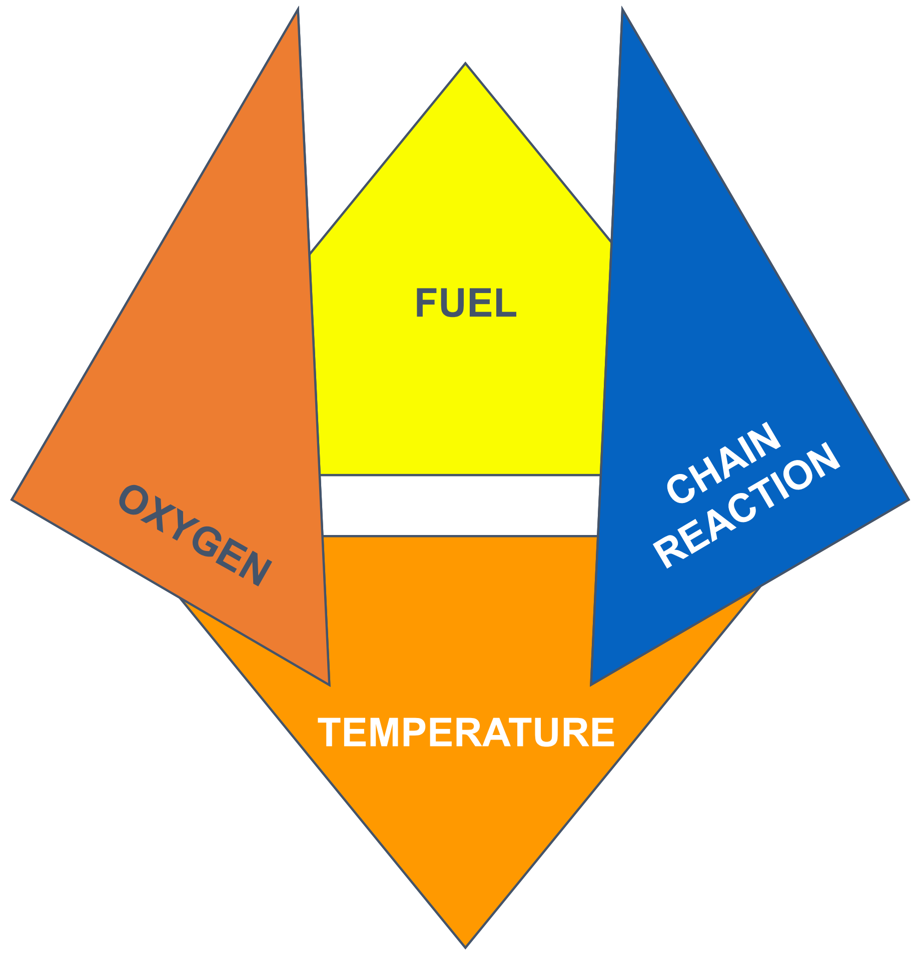
After *ignition*, a growing fire can be detected by the Occupants or a smoke detector or a heat detector located on the ceilings – automatic sprinkler system is activated

- Smoke detectors are more sensitive than the heat detectors

- After *flashover* -neighbours detect the fire coming out of the windows or openings.

The Combustion Process

THE FIRE TETRAHEDRON



Source of Ignition (Fuel)

- Organic materials: Naturally occurring materials on earth
  - wood, coal, paper

- Flammable liquids: Liquids that produce a vapor below 32^{o}C that will readily ignite from an ignition source
  - paints, thinners, solvents

- Flammable gases: Gases normally under pressure in bottles, tanks and piped systems (i.e. propane for burning/heating torchs, acetylene - burning/heating).
  - butane, propane

Source of Ignition (Heat)

- *Electrical* - fires, contactors, switches
- *Smoking* - lighters, matches, cigarette tips
- *Hot Surfaces* - cookers, oven rings
- *Chemical Reactions* - acid and water, epoxy adhesives
- *Static Sparks* - Dry atmosphere and electrical charge build up (e.g. walking on carpets in dry air-conditioned offices). Fast rotating or moving materials (e.g. machines).
- *Lightning* - High build up of electrical charge will seek the easiest path to earth.

Source of Ignition (Oxygen)

- Oxygen: 1/5 of the atmosphere

- Oxygen: Man made supplies, i.e. pressurized liquids in bottles, high pressure tanks/spheres

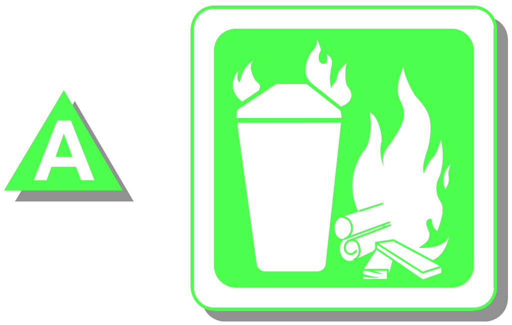
- Test for leaks should be undertaken at gauges and other connections - Use soapy water for leak testing.

Fire classifications

- Class A - ordinary combustibles
- Class B - flammable liquids
- Class C - electrical fires
- Class D - metals fires

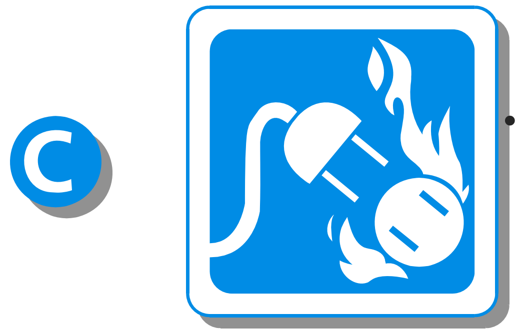
Fire Classes

A Trash Wood Paper



- wood
- cloth
- paper
- rubber
- many plastics

C Electrical Equipment



- *energized electrical equipment*

B Liquids Grease

- *gasoline*
- *oil*
- *grease*
- *tar*
- *oil-based paint*
- *lacquer*
- *flammable gases*

COMBUSTIBLE

METALS

- *magnesium*
- *sodium*
- *potassium*
- *titanium*
- *zirconium*
- *other flammable metals*

Fire Extinguisher Applications

FIRE CLASS	*EFFECTIVE EXTINGUISHER TYPES*
A Trash Wood Paper 	PRESSURIZED WATER, MULTIPURPOSE DRY CHEMICAL, LARGER SIZE HALON, WET CHEMICAL
B Liquids Grease 	MULTIPURPOSE DRY CHEMICAL, CARBON DIOXIDE, HALON
C Electrical Equipment 	MULTIPURPOSE DRY CHEMICAL, CARBON DIOXIDE, HALON, WET CHEMICAL
COMBUSTIBLE  METALS	COMBUSTIBLE METAL
K Cooking Media 	WET CHEMICAL

Fire Extinguisher Summary

EXTINGUISHER TYPE	*WORKS BY*	*EFFECTIVE AGAINST*
PRESSURIZED WATER	**COOLING**	 A
CARBON DIOXIDE	**SMOTHERING**	 B C
MULTIPURPOSE DRY CHEMICAL	**SMOTHERING**	 A B C
HALON	**SMOTHERING**	 A B C
COMBUSTIBLE METAL	**SMOTHERING**	 D
WET CHEMICAL	**COOLING/ SMOTHERING**	 A C

Storage of Materials: Need/Objective

- To prevent deterioration or intrusion of foreign matter
- To ensure preservation of their quality and fitness for the work.
- Type of storage required for a material depends on
  - Durability requirements and
  - Vulnerability to damage or theft
  - to avoid double handling
- Segregate materials by type, size and length
- Place in neat, orderly piles that are safe against falling- get damaged- cause injury
- If piles are high-shall be stepped back at intervals in height- not to cause hazard to passerby
- stairways/passageways/gang-ways: keep free from obstructions (materials, tools or trash)

Storage of Materials: Need/Objective

- Stacks closer to passageway: Day- post warning signs; Night- keep red lights around.
- Inspection and removal: Arrange Stacks/piles of materials with 1m passageway around
- Store materials on well drained, firm and unyielding surface.
- Stacked material should not cause any undue stressed on walls or other structures.
- Material with fire hazard (timber, coal, paints): to provide protection against fire/to minimize fire spread- segregate from each other.
- Permission needed for stacking of materials on roadside berms in the street/public places
- Remove remnants after the construction is over, to avoid any hazard to the public.

Storage of Materials: Cement

- Smaller & medium usage: 50kg bags
- Bulk usage: storage in silos/site-based RMC plant/Use of RMC avoid large storage at site
- Storage: Dry, leak-proof and moist proof Building/shed
- Building to be free from draughts/moist air: may cause an air set of material (hardening)

- Protection from dampness
  - well-ventilated building
  - Should not be stored directly on the ground- to eliminate dampness
  - Stack off the floor on wooden planks – keep 150 to 200 mm clear from the floor

- Leave a minimum space of 450 mm all round between exterior walls and stacks.
- Stack cement bags close together to minimise circulation of air within a stack


CEMENT
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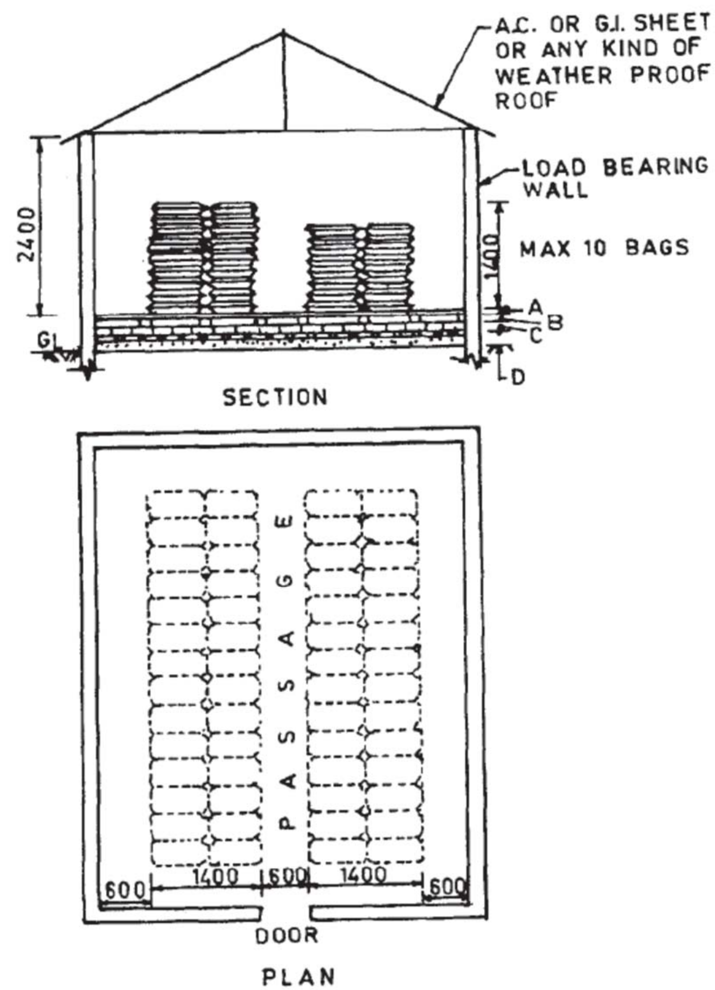


A = Planks
B = Wooden Battens
C = 150 Dry Bricks in Two Layers or Lean Cement Concrete
D = 150 Consolidated Earth

All dimensions in millimetres.

FIG. 1 TYPICAL ARRANGEMENT IN CEMENT GODOWN

Storage of Materials: Cement

- Cement storage for long time to be avoided
- Store to facilitate rotational use (Use in the order of receipt)
- Schedule delivery to avoid prolonged storage
- Restrict: Stack width:4 bags length/3m; height:15 bags; Avoids lumping up under pressure
- Humid Climate: Do not store more than 2 months
- Dry Climate: storage for a season's requirements if delay in delivery anticipated
- Storage during monsoon/humid areas/when the cement stored for a longer period: Enclose stack completely with water proofing membrane.
- Rule of thumb: A room of 40 m^2 area; h= 2.5 m -allowing for air circulation around walls– stores 50t of cement.

Storage of Materials: Lime

Quicklime before slaking (burnt limestone, calcium oxide (CaO)) : Slake it as soon as possible.

- Store as compact heaps on a platform-cover avoid blown away or contact with rain or water
- Quicklime stored in a shed: min. 300 mm around the heaps - to avoid bulging of walls.
- Separate from combustible materials to prevent fire hazards

Hydrated lime($CaOH_2$): Supplied in jute bags lined with high-density polyethylene woven bags lined with polyethylene/craft paper-

- store in a shed/building - protect from dampness- minimize the warehouse deterioration

Dry slaked lime: Short storage: store on a platform - covered to protect from rain and wind.

Long Storage: store in a dry and closed shed/building

Storage of Materials: Masonry units

- MUs shall not be dumped at random location
- Store different types separately – avoid double handling is kept minimum.
- Stack on firm ground in regular tiers directly as they are unloaded -to minimize breakage
- For ease inspection and counting- Stack bricks on edge -each stack is 50 bricks long, 10 bricks high, and not more than 4 bricks wide.
- Clear distance between stacks: 0.80 m.
- Facing bricks: Cover with tarpaulin or polythene sheet to prevent discoloration
- Stack concrete Hollow/solid/AAC/ stone blocks in stable stacks – avoid damage, toppling.

Storage of Materials: Aggregate

- Fine and coarse aggregates shall be stored on a hard dry and level patch of ground.
- Store on platform of planks/corrugated iron sheets/floor of bricks/layer of lean concrete -to avoid contamination with clay, dust, vegetation, and other foreign matter.
- Stack FA in a place to prevent being blown by wind.
- Stack CA and FA in separate stockpiles with dividing walls to prevent getting intermixed.
- Requirement of CA in different sizes – stack separately with partitions – label clearly
- Make sure that stockpiles are not used as a rubbish tip.


CAT


BAY 5
BAY 4
BAY 3
BAY 2


3
4
5

Table 7 Coarse Aggregates

(*Clauses* 6.1 *and* 6.2)

Sl No.	IS Sieve Designation	Percentage Passing for Single-Sized Aggregate of Nominal Size						Percentage Passing for Graded Aggregate of Nominal Size			
		63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm	40 mm	20 mm	16 mm	12.5 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	80 mm	100	-	-	-	-	-	100	-	-	-
ii)	63 mm	85 to 100	100	-	-	-	-	-	-	-	-
iii)	40 mm	0 to 30	85 to 100	100	-	-	-	90 to 100	100	-	-
iv)	20 mm	0 to 5	0 to 20	85 to 100	100	-	-	30 to 70	90 to 100	100	100
v)	16 mm	-	-	-	85 to 100	100	-	-	-	90 to 100	-
vi)	12.5 mm	-	-	-	-	85 to 100	100	-	-	-	90 to 100
vii)	10 mm	0 to 5	0 to 5	0 to 20	0 to 30	0 to 45	85 to 100	10 to 35	25 to 55	30 to 70	40 to 85
viii)	4.75 mm	-	-	0 to 5	0 to 5	0 to 10	0 to 20	0 to 5	0 to 10	0 to 10	0 to 10
ix)	2.36 mm	-	-	-	-	-	0 to 5	-	-	-	-

Table 8 Sizes of Coarse Aggregates for Mass Concrete

(*Clause* 6.1.1)

Sl No. (1)	Class and Size (2)	IS Sieve Designation (3)	Percentage Passing (4)
i)	Very large, 150 to 80 mm	160 mm	90 to 100
		80 mm	0 to 10
ii)	Large, 80 to 40 mm	80 mm	90 to 100
		40 mm	0 to 10
iii)	Medium, 40 to 20 mm	40 mm	90 to 100
		20 mm	0 to 10
iv)	Small, 20 to 4.75 mm	20 mm	90 to 100
		4.75 mm	0 to 10
		2.36 mm	0 to 0.2

Table 9 Fine Aggregates

(*Clause* 6.3)

Sl No.	IS Sieve Designation	Percentage Passing			
		Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
(1)	(2)	(3)	(4)	(5)	(6)
i)	10 mm	100	100	100	100
ii)	4.75 mm	90-100	90-100	90-100	95-100
iii)	2.36 mm	60-95	75-100	85-100	95-100
iv)	1.18 mm	30-70	55-90	75-100	90-100
v)	600 µm	15-34	35-59	60-79	80-100
vi)	300 µm	5-20	8-30	12-40	15-50
vii)	150 µm	0-10	0-10	0-10	0-15

NOTES

Table 10 All-in-Aggregate Grading

(*Clause* 6.4)

Sl No.	IS Sieve Designation	Percentage Passing for All-in-Aggregate of	
		40 mm Nominal Size	20 mm Nominal Size
(1)	(2)	(3)	(4)
i)	80 mm	100	—
ii)	40 mm	95 to 100	100
iii)	20 mm	45 to 75	95 to 100
iv)	4.75 mm	25 to 45	30 to 50
v)	600 µm	8 to 30	10 to 35
vi)	150 µm	0 to 6	0 to 6

Table 2 Limits of Deleterious Materials

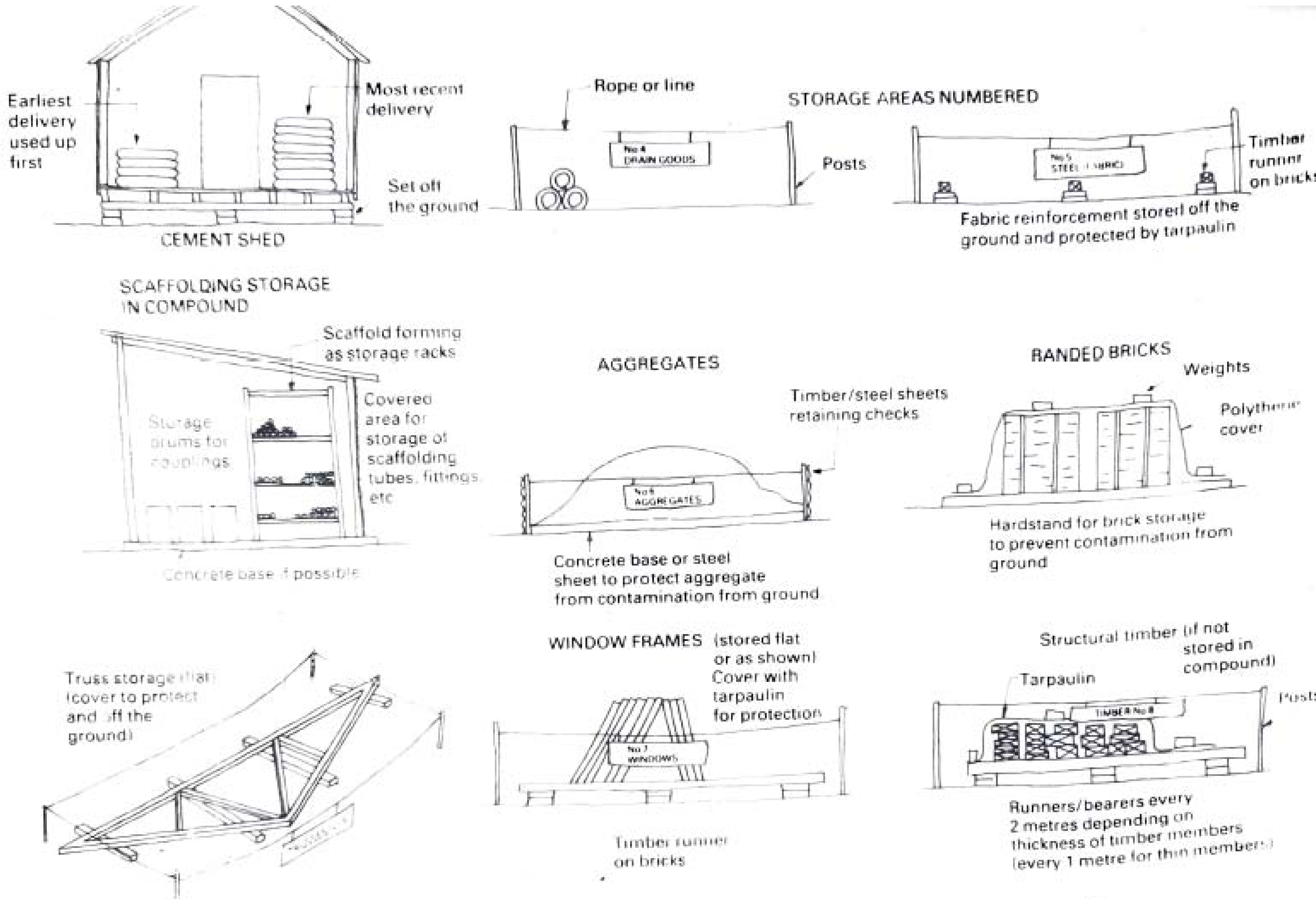
(*Clause* 5.2.1)

Sl No.	Deleterious Substance	Method of Test, Ref to	Fine Aggregate Percentage by Mass, *Max*			Coarse Aggregate Percentage by Mass, *Max*		
			Uncrushed	Crushed/ Mixed	Manufactured	Uncrushed	Crushed	Manufactured
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Coal and lignite	IS 2386 (Part 2)	1.00	1.00	1.00	1.00	1.00	1.00
ii)	Clay lumps	IS 2386 (Part 2)	1.00	1.00	1.00	1.00	1.00	1.00
iii)	Materials finer than 75 µm IS Sieve	IS 2386 (Part 1)	3.00	15.00 (for crushed sand) 12.00 (for mixed sand) *see* Note 1)	10.00	1.00	1.00	1.00
iv)	Soft fragments	IS 2386 (Part 2)	—	—	—	3.00	—	3.00
v)	Shale	(*see* Note 2)	1.00	—	1.00	—	—	—
vi)	Total of percentages of all deleterious materials (except mica) including Sl No. (i) to (v) for col 4, 7 and 8 and Sl No. (i) and (ii) for col 5, 6 and 9	—	5.00	2.00	2.00	5.00	2.00	2.00

Table 1 Extent of Utilization
(*Clause* 4.2.1)

Sl No.	Type of Aggregate	Maximum Utilization		
		Plain Concrete Percent	Reinforced Concrete Percent	Lean Concrete (Less than M15 Grade) Percent
(1)	(2)	(3)	(4)	(5)
i) Coarse aggregate:				
a)	Iron slag aggregate	50	25	100
b)	Steel slag aggregate	25	Nil	100
c)	Recycled concrete aggregate[1)] (RCA) (*See* Note 1)	25	20 (Only upto M25 Grade)	100
d)	Recycled aggregate[1)] (RA)	Nil	Nil	100
e)	Bottom ash from Thermal Power Plants	Nil	Nil	25
ii) Fine aggregate:				
a)	Iron slag aggregate	50	25	100
b)	Steel slag aggregate	25	Nil	100
c)	Copper slag aggregate	40	35	50
d)	Recycled concrete aggregate[1)] (RCA) (*See* Note 1)	25	20 (Only upto M25 Grade)	100

Materials	*Size of Stack* (in m)		
	Length	Breadth	Height
Soling stone	5.0	2.0	0.50
	or 5.0	1.0	0.50
Coarse aggregate	2.0	2.0	0.50
	or 5.0	5.0	1.00
Fine aggregate	2.0	2.0	0.50
	or 5.0	5.0	1.00
	or 5.0	1.0	0.50



Note: The positions are marked out at commencement of work (at site establishment stage) to ensure neat layout and to prevent excess handling, damage, deterioration, discolouration, contamination. Drivers (delivery) can also be easily directed to storage areas

Fig. 7.3.3 Storage and signs

Storage of Materials: Fly ash

- Store each consignment separately
- To be easily accessible for inspection and identification of each consignment.
- Storage provision for bulk quantities of fly ash is like that of fine aggregate.
- Fly ash in Bags: Max. height of stack =15 bags high.

Table 1 Storage and Stacking Check List
(*Clause* 4.1)

Sl No.	Material/ Component	Base			Stack				Type of Cover		
		Firm Level Ground	Hard Floor	Off-Floor	Heaps	Tiers	Flat	Vertical	Open	Open but Covered	Under Shed
1.	Cement			√		√					√
2.	Lime										
	a) Quick lime		√		√					√	
	b) Hydrated lime			√		√					√
3.	Stones and Aggregates										
	a) Stones, aggregates, fly ash and cinder	√			√				√		
	b) Veneering stones	√				√		√	√		
4.	Bricks and Blocks	√				√			√		
5.	Tiles										
	a) Clay and concrete floor, wall and roof tiles	√				√	√		√		
	b) Ceramic tiles		√			√	√				√

Storage of Materials: Timber

- Timber is a hygroscopic material- prevent induced moisture movement–maintain moisture content
- Stack over well treated and even surface beams/sleepers/brick pillars – 150 mm above ground – to eliminate getting affected by accumulation of water
- Each size members be stored separately
- Materials of equal length shall be piled together in layers with wooden battens

  (Crossers- made of sound wood, straight and uniform in thickness) which separates one layer from another. The crossers shall be placed in each layer in vertical alignment
- Non-availability of Crossers: use smaller sections of available structural timber.
- In any layer, an air space of about 25 mm shall be provided between adjacent members.
- Longer pieces shall be placed in the bottom layers and the shorter pieces in the top layers, but one end of the stack shall be in true vertical alignment.

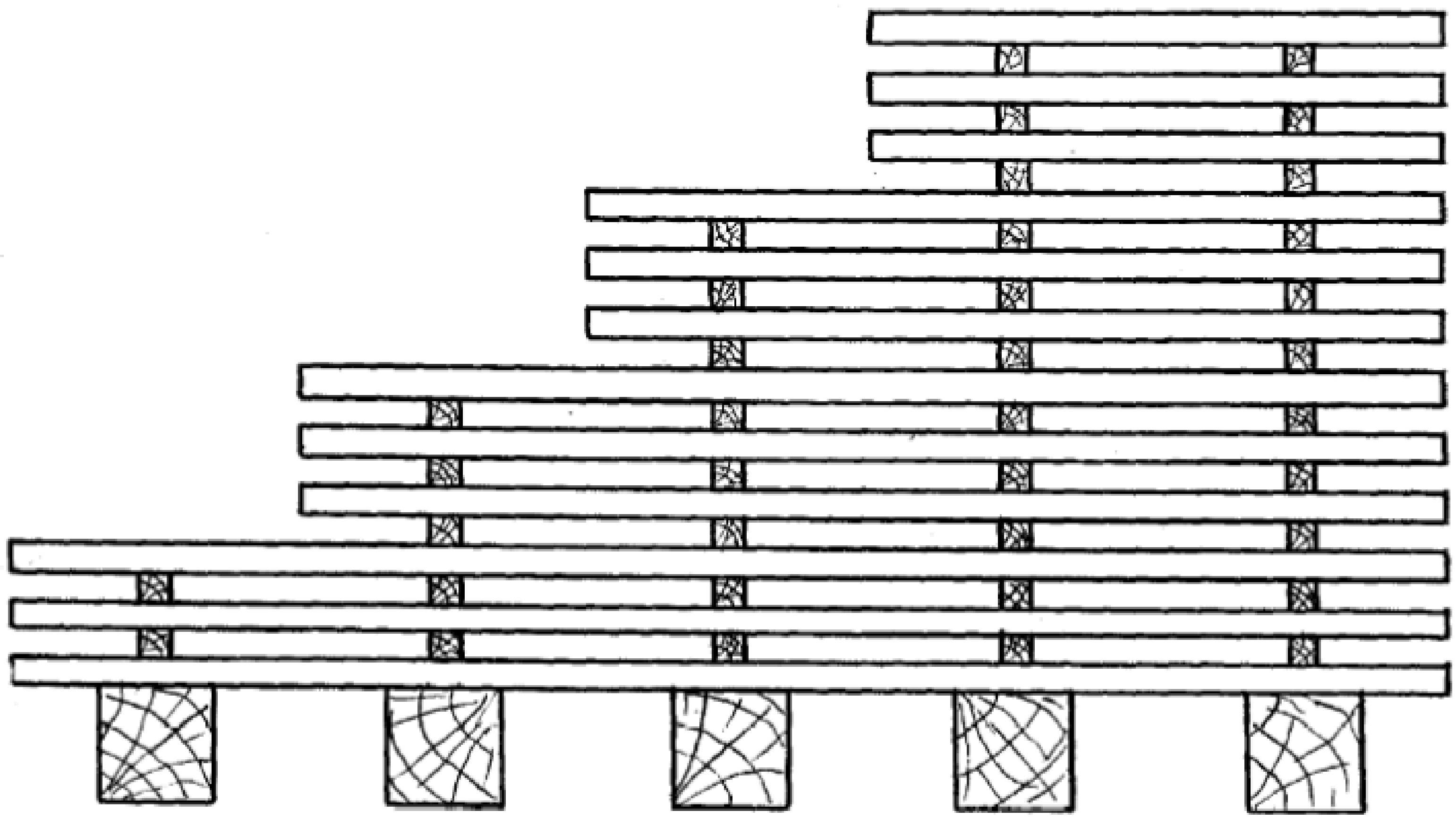
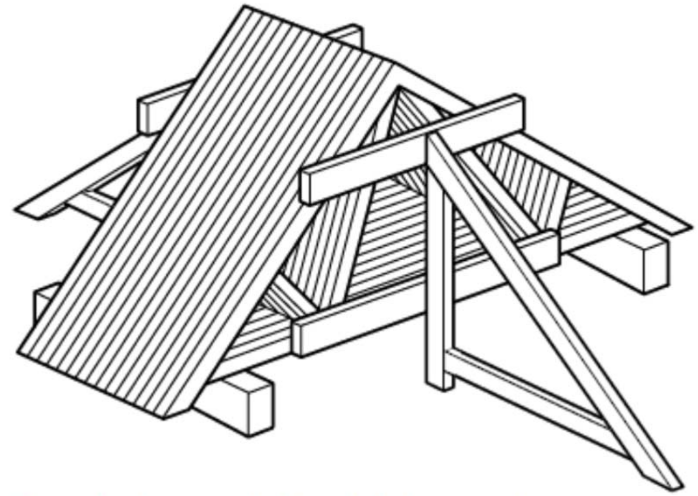


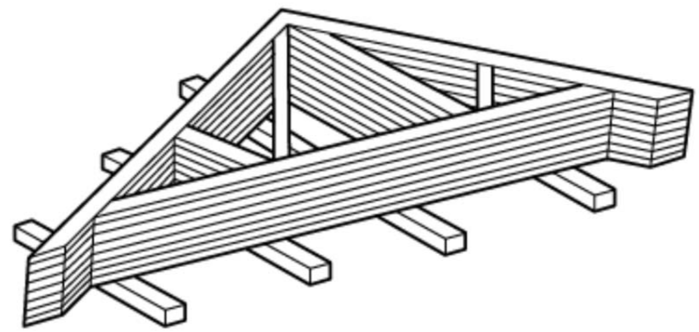
FIG. 1.1 TYPICAL TIMBER STACK

Storage of Materials: Timber

- Width of stack: 1.5 m; Height of stack: 2.0 m
- Distance between adjacent stacks: min. ~400 – 500 mm.
- Ideal storage: a rack of scaffold tubular with a sheet roof covering
- In case of stacking with battens are not possible- store on raised foundations, close piled in heaps satisfying the above height, width and spacing requirements.
- Protect stacks from hot dry winds or direct sun and rain.
- Place heavy weights (metal rails/large sections of wood) on top of the stack to prevent distortion or warping of the timber in stacks.
- Long duration storage (> 1 year) –to prevent end-cracking in the material- coat ends of members with coal tar or aluminum leaf paints or microcrystalline wax



Trussed rafters: vertical stack before covering



Trussed rafters: horizontal stack before covering

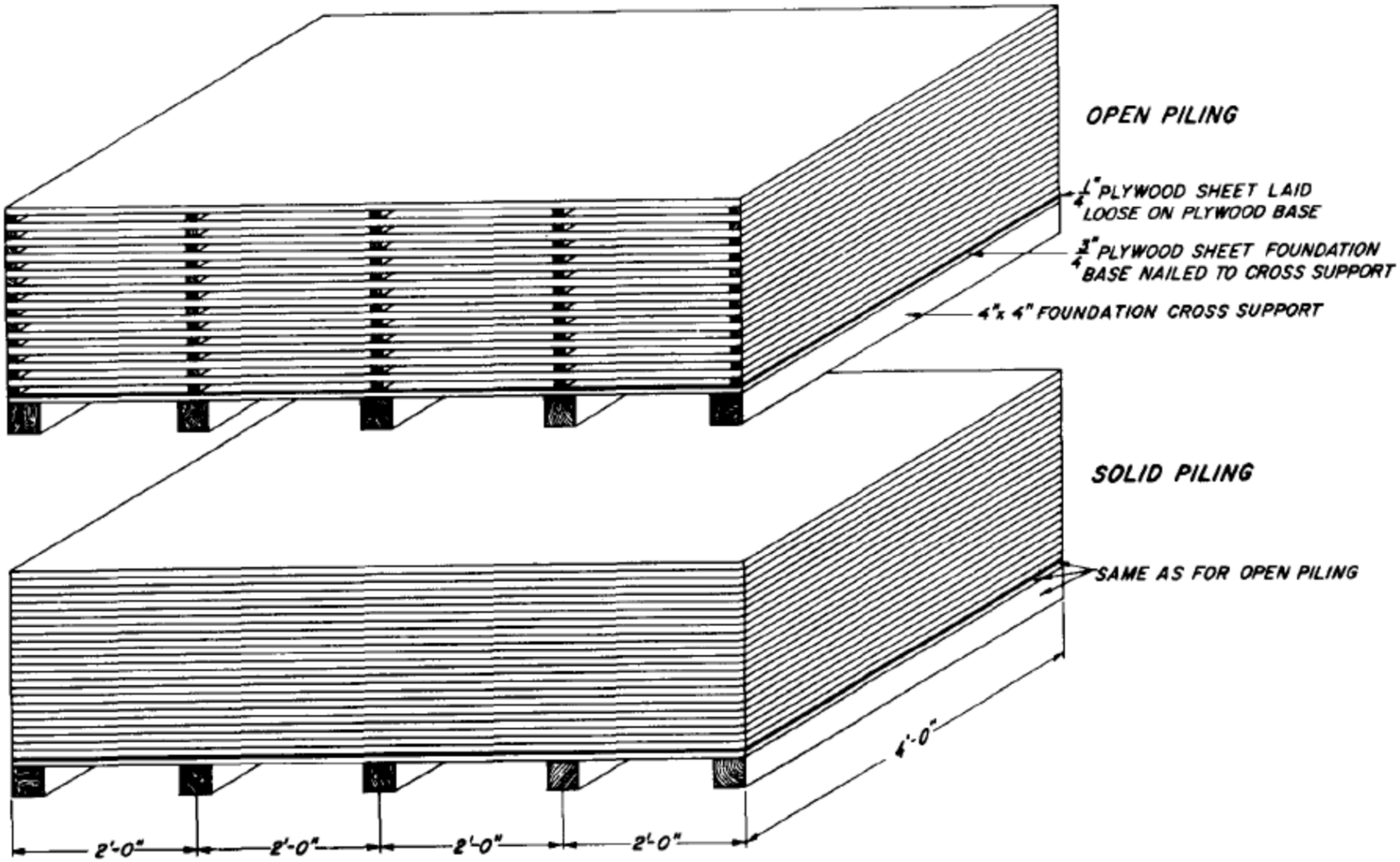


Figure 30.—Plywood correctly piled on a platform foundation. Solid piling is adequate unless plywood is over 20 percent moisture content.

Storage of Materials: Structural/Reinforcing/Pre-stressing Steel

- Store to prevent distortion and corrosion.
- To prevent scaling and rusting- coat steel with cement wash before staking.
- To facilitate issue in sizes and lengths as to minimize wastage- Store bars of different classification, size, length separately
- Store Structural steel on a platform 150 mm above GL- stack each classification separately
- For easy identification: Paint ends of bars and sections of each class with separate nominated colours

Storage of Materials: Doors, Windows, and Ventilators

- Metal doors, windows and ventilators: Stack in upright (on their sills) on wooden battens – free from dirt or ashes.
- Stack as per manufacturer's instructions- remove from crates only as and when required.
- Metal frames: shall not be stored for long periods to avoid getting out of shape and hinges being strained and shutters drooping.
- Aluminum frames and shutters: Protect from loose cement/mortar by suitable tarpaulin coverings supported on temporary framing to permit circulation of air to prevent moisture condensation.

Storage of Materials: Doors, Windows, and Ventilators

- Wooden frames and shutters Store in a dry and clean covered space away from infestation.
- Stack frames one over the other in vertical stacks with cross battens at regular distances to keep the stack straight.
- Shutters shall be stacked one over the other, at least 80 mm from the ground on pallets or beams to ensure that they will not be affected by accumulation of water
- Cover top of the stack - weighed down by means of a suitably placed weight.
- Store Precast door and window frames in upright position adopting suitable measures against risk of subsidence of soil/support.

Table 1 Storage and Stacking Check List

(*Clause* 4.1)

Sl No.	Material/ Component	Base			Stack				Type of Cover		
		Firm Level Ground	Hard Floor	Off-Floor	Heaps	Tiers	Flat	Vertical	Open	Open but Covered	Under Shed
6.	Partially Pre-fabricated Wall and Roof Components										
	a) RC planks, pre-fabricated brick panels and ferro-cement panels	√						√	√		
	b) Channel units, cored units and L-panels	√				√			√		
	c) Waffle units, RC joists, single tee and double tee	√					√		√		
7.	Timber			√		√					√
8.	Steel	√					√		√		
9.	Aluminium Sections		√				√				√
10.	Doors, Windows and Ventilators		√					√			√

Storage of Materials: Roofing Materials

- Stack on firm level ground with timber or other packing beneath them to a height < 1m
- When stacked in open site protect from damage by the winds.
- Damaged sheets shall not be stored with sound materials.

- <u>Corrugated Galvanised Iron sheets</u>: Stack in not more than 100 bundles per stack, built solidly with each bundle consisting of 10 sheets.
- Bundles shall be so laid that the corrugations run in the same direction in every course.
- One end of the stack shall be raised by 100 to 150 mm to allow water to flow freely.
- For longer storage- use shed with covered roof

Storage of Materials: Roofing Materials

- Tiles: Roof tiles have a greater resistance to load when it is imposed on the edge- Stack on edge and in pairs, head to tail, to give protection to the nibs.

- Ideal stack- five to seven rows high, with end tiles laid flat to provide an abutment.

- Tiles of different quality, size and thickness shall be stored separately.

Storage of Materials: Boards

- <u>Gypsum boards</u>: Stored flat in a covered clean and dry place.

- <u>Plywood/fibre board/Particle board/Block board</u>: Should not be stored in open and exposed to direct sun and rain.

- Stack on a flat Padding/dunnage, on the top of which a wooden frame shall be constructed with battens of 50 x 25 mm - it supports all four edges & corners of the boards with intermediate battens placed at suitable intervals to avoid warping.

- Raise the stack above ground level to prevent water causing dampness

- Stacked in a solid block in a clear vertical alignment with the top sheet suitably weighed down to prevent warping.

Storage of Materials: Plastic and Rubber Sheets

- Well ventilated-Coolest Room - direct solar light should not fall on material-.
- Keep away from electric generators, motors and other electrical equipment that provide harmful gases which may damage the sheets.
- Prevent contamination of the sheets with oils, greases, organic solvents, acids, and fumes
- Avoid undue stretch and strain, kinks, sharp bends or folds of the sheets
- Long-term storage: Provide space to facilitate <u>to turn them over </u>periodically.

Storage of Materials: Glass Sheets and Sanitary appliances

- Keep Glass sheets dry - suitable covered storage space.
- Store on their long edges- stacks of 25 panes each supported at two points by fillets of wood at about 300 mm from each end.
- First sheet laid in each stack shall be with bottom edge ~25 mm away from base of the wall
- Whole stack to be upright and as close as upright as possible.
- Cover floor with gunny bags to prevent slipping on smooth floor

- Store Sanitary appliances under cover to prevent damage.
- While storing- consider the sequence of removal from the store to the erection location
- Vitreous fittings and metal ones shall be stored separately.

Storage of Materials: Concrete Pipes and fittings

- Unload into the trench directly, if the trench is ready
- Stack in pyramid shape or place pipes lengthwise and crosswise in alternate layers.
- Pyramid shape stacking - smaller diameter pipes for conserving space in storing them.
- Stack height < 1.5 m- separate stack for pipes of each class/size
- Store Detachable joints and fittings under cover by separating them
- Keep Rubber rings clean, away from grease, oil, heat and light.

Table 1 Storage and Stacking Check List
(*Clause* 4.1)

Sl No.	Material/ Component	Base			Stack				Type of Cover		
		Firm Level Ground	Hard Floor	Off-Floor	Heaps	Tiers	Flat	Vertical	Open	Open but Covered	Under Shed
11.	Roofing Sheets										
	a) AC	√				√	√		√		
	b) GI and Aluminium sheets	√				√	√			√	
	c) Plastic sheets			√		√	√				√
12.	Boards like Plywood, Particle Boards, Fibre Boards, Blockboards and Gypsum Board			√		√	√				√
13.	Plastic and Rubber Flooring										
	a) Sheets in rolls	√						√			√
	b) Tiles	√				√	√				√
14.	Glass Sheets		√					√			√
15.	Glass Bricks/Blocks		√			√					√
16.	CI, GI and AC Pipes and Fittings										
	a) Pipes	√				√	√		√		
	b) CI and GI Fittings		√				√				√
	c) AC Fittings		√				√		√		

Storage of Materials:

Polyethylene Pipes

- Black polyethylene pipes – open or covered storage
- Natural polyethylene pipes: Covered storage- prevent sunlight -Avoid storage temp. > 27^0C
- Straight pipes: stack horizontally in racks on continuous support – prevent permanent set
- Coils: Store either on edge or by stacking flat one on top of the other.

Storage of Materials:

Unplasticized PVC Pipes

- Store on reasonably flat surface- supported through out its length- free from stones/ sharp projections - Avoid racks
- Stacking to large piles cause distortion of bottom pipes (jointing problems), stack height < 1.5 m.
- Sockets and spigots should be stacked in layers with sockets placed at alternate ends of the stack to avoid lopsided stacking.
- Pipes of different diameters and classes shall be stored separately- do not insert one pipe inside another
- In tropical climates – store under shade.

Storage of Materials: Pipes of Conducting Materials

- Stack in solid level sills –contain to prevent spreading or rolling of the pipe.
- Pack between successive layers- to avoid spreading of the pile.
- Maintain min. safety distances from the overhead power lines stacking of pipes/ other conductive materials at site:

11 kV and below	- 1.4 m
> 11 kV <33 kV	- 3.6 m
>33 kV <132 kV	- 4.7 m.

Storage of Materials:

Piling and Poles: Stack on solid, level sill to prevent rolling or spreading of the stack. Area must be free of vegetation and flammable materials.

Paints, Varnishes and Thinners: Flammable

- Store in sealed or closed containers in a well-ventilated storage space,
- Do not expose to heat, smoke, sparks, and flame.
- Lay loose sand for 100 mm on the floor of the paint storage area.
- Switches, electrical equipment are necessary, they shall be of explosion proof design.
- Store to facilitate use of lots in the same order in which they are received.

Bitumen, Tar and Asphalt

- Drums or containers shall be stacked vertically on their bottoms in up to 3 tiers.
- Store Bituminous roofing felts away from other combustible materials.

Sl No.	Material/ Component	Base			Stack				Type of Cover		
		Firm Level Ground	Hard Floor	Off-Floor	Heaps	Tiers	Flat	Vertical	Open	Open but Covered	Under Shed
17.	Polyethylene Pipes			√		√	√				√
18.	Unplasticized PVC Pipes	√				√	√		√		
19.	Bitumen, Road Tar, Asphalt, etc in Drums	√				√			√		
20.	Oil Paints		√			√					√
21.	Sanitary Appliances			√			√				√

Storage of Materials: Flammable Materials

- Store as per regulations
- If well secured– Maintain several months fuel/oil requirements in anticipation of shortages.
- Remote areas/road communication is interrupted by periodic flood or snow- necessary to stockpile supplies for one full season.
- Diesel /Gasoline- store in tanks/ in Jerry cans- store inside a locked building.
- Avoid contamination when outdoor storage drums (moisture/dirt in hydraulic brake and transmission fluid, gasoline or lubricants cause malfunction/ failure of equipment)
- Keep storage area free of accumulation of spilled products, debris, and other hazards.
- Do not store compressed gases & petroleum products closer in the same building

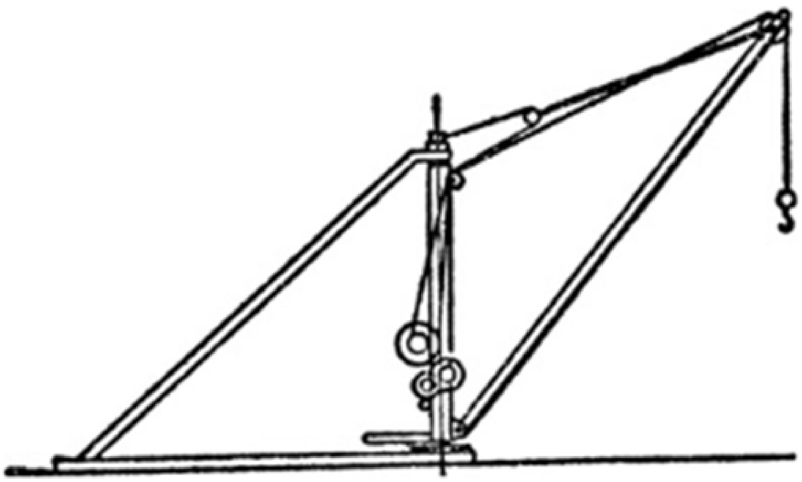
Storage for Equipment and Tools

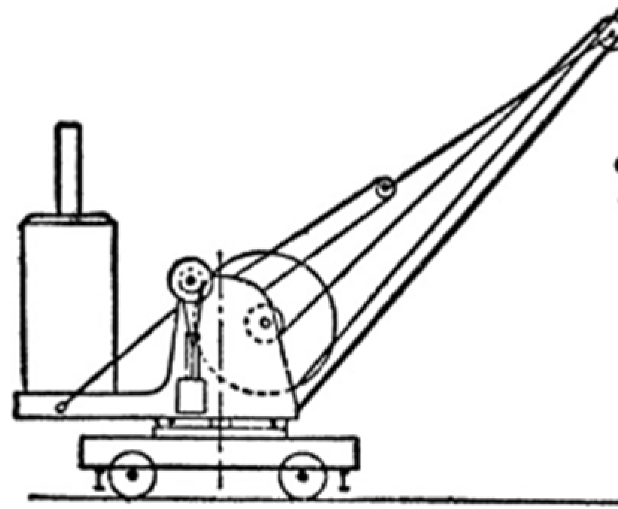
- Size and capacity of workshop facilities depend on size of the project and distance from the nearest location where adequate commercial repair facilities are available.
- Where major maintenance and repair facilities are close at hand, site maintenance involves little more than greasing, changing of oil and filters and repair of tyres.
- Such work requires a suitable set of tools and a building with a concrete or brick floor.
- Large project in a remote area: Major maintenance and some repairs to be done at site
- Such work requires a frame for supporting lifting tackle to remove engines, an inspection pit; and machining, welding, and heat treatment facilities.

Storage for Equipment and Tools

- Equipment storage ground requires reasonably flat, well drained ground.
- Should be able to facilitate maneuvering the equipment within the site with progress in construction
- Space should be provided for reversing of towed vehicles.
- location & working of plant movement: aim to minimize the repositioning of the machine and maximize the coverage of area that the plant is required to operate over (Ex: Cranes)
- Tower cranes/derricks and cableways: Located such that repositioning not needed during a construction- costly/ time consuming-crane will not be available during repositioning work
- Excavating plant, particularly on extended sites such as roads and airfields, should " work as they go"- for example, a scraper should start its run directed towards the spoil tip.


WEST LINUS





Storage of Materials: Water

Water tanks (ground level and overhead tanks) of appropriate size shall be provided to store water for

- Construction
- Curing
- Fire-fighting
- Drinking
- Supply to w/c; wash basin, bathrooms

- Estimation of quantity required,
- Storage capacity required,
- Source of water supply (nearby water course; local authority pipeline, bore wells)
- Pump capacity required

Precautions have to be taken to eliminate organic impurities.

Site Organisation

Water for construction: Sources of water

Public Water Supply:

- Availability and required amount to be ascertained - Yes/No
- Quality conforming to standards for its suitability for construction - Yes/No

Alternate sources: Ground water; supply from nearby location; treat ground water and use

Ground water Source: Rainwater that percolates beyond the reach of vegetation, either

i) Collecting in underground basins or

ii) Flowing underground subsurface streams constitutes.

During percolation- water encounters organic and inorganic substances - acquires chemical characteristics representative of the strata passed through.

Water for construction: Sources of water

If Site Ground water: suitable – different types of well for tapping of ground water

Well Types: Masonry shafts or Tube wells inserted into the ground to tap the subsurface.

Shallow well:

- Dug well type sunk or built, bored type or driven type.
- Yield limited- shallow pervious layer overlying 1^{st} impermeable layer.

Deep well:

- Taken into pervious layers below 1^{st} impermeable stratum
- Sunk/bored/ drilled type
- Provide larger supplies from different pervious layers below the first impervious layer.
- Yield a safer supply than shallow wells but may contain more minerals.

Water for construction: Sources of water

If Site Ground water – not suitable

Other sources:

- Locate potential suitable water source from a nearby location
- Mode of transport: Lorries/pipelines
- Make Provision for storage of water at site

Water for construction

Quality of water for mixing and curing of concrete

- Impurities in it may interfere with the setting of the cement
- May affect strength of the concrete or
- Cause staining of its surface, or
- Lead to corrosion of reinforcement.

Water for construction:

- Clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

Water for construction

Permissible values as per IS 3025:

- To neutralize 200 ml of water sample, using phenolphthalein as an indicator, it should not require more than 2 ml of 0.1 normal NaOH.
- To neutralize 200 ml of sample water, using methyl orange as an indicator, it should not require more than 10 ml of 0.1 normal HCl.

Permissible limits of solids	Max
Organic	200 mg/l
Inorganic	3000 mg/l
Sulphates (as SO_4)	500 mg/l
Chloride (as Cl)	2000 mg/l for plain concrete work1000 mg/l for RCC work
Suspended matter	2000 mg/l

Water for construction

- Potable water: Generally satisfactory for mixing concrete
- Water with high conc. of sodium/potassium: alkali-aggregate reaction-unfit for concrete
- Water not fit for drinking: may be satisfactorily used in making concrete.
- Water with a pH of 6 to 8 which does not taste saline or brackish is suitable for use
- Dark colour/smell do not mean presence of that deleterious substances
- Natural waters that are slightly acidic are harmless
- Water containing humic or other organic acids affect hardening of concrete
- Presence of algae in mixing water results in air entrainment - consequent loss of strength.
- Hardness of water should not affect the efficiency of air-entraining admixtures.

Water for construction

Suitability test for making concrete:

- Sample of water shall include possible seasonal variations also.
- Initial setting time as per IS 4031, with the cement and the water proposed to be used
- Limit: IST > 30 minutes ; shall not differ by 30 min. from IST of paste with distilled water
- Average 28-day compressive strength: 150mm cubes (IS 516): Strength between concrete with proposed water and that with distilled water shall not be less than 90 percent
- pH value of water shall not be less than 6.

Water for construction: Curing water

- Water used for mixing concrete or even slightly inferior quality is acceptable for curing
- should not produce any objectionable stain or unsightly deposit on concrete surface.
- Presence of tannic acid / iron compound is objectionable.
- Possibility of staining due to impurities to be checked by a performance test involving simulated wetting and evaporation – not based on chemical analysis
- Curing water to be free from substances that attack hardened concrete

Site Lighting

Types: Daylight/Artificial lighting

Requirement:

- Lighting for roads/passageways / corridors
- Lighting for working during late in the evening and night
- Supplementary Lighting during inclement weather and winter period

Inadequate lighting:

- loss of productivity in construction
- increased risk of accidents and injury
- increases wastage of materials
- reduction in security level.

Site Lighting

Advantages of artificial lighting on a construction site:

- Site activities need not depend on availability of daylight: Activity schedule to suit the needs of the contract, the availability of material & workers.
- Overtime/ shift system can help to overcome delays that might occur from any cause.
- Delivery/ collection of materials/plant – schedule outside normal site working hours- helps to eliminate delays and/or congestion.
- Reduction in the amount of spoilt material and the consequent rectification caused by working under inadequate light.
- An effective deterrent to this would-be trespasser or pilferation
- Improved labor relationships by ensuring regular working hours/ regular earnings.

Site Lighting: Planning

- Lighting requirements depends on
  - site layout
  - size of site
  - shape of site
  - geographical location, and
  - availability of electric supply.
- Plan Artificial site lighting such that it is easy to install and modify as needs change and remove whilst work is in progress.
- Initial cost of installing a system of artificial lighting (internal & external activities) - offset by
  - higher output
  - better quality work
  - a more secure site and
  - apportioning the costs over several contracts

TASK ILLUMINATION

Depend on: Size of task, brightness contrast, and visual capacity in terms of time required to see the task

Sl. No.	Nature of Task	Illumination level (lux)
1	Most difficult task (extra fine assembly, precision grading extra fine-finishing)	10000
2	Very difficult seeing task (such as fine assembly, high-speed work, fine finishing)	1000
3	Difficult and critical seeing task (ordinary bench work and assembly, machine shop work, office work)	500
4	Ordinary seeing task (automatic machine operations, rough grading, continuous processes, packing and shipping)	300
5	Casual seeing task (stairways, washrooms and other surface areas, active storage)	100
6	Rough seeing task (corridors, passageways, inactive storages)	50

Site Lighting: Fundamentals

- Level of illumination at which one can work in safety & carry out tasks to an acceptable standard (speed & quality) is quite low since human eye is very adaptable and efficient.

Recommended Illumination

- External lighting: Material handling and open circulation areas - 30 lux
- Internal lighting: Circulation and working areas - 50 lux
- Reinforced and concreting - 50 lux
- Painting and Decorating, fine craftwork, site office - 200 lux
- Brick laying, Joinery and Plastering - 100 lux
- Drawing board positions - 300 lux

Site Lighting: Light Sources: Lamps

- When deciding on the type of installation to be used two factors need to be considered;
- Type of lamp to be used
- Nature and type of area under consideration. The properties of the various types of lamps available should be examined to establish the most appropriate for any site requirement.

Type of Lamps: Incandescent; Gas Discharge; Electro-luminesent

Incandescent Lamps: Light is generated by bringing a filament to a high temperature by passing an electric current through it

Types:

- General Lighting and serviced Lamps
- Halogen Lamps
- Reflector lamps

General Lighting and Services Lamps

Components

Filament – Tungsten

- straight, coiled, flat

Glass bulb filled with inert gas – reduces evaporation of filament

Molybdenum wires and glass mount - support the filament

Advantages:

- Better colour rendition
- Low installation cost
- Instant light

Application areas:

- Rest areas, stairways, toilets- where requirement of illumination levels are low

Halogen Lamps

- Glass envelope contains an inert gas and a small amount of halogen
- Increased life
- No darkening of bulb due to re-deposition of tungsten
- High colour rendering index efficacy
- Extensively used in floodlighting, spotlights etc.

Reflector Lamps

- Inside surface of the bulb is given a true mirror finish
- Emits whiter light than GLS lamps
- Excellent colour rendering
- Better luminous efficacy and life
- Good directability of light

Gas Discharge Lamps

Gases or metal vapours are excited by passing current to emit radiation in the form of light

Types: Low pressure discharge lamps; High pressure discharge lamps

<u>Low pressure discharge lamps</u>

- Inert gas and a metal vapour at a pressure well below 1 bar
- Hardly any interaction between gas molecules
- Pure line spectrum
- Large discharge tubes
- Lower efficacy

<u>High pressure discharge lamps</u>

- Operated at a pressure well above 1 bar
- Great interaction between gas molecules
- Light emitted in broader frequency range
- Small discharge tubes
- Better efficacy

Low Pressure Discharge Lamps

Fluorescent Lamps; Sodium Vapour Lamps

<u>Fluorescent Lamps</u>:

- Consists of a tubular bulb having an electrode sealed to one end and containing mercury vapour at low pressure with a small amount of inert gas
- Gas aids in the starting of the lamp
- Inner surface of the tube is coated with fluorescent powders
- High luminous efficacy and life
- Spectrum produced is not continuous
- Poor colour rendering properties
- Need high voltage levels to start the arc

Compact Fluorescent Lamps

- Same properties as conventional fluorescent lamps
- More compact
- Consists of one or more curved discharge tubes
- Used in louvred luminaires
- An energy saving alternative to incandescent lamps in residences

Sodium Vapour Lamps

- Sodium vapour (less volatile) is excited instead of mercury vapour
- Inert gas is necessary to effect ignition
- Require high ignition voltage and long run-up time to reach maximum efficacy
- Extra-ordinarily high luminous efficacy
- Light produced is monochromatic (yellow)
- Poor colour rendering quality
- Used in outdoor lighting/yard lighting/open storage

High Pressure Discharge Lamps

- Mercury Vapour lamps; Metal Halide; High Pressure sodium vapour lamps

<u>Mercury Vapour Lamps</u>

- Consists of a short quartz glass discharge tube containing a mixture of inert gas and mercury at a pressure of about 0.2MPa to 1MPa
- Additional auxiliary electrode for the ignition of the lamp
- Moderate luminous efficacy and very long lamp life
- Colour rendering is poor – colour produced is bluish white
- Control gear is necessary
- Used in godowns, street lighting, station platforms, parking areas, showrooms, offices, exhibitions

Metal Halide Lamps

- Similar in construction to high pressure mercury vapour lamps except that the discharge tube contains one or more metal halides in addition to mercury
- Iodides of sodium, scandium, indium and thallium
- Luminous efficacy and colour rendering properties are improved
- No need of auxiliary electrode
- Mercury serves as an ignition aid
- Control gear is necessary for operation
- Used in floodlighting and sports-field lighting, where a compact source giving white light is required.

High Pressure Sodium Vapour Lamp

- Discharge tube is made of alumina ceramic
- Lamps are filled with inert gases and an amalgam of mercury and sodium
- rare gas and mercury component serve to ignite the lamp and stabilise the discharge process.
- A coating provided on the surrounding bulb only serves to reduce the luminance of the lamp and to improve diffusion

Electroluminescent Lamps: LED

Light is emitted in response to a strong electric field or an electric current passing through a material

- Consists of several light emitting diodes
- Long life, high efficacy and compact shape
- Good impact resistance
- Can produce many colours
- Used in traffic lights, floodlighting, torches etc

Characteristics of common light sources

Light Source	Efficiency (Lumens/Watt)	Average Lamp Life	Colour Rendering Index
Standard Incandescent	5-20	750-1,000	100
Tungsten Halogen	15-25	2,000-4,000	100
Compact Fluorescent	20-55	10,000	80
Mercury Vapour	25-50	Up to 24,000	15-30

Light Source	Efficiency (Lumens/Watt)	Average Lamp Life	Colour Rendering Index
Metal Halide	45-100	10,000-20,000	60-90
High Pressure Sodium	45-110	Up to 24,000	9-70
LED	25-60	50,000-100,000	70-95

luminaire

- Controls distribution of light given by a lamp(s) and which includes all the items necessary for fixing and protecting those lamps and for connecting them to the supply circuit.

<u>Components</u>

- Lamp(s)
- Lamp sockets
- Outer shell/housing for lamp alignment
- Ballasts (for electric discharge lamps)
- Reflective material
- Lenses or louvers
- Housing
- Connection to power source

Impact how much light reaches area and distribution pattern

Luminaires

Luminaires: Different luminaires depending on industrial requirement

Enclosed, Ventilated open, Non-ventilated open

ENCLOSED smoky & dusty areas (steel mill, foundry, flour mills & coal yard)

Heavy duty type with gasketted glass cover to protect the reflector and the light source from collection of dust

Humid atmosphere (Steam processing, plating and wash rooms)

VAPOR TIGHT FIXTURES

- where heavy oils are used or
- processed and oil mists are penetrated

FLAME PROOF FITTINGS: explosive atmosphere

VENTILATED TYPE :

High bay areas (Dust collected on luminaires in cleaned automatically by fast raising air currents)

Diffuse reflectors: 70-80% reflectance but declining in time painted or powder coated white finish.

Specular reflectors: 85-96% reflectance and less decline in time

- Polished or mirror-like
- Not suitable for industrial open-type strip fixtures

Luminaires

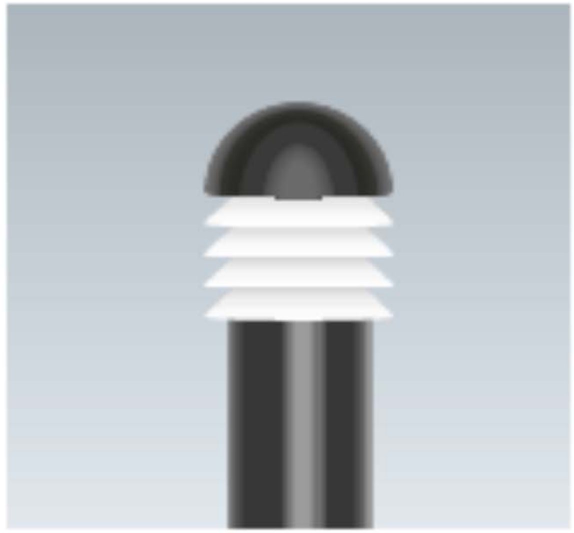
Luminaire with high-pressure sodium vapour lamps or metal halide lamps for thoroughfare lighting

Luminaire with high-pressure sodium vapour lamps, metal halide lamps or compact fluorescent lamps for collector or residential streets and outsdoor parks/Sites

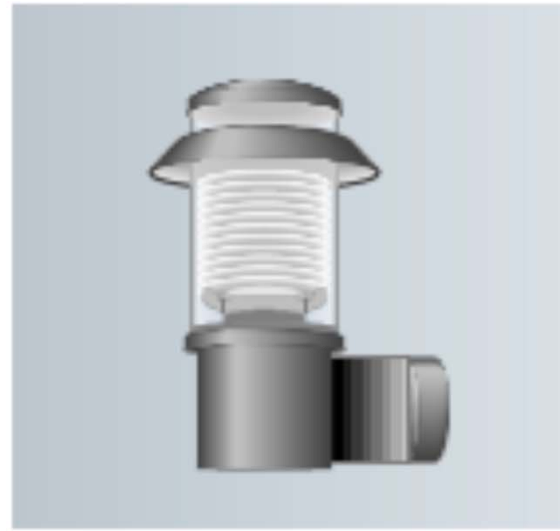
Pendant luminaire with high-pressure sodium vapour lamps, metal halide lamps or high-pressure mercury vapour lamps for suspension on catenary (overhead) wires for sites/thoroughfares.

Luminaires

Secondary luminaire with high-pressure sodium vapour lamps or metal halide lamps and indirect optical control system for decorative lighting



Bollard luminaire with compact fluorescent lamps, energy-saving lamps, tungsten halogen lamps or incandescent lamps for path lighting in parks and gardens



Wall luminaire with compact fluorescent, energy-saving, tungsten halogen or incandescent lamps for mounting on buildings, e.g. in parks and gardens or narrow downtown streets

Luminaires

Luminaire with tubular fluorescent lamps for local service street lighting

Decorative luminaire with high-pressure sodium vapour lamps, metal halide lamps, high-pressure mercury vapour lamps or compact fluorescent lamps for service streets, residential streets, squares and pedestrian precincts.

Decorative luminaire with high-pressure sodium vapour lamps, metal halide lamps, high-pressure mercury vapour lamps or compact fluorescent lamps for pedestrian precincts and squares; also suitable for service streets, residential streets and path lighting.

Luminaires

Pedestal luminaire with incandescent, tungsten halogen, energy-saving or compact fluorescent lamps for mounting on walls or pillars in parks and gardens or for paths leading to buildings

Recessed wall luminaire with compact fluorescent, energy-saving or tungsten halogen lamps for paths lighting used on stairs and approach paths.

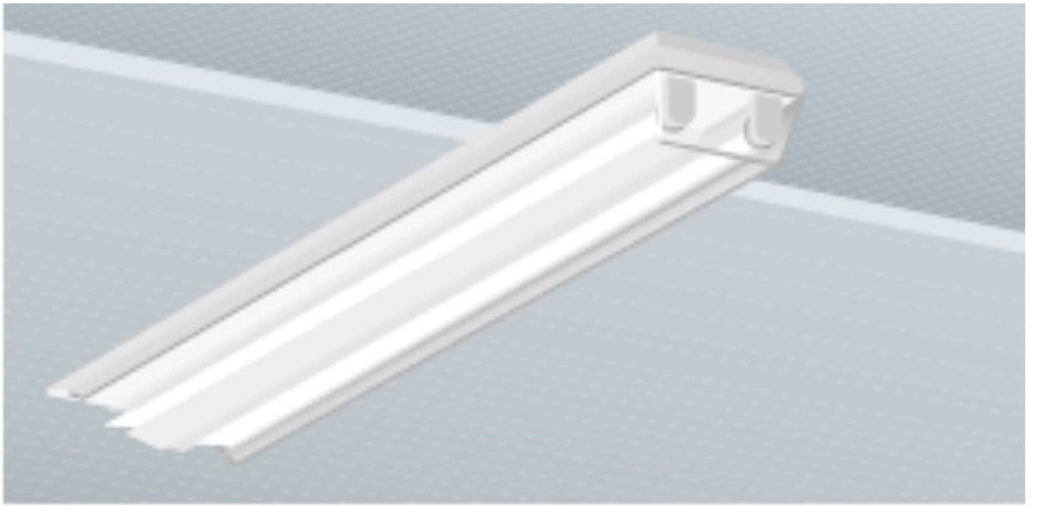
Flood with high-pressure sodium vapour lamps, metal halide lamps for illuminating buildings, artwork or vegetation.

Recessed ground flood with high-pressure sodium vapour lamps, metal halide lamps or tungsten halogen lamps for floodlighting from below.

Luminaires

Luminaire with high-pressure sodium vapour lamps for pedes-trian crossing lighting.

Luminaire with high-pressure sodium vapour lamps or metal halide lamps for tunnel lighting.



Damp-proof luminaire with tubular fluorescent lamps for indoor car park and underpass lighting.

Pole Mounting Height

- Luminaires on poles can provide illumination in every direction at distances of two to two and half times the mounting height from the pole.
- Luminaires on a single pole can serve an area of about four times the mounting height - squared.
- Ex: A 50-ft pole can cover about 40,000 sq ft

  A 150-ft pole about 369,000 sq ft.

TABLE 8 LUMINAIRE CLASSIFICATION

SL No.	TYPE	DISTRIBUTION OF FLUX EMITTED AS PERCENTAGE OF TOTAL FLUX OUTPUT	
		Upward	Downward
(1)	(2)	(3)	(4)
i)	Direct	0-10	90-100
ii)	Semi-direct	13-40	60-90
iii)	General diffusing	40-60	40-60
iv)	Semi-indirect	60-90	10-40
v)	Indirect	90-100	0-10

Site Lighting: Site Lighting Installations

Lumen Method:

Number, type of lamp, luminaire and layout for construction site, consideration must be given to the nature of area and work to be lit; Mounting height to spacing ratio for lamp & luminaire

- External and large circulation areas
- Flood lighting
- Overhead dispersive lighting
- Beam flood lighting
- Walkway lighting
- Local lighting

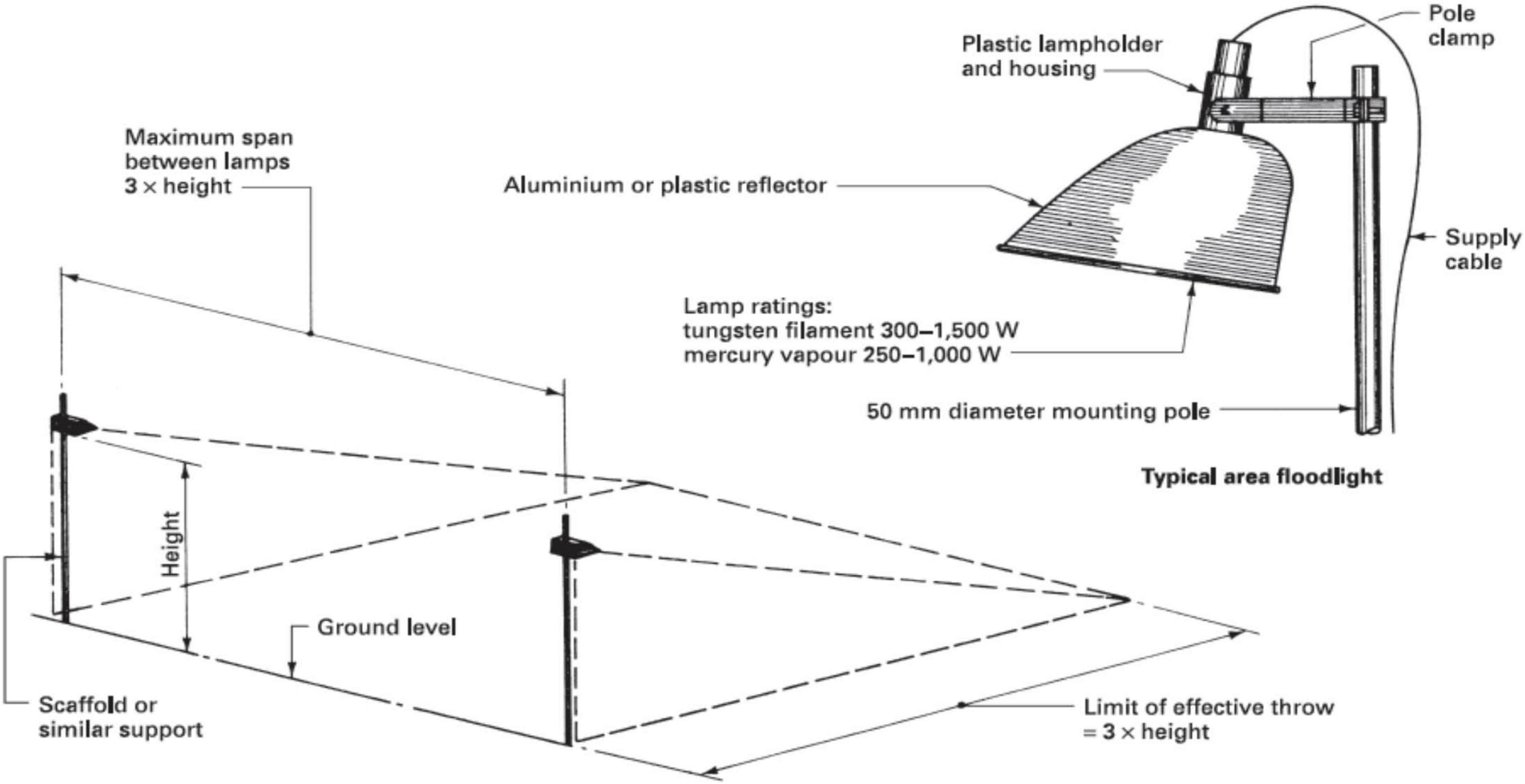


Figure 1.3.2 Area lighting: lamps and spacing ratios: 1

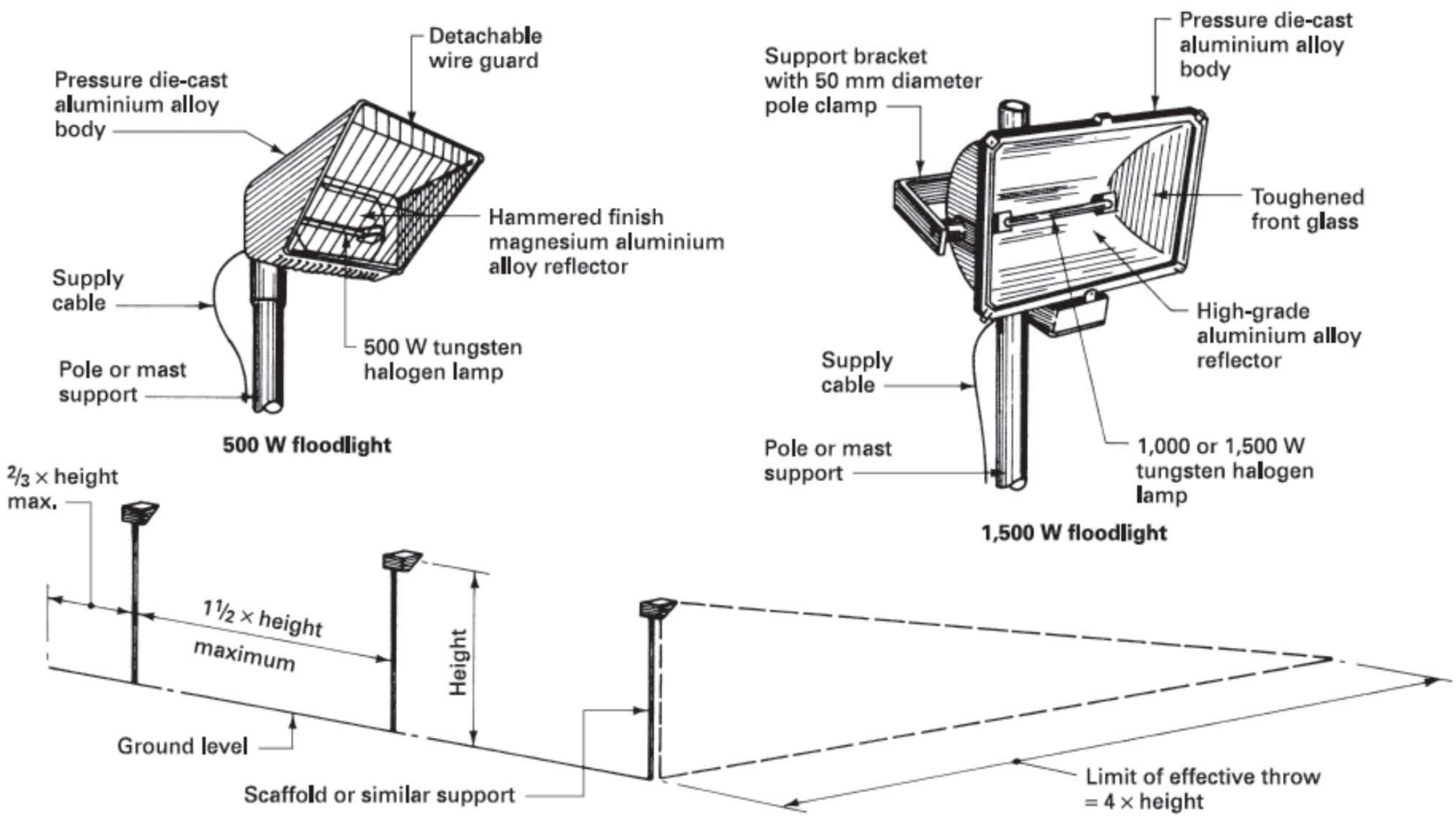
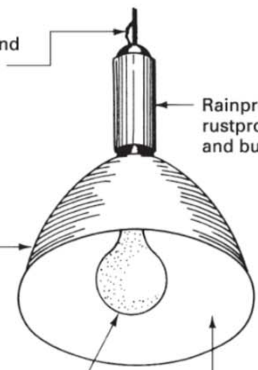


Figure 1.3.3 Area lighting: lamps and spacing ratios: 2



Typical dispersive lamp

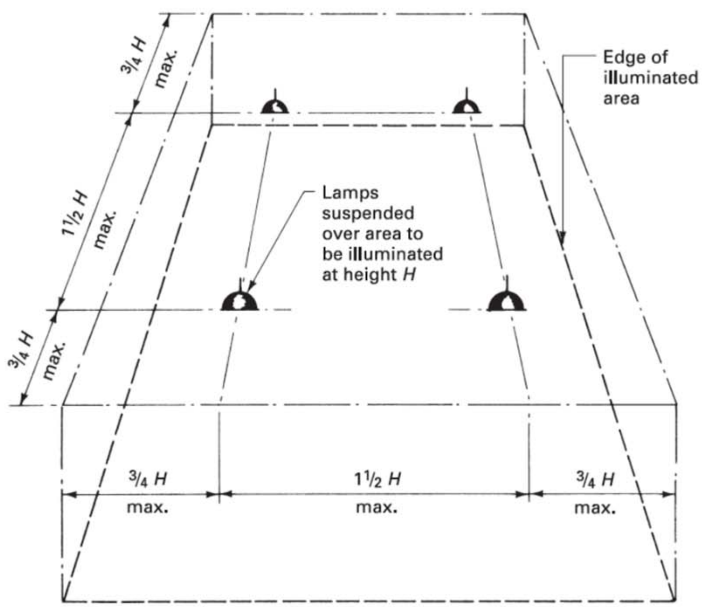


Figure 1.3.4 Area lighting: overhead dispersive lamps

Site Protection

- Site selection and layout of facilities on a site can have a significant influence on the cost which an organization may have to pay for security or lack of it.

- Two financial benefits can be realized if effective security planning is done at an early stage.

  i) Reduction in cost of losses that threaten every construction site regardless of size or type.
  (Examples of such losses are theft, terrorism, and sabotage)

  ii) Reduction in costs required to provide adequate security for the protection of assets and personnel.

- Large sites tend to be more difficult to secure,

- Compact sites in the centre of towns require the minimum effort and cost to keep out intending trespassers, as the public act responsibly when intruders are seen at work.

Site Protection: Types of Fencing

- Fence provides a degree of protection to Construction site
- Fence fulfills two functions, viz., defines the limit of the site or compound, and acts as a deterrent to the would-be trespasser/thief.
- Fence can be constructed to provide physical barrier of <u>solid construction</u> or a <u>visual barrier of open work construction</u>.
- If Fencing is part of contract- advantageous to do it at the beginning of the site operations.
- Type of fencing chosen will depend upon degree of security required, cost implications, type of neighborhood and duration of contract.
- Security fence around the site or compound; min Height: 1.8 to 2 m
- Should include min. number of access points which should have a lockable barrier or gate.

Site protection: See-through or Solid guarding

- Decision on perimeter guarding should be i) seen through type or ii) solid type - depends on the situation, and on what other security precaution are to be taken.

- Advantages of seen through Fencing: i) lower cost, ii) allows an intruder to be observed before he gets inside and gives him no cover from outside observation once he has got in.

- Solid & substantially high wall or close boarded fencing spikes, barbed wire or anti-vandal sealing barrier in the top will be a formidable obstacle to scaling.

- Advantages of solid fencing: privacy, reduction in noise/dust level, formation of wind break

- Solid guarding 1.6m high will give basic security, and if built taller with protection against sealing, maximum security can be achieved.

Site protection: Fencing materials

- Timber, concrete, wrought iron, standard wire and chain link.

- Stranded wire used either with timber or concrete posts is an inexpensive form of fencing- widely used on large sites (little aesthetic value)

- <u>Stranded wire fence</u>: strands are in tension- straining posts must be introduced at ends and corners and any long straight sections of fencing should have straining posts at least every 70m.

- Other forms of wire fencing which give varying amounts of enclosure are woven wire and the popular chain link- require straining posts.

- Concrete fence is heavy in appearance and lacks the weathering qualities of timber- Durable-no maintenance. Posts fixed at around 1.8m spacing are linked by precast planks.

- Timber offers variety of forms and effects to the designer- range of height between 1 and 2m, centres of posts between 1.8 to 2.4m depending on the type, and sections of posts between 75x75mm and 150x150mm.

Site protection: Fencing materials

<u>Fixing of posts</u>:

i) Setting in concrete provides a very firm fixing but tends to rot the timber at point of entry.

ii) Post can be driven into position- tends to damage the head and encourage the entry of water.

iii) Wedge the posts with large stones in a hole, placing more small stones around the base before backfilling and well ramming the surrounding area- ensures good drainage around the base

- Fence or gate post should be in proportion to its length of 1/4 below ground and 3/4 above ground, with a minimum of 450mm below ground level.
- Most durable species of timber for use in fencing are Oak, Larch &Chestnut (others need treatment)
- Coat the post below ground with a tar material, thus forming a waterproof coating.
- Capping of fencing posts and vertical members of fencing -to protect the end-grain and thus prolong the life of the fence.
- Where this is not possible, a weathering face should be formed to take water quickly away. Galvanized nails must always be used to avoid black stains.

Site protection: Small sites

- Common fence that gives at least basic security are chain link, close-boarded and wooden palisade that can carry barbed wire on top to give additional protection, if required.

- Steel palisade fences used to provide strong to maximum security are also in common use.

Small site- entire area may be encircled by means of the following fences:

- Low chestnut paling or wire fence: to define the site boundary- shows to all concerned the limits of pedestrian and vehicular rights of way and prevents everything and everyone from straying on to the site by accident.

- It has the advantage of ensuring work people to remain on site.

- It keeps unwanted inquisitive individuals away from the work area

Steel palisade fences

Site protection: Small sites: Chain link fence

- For maximum security: 2.4m high to the top of the chain link and 2.9m to the top of the barbed wire above the chain link.
- Limit mesh size to 50mm to prevent climbing with toes in mesh.
- Bury 300mm of chain link in the ground, or thread hairpin staples through the bottom row of mesh and cast them into a concrete sill cast at ground level between posts to prevent borrowing and listing of bottom of chain link.
- To prevent bunching the lines of barbed wire together and getting over between the barbed wire and the top of the chain link, fit spacing bars to barbed wire and use chain link with barbed top.
- Use burr bolt ends over nuts to prevent dismantling.
- Use a bracing rail and diagonal reverse bracing instead of a strut to strengthen straining posts and to prevent climbing straining posts.

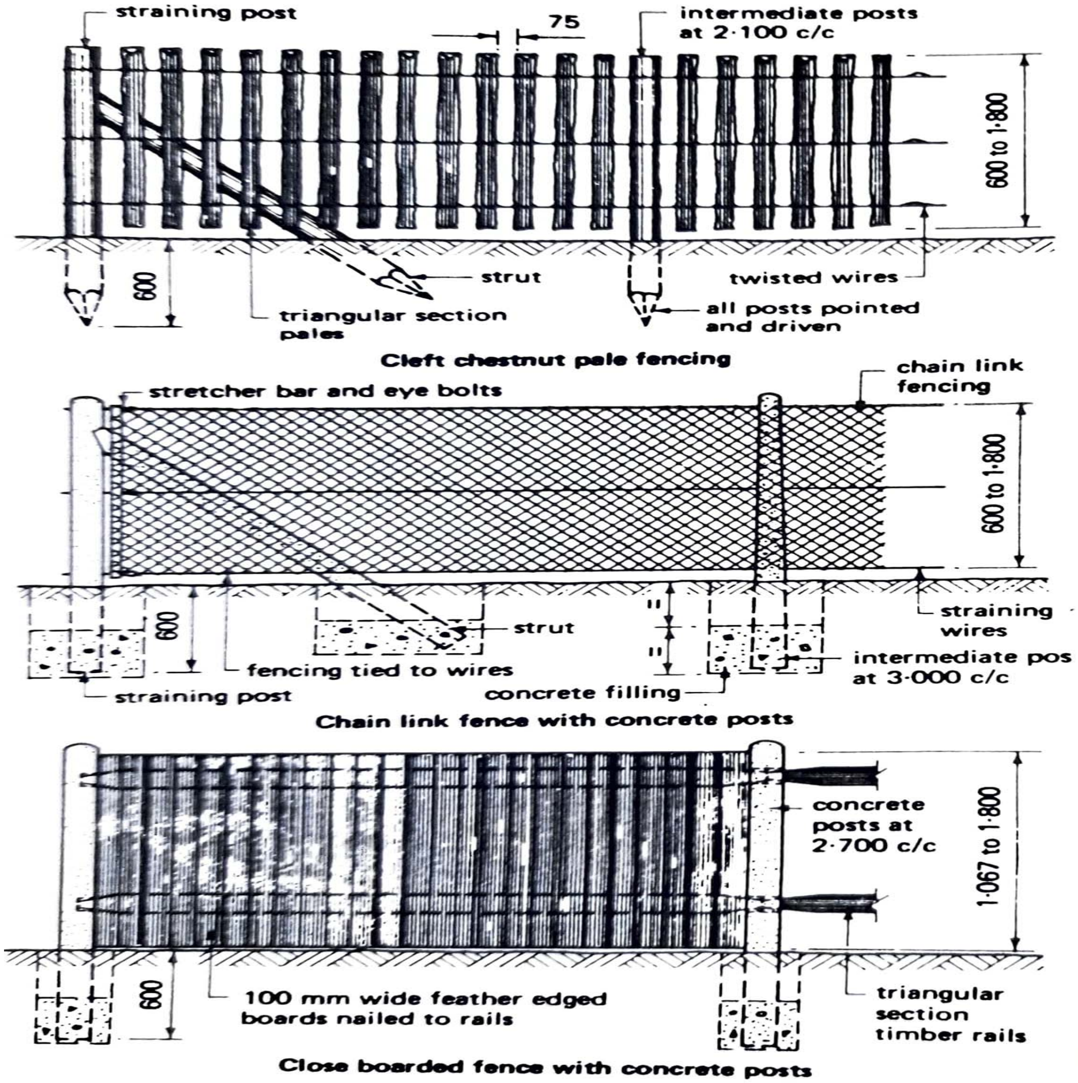
Site protection: Small sites

- High wire (Chain link) or close boarded fence with barbed wire fixed at the top defines the boundary of the site and prevents anyone from gaining access without some vigorous effort.
- Advantage: minimising the nuisances of dust and noise to the surrounding building occupiers.
- Doors/gates and locks should be commensurate in strength with the boundary fences or hoards in which they are used.
- Steel palisade Fences: Strong fences obtainable from 1.2m to 3.6m high. Corrugated or angle pales are used for fences up to 2.1m in height, corrugated pales only for maximum security which should be at least 2.4m high.
- I-section beams: for posts; Angles for rails. Galvanized/ plastic-coated finishes are available.
- Fencing is designed for use without struts. Fixing bolts are burned over nuts to prevent dismantling.
- A sill 125mm wide, 225mm deep is to be provided under the line of pales, the top of the sill to be approximately at ground level and not more than 50mm below the bottom of the pales.

Site Protection: Large sites

Type of fencing used depends on that which is available to the contractor-constructed considering the following points:

- Chain link fences 2-3m high should be fixed to concrete, timber or steel posts which are concreted into the ground.
- Top of the chain link fence should be finished off with two strands of barbed wire.
- Base of the wire should be sunk into the ground about 250 mm to prevent anyone from gaining easy access by tunneling or undermining.
- Care should be exercised to provide a gate or gates and padlocks of similar strength and security as the compound fencing.
- Gates should be hung carefully to limit the space at the bottom with perhaps a bed of concrete across the threshold to prevent thieves from gaining access by undermining.
- Chains should not be used to secure gates and the padlock should be of extra security type which makes it extremely difficult to cut with bolt-scrappers.



g. I.6 Typical fencing details

Site Protection: Gates for fences

- Designed to provide security comparable with that of the fence - variety of sizes and forms.

Factors to be considered when choosing/designing a gate

- make sure that the material is not incongruous with the material of adjacent fence or wall.
- keep the weight of the gate as small as possible without impairing the strength.
- Hanging post must be strong to withstand cantilevering action of the gate and securely fixed to prevent it from being shaken loose.
- Chain link fence: Gates are made of circular or rectangular hollow steel sections. For greater rigidity, use 50x50mm steel mesh welded at intersections instead of chain link infill.
- Gates for steel palisade fences are made with rectangular hollow steel sections welded together. Construction is not braced but corner strengthening pieces are used if necessary.
- Panels of rails and pales are then secured to the framing.

Site Protection: Gates for fences

- Hinged gates require a large area for opening and closing and the road must have flanking walls or other boundaries for the gates to open against.
- Can be operated by electrical power, but the greater mechanical advantage of manual operation enable that even heavy gates can easily be moved by hand.
- Swing of the gates must be marked on the road surface to indicate that the vehicles must keep clear.
- Sliding gates-better than hinged gates for wide openings- need less space Suited for powered operation.
- If the gate is very long, or very high or perhaps very heavy because of armour plate infill it will need to run in a track that carries its weight.
- Free-carrying gate can be used, which has the advantage of being able to operate over surfaces at different levels and of being unaffected by snow and ice.
- Open site access roads should have a gate erected across them, or at least be sealed off with planks or drums filled with sand at night or at weekends and to make it obvious to anyone that beyond these points they would be trespassing.

Site Protection: additional measures

- Store materials away from the fencing (inside/outside) to prevent anyone from using the stacks or piles as access bridges to the inside compound area.

- Keep Internal Storage sheds away from the fencing unless the windows are facing inwards. Where the windows face outwards, anti-burglar bars should be fitted on the internal faces and security wire could be fixed on the outside as an anti-vandalism measure.

- Ladders, picks, shovels, and bolt-croppers should be locked away (inside the compound area) to prevent thieves using them as access implements.

- Burglar alarm could be installed which also could operate a flashing light set at the top of a tower, to alert security to the exact spot of the break-in.

- Flashing light is important on large open sites where there may be two or more compound or storage areas, the direction from which alarms are sounding being sometimes difficult to access.

Site Protection: Storage building

- Storage buildings: valuable items of small plant, equipment and materials are stored.
- Should be well constructed and should have strong doors, windows, and locks.
- Where possible they should be situated inside the compound as an added security measure or should be grouped together for ease of patrolling by the security officer when the site is closed.

Site Protection: Administration offices

- To protect valuable items of stationery, equipment- required for the proper processing of information within offices; conducting of administrative or management duties
- Protect the administrative area from intruders both during working hours and after

a) Establish control of security keys to prevent the wrong persons from obtaining the original or from copying them.

b) Night light could be left on in the office if the size of the administrative area warrants it.

c) Notices should be strategically placed around administrative areas and access roads warning every visitor to report to the main or other offices before proceeding further.

d) Other warning notices such as "Trespassers Will Be Prosecuted" may deter the less determined opportunist thief.

e) Office safe should be secreted behind a panel or cabinet and built into a brick or concrete surround. An added precaution would be to strap and bolt the safe into a concrete base.

Site Protection: Plant and machinery

To prevent stealing of plants

- Remove those pieces no longer required from the site, or to place them within a secure compound.

Other mechanical plant may be secured temporarily by one or more of the following:

a) Disengage by removal of starter devices.

b) Cabins locked up.

c) Simple but valuable parts removed, For example, spark plugs.

d) Provision of wheel locks- prevents wheels being removed.

e) Tow bar locks-to prevent the easy coupling up and towing away of generators, trailer, compressors, and even caravans.

Fence vs Hoarding

Fence: Thin, Manually constructed barrier which separates two pieces of land/site perimeter

Hoarding**:** A temporary fence-like structure built around the building work to add security and prevent accidents to the public.

Site Protection: Hoarding

- Obtain permission from local authority for erecting a hoarding

Close boarded fences or barriers erected adjacent to a highway or public footpath

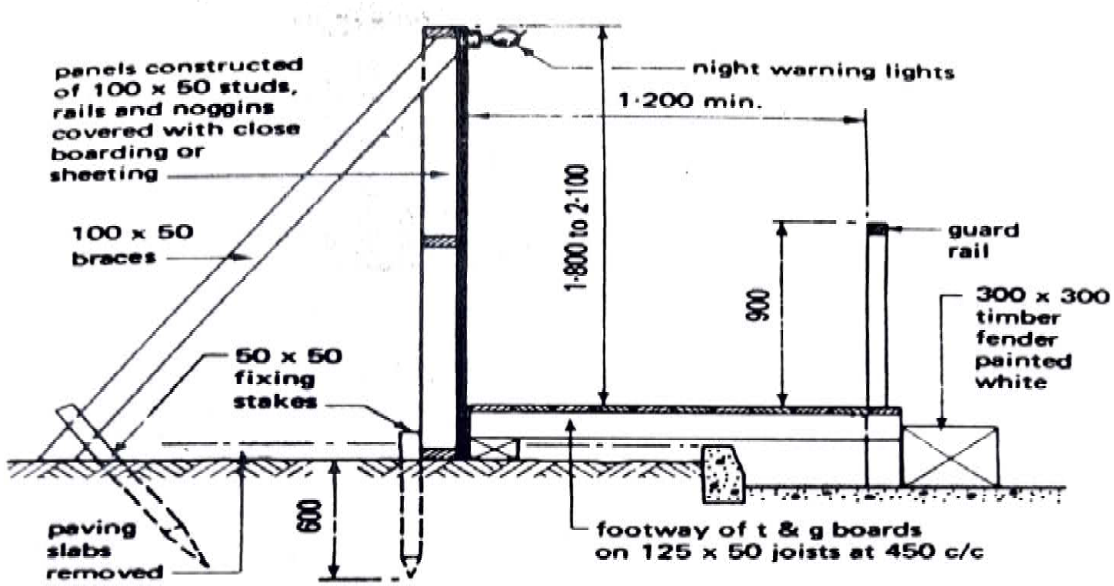
- to prevent unauthorized persons obtaining access to the site and
- to provide a degree of protection for the public from the dust and noise associated with building operations.

vertical hoarding:

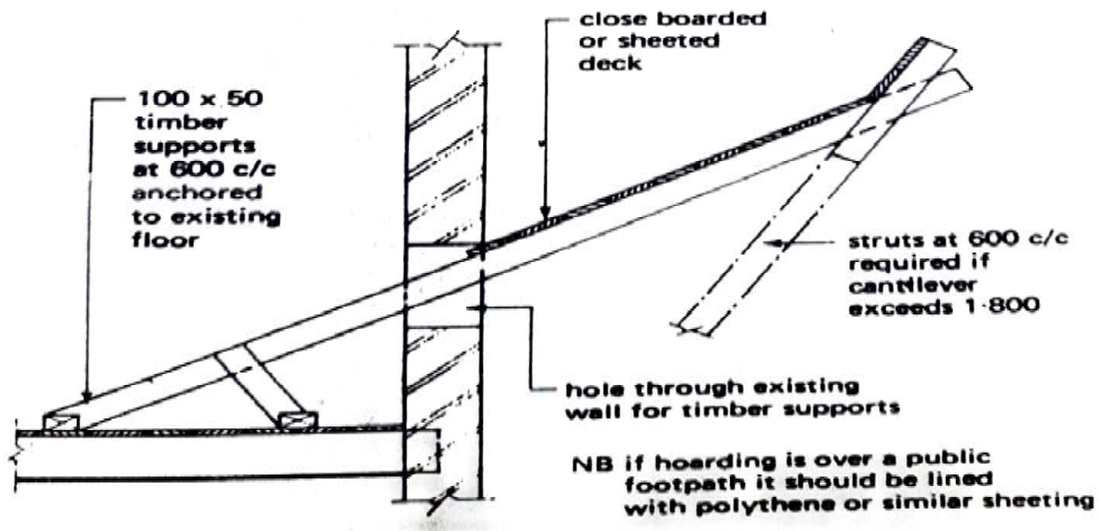
- Consists of a series of closed boarded panels securely fixed to resist wind load and accidental impact loads.
- Free standing or fixed by stays to the external walls of an existing building.

Fan hoarding:

- Protects a person from falling objects, by placing at a level above normal traffic height
- Arranged such that any falling debris is directed back towards the building or scaffold.

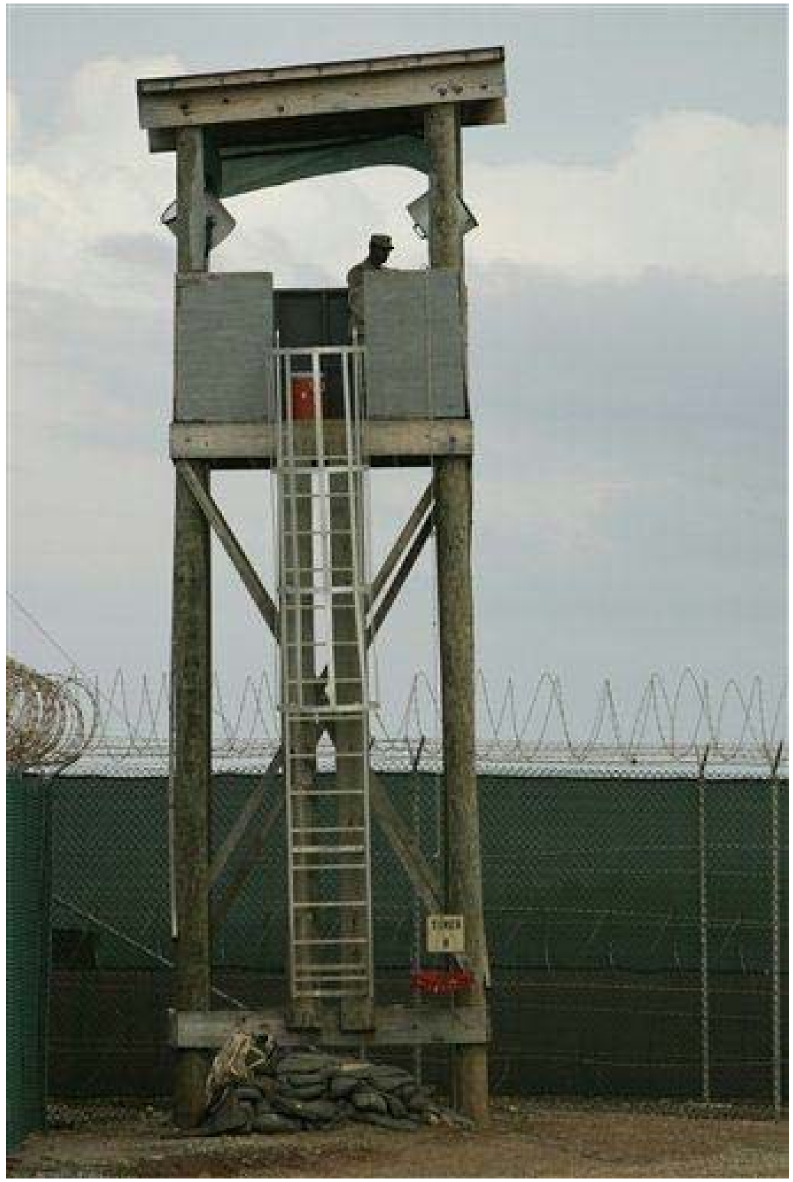


Typical freestanding vertical hoarding



Site Protection: Guard Towers

- Included in large construction site design as another physical control element.
- Tower height increases observation range during daytime &at night with artificial illumination
- During inclement weather and at night without lights- towers lose this advantage and must be supplemented by on the ground observation.
- Elevation of the observer in the tower has Psychologically unnerving effect on a potential intruder
- Activity of the standing watch in a tower tends to lull the guard into a state of drowsiness.
- Mobile towers are useful in some temporary situations, such as in large open storage area where there is activity in receiving and storing equipment.
- Towers can be integrated into buildings so that they are made a part of the structure.
- All towers should have a support force available for emergencies, Rotate guards on shift/intervals



Site Protection: Entrance and Exit Control

- Traffic barriers at perimeter entrances are of <u>light construction- </u>only for control of vehicles
- Where there is a danger of vandalism- install barriers of <u>robust construction</u>
- Space constraint: Lifting arm type suitable.
- Raising road barriers: used to close roadways temporarily.
- Traffic lights needed to warn drivers when the barriers are raised.
- For maximum security requirements for inspection of vehicles entering or leaving the premises- barriers used in pairs enables the passage of vehicles to be fully controlled- no rushing of a lowered barrier by a following vehicle.
- Methods of access control for labour and staff: Card operated or supervised one.

Site Electricity

- Temporary supply of on construction sites:
  - Outdoor electrical installations open to sky or partially covered,
  - To provide lighting to the various units of accommodation and also
  - To provide the power to drive small and large equipment and plants.
- Many of these installations are unprotected from environmental hazards as compared to installations in buildings.
- Requires frequent modifications
- Major risk: short-circuit resulting in fire accidents & exposure to live wire resulting in shock
- Shall conform to Indian Electricity Rules (1956), which are detailed in the National Electrical Code of India, and regulations of the local electric supply authority concerned.

Site Electricity

Environmental conditions influence installations:

- Ambient temperature,
- Atmospheric humidity,
- Altitude
- presence of water (possibility of splashes or jet of water in any direction, partial or total covering of water- may affect external light fittings and site equipment),
- Presence of foreign solid bodies (small objects and dust in large quantities),
- Presence of flora and or mould growth and fauna,
- Presence of corrosive or polluting substances,
- Impact (construction demolition operation),
- Seismic effects,
- Lightning (hazard form exposure of equipment) and
- Wind

- Materials, fittings, equipment/appliances: shall conform to Bureau of Indian Standards
- Workmen shall hold certificate competency
- Execution under the supervision (person holding a certificate of competency)

Site Electricity: Supply Intake Arrangements

Two sources of electrical supply

- Portable self-powered generators,
- Metered supply from the local area electricity board.

Portable self-powered generators

- useful for smaller construction sites till obtaining temporary electric supply
- Serve as a standby in case of power failure.

- Estimation of maximum anticipated load demand in kW for the construction period including spare capacity

Supply intake arrangements

- High Voltage feeder/ a HV feeder and step down transformer/
- A service line at voltage below 250V/tapping from one of the existing service connections.
- Redundancy: Several sources of supply- fixed or mobile power generators.

Site Electricity: Characteristics of Electrical Supply

Voltage and voltage tolerance: For medium/ low voltage system, values of 240V single phase and 240V/415V for 3-phase system- as per National Electrical Code.

Recommended voltages for construction sites:

415 V three-phase:

- Supply to transformer unit, heavy plants such as cranes and movable plant fed through a trailing cable
- Hoists and plants powered by electric motors in excess of 2 kW rating

240V single-phase:

- Supply to transformer unit
- Supply to distribution unit
- Installations in site accommodation buildings
- Fixed floodlighting
- Small static machines
- Portable hand lamps
- Small items & plants
- Portable & handheld tools.

Site Electricity

- Voltage Limits: volage drop < 6% in the case of low or medium voltage.

Limits of voltage for continuous operation of equipment

System voltage	Highest voltage	Lowest voltage
240 V	264 V	216 V
415 V	457 V	374 V

Cross section of conductor depends on:

- Admissible maximum temperature
- Admissible voltage drop
- Electromechanical stress likely to occur due to short-circuits
- Other mechanical stresses to which the conductors may be exposed
- Maximum impedance with respect to the functioning of the short-circuit protection.

Site Electricity: Electrical Distribution Installations/Equipment

- Equipment which can be used to distribute an electrical supply around a construction site:

a) Supply incoming units: Supply, control and distribution of mains supply on site, accommodates supply board's equipment, and has one out going circuit.

b) Main distribution unit: Control and distribution of mains supply for 415 V 3-phase and 240 V single phase.

c) Supply incoming and distribution unit: Combination of (a) and (b) for use on sites where it is possible to locate these units together.

d) Transformer unit: Transforms and distributes electricity at a reduced voltage and can be single phase, three-phase or both.

e) Outlet unit: Connection, Protection, and distribution of final sub-circuits at a voltage lower than the incoming supply

f) Extension outlet unit: Similar to outlet units except outlets are not protected.

g) Earth monitor unit (EMU): Flexible cables supplying power at main voltage from main distribution unit to movable plant incorporate a separate pilot conductor in addition to the main earth continuity conductor. A very low voltage current passes along these conductors between the portable plank and the fixed EMU. A failure of the earth continuity conductor will interrupt current flow which will be detected by EMU and the device will automatically isolate the main circuit.

Site investigation

https://www.nationalgeographic.org/encyclopedia/soila-composition/

Site Reconnaissance

Study of following features

- Local topography
- Excavations
- Cuttings
- Quarries
- Escarpments (sudden change of elevation of ground level)
- Evidence of erosion or land slides
- Fills
- Water level in wells
- Drainage pattern

Site Exploration

To provide reliable, specific and detailed information about soil and ground water conditions.

Precise information regarding

- Order of occurrence and extend of soil and rock strata
- Nature and engineering properties of soil and rock formation
- Location of ground water and its variation

Soil Investigation

- Understanding of Physical make up, Engineering and chemical properties of sub-soil strata

- Sub-soil: Layers of strata that lie between top-soil and the bed rock

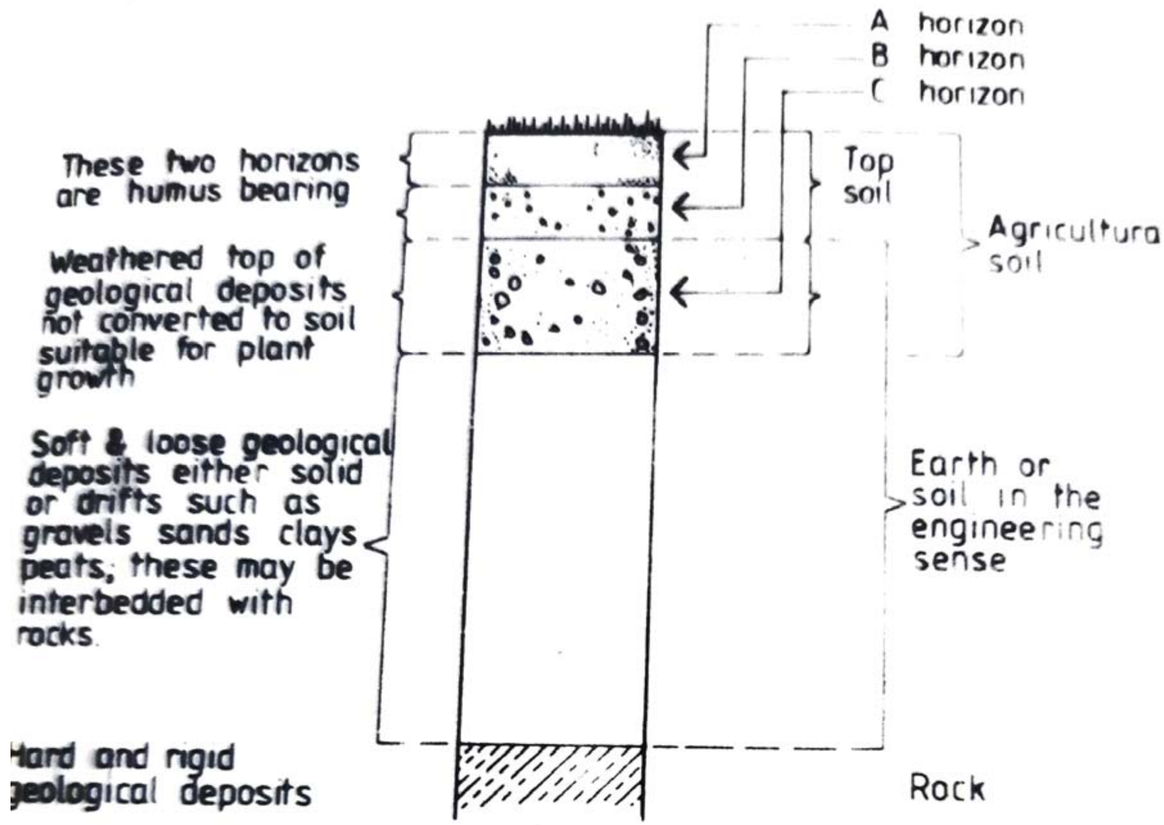


Figure 2.1 Relationship between engineering and non-engineering soils

Classification of soil

- Soft/Loose soil
- Hard/Dense soil
- Ordinary Rock
- Hard rock

Soft loose soil

Yields to ordinary application of pick and shovel/spade/rake/other ordinary digging tools.

- Sand, gravel, loam, clay, mud, black cotton soil.
- Vegetable or organic soil, turf, peat, soft shale or loose murrum.
- Mud concrete below ground level.
- Any mixture of soils mentioned above.

Classification of soil: Hard/dense soil

Requires close application of picks or jumpers and rippers to loosen

- Stiff heavy clay, hard shale/compact murrum requiring grafting tool and/or pick and shovel.
- Shingle and river or nallah bed boulders.
- Soling of roads, paths, etc., and hard core. (**Soling:** hand packing rubble stones one adjacent to another, to provide a stable base to the foundation and footing)
- Macadam surface of any description (water bound, grouted tarmac, etc.). (compacted subgrade of crushed granite or greenstone designed to support the load, covered by a surface of light stone to absorb wear and tear and shed water to the drainage ditches)
- Lime concrete, stone masonry in lime or cement mortar below ground level.
- Soft conglomerate or soft laterite when the stone can be detached from matrix with picks.

Classification of Soil: Ordinary Rock (not requiring blasting, wedging, or similar means)

- Quarried or split with crow bars or picks,
-
- Ex: Limestone, hard laterite, hard conglomerate and unreinforced cement concrete below ground level.

https://mapio.net/pic/p-78658758/

Fig: Ordinary rock(Laterite soil)

Classification of Soil: Hard Rock (requiring blasting)

- Any rock or boulder for the excavation of which blasting is required

- Ex: Quartzite, granite, basalt, reinforced cement concrete (reinforcement to be cut through but not separated from concrete), etc., below ground level.

Fig: Granite blasting

http://www.easyblast.in/silent-blasting-chemical/

Classification of Soil: Hard Rock (blasting prohibited)

- where blasting is prohibited: Excavation done by chiseling, wedging or other agreed method.

Fig: Hard rock cutting without blasting

https://www.dexpan-canada.com/dexpan-reviews

Table 2.1 Categories of ground beneath a site

Material type	Strength	Compressibility	Permeability
Rock	Very high	Very low	Medium to high
Granular soil	High	Low	High
Cohesive soil	Low	High	Very low
Organic soil	Very low	Very high	High
Made ground	Medium to very low	Medium to very high	Low to high

Table 2.2 Principal soil types

Soil type	Description
CLAY	Cohesive soil
BOULDERS	Granular soils
COBBLES	Granular soils
GRAVEL	Granular soils
SAND	Granular soils
SILT	Granular soils
PEAT	Organic soil
MADE GROUND	Man-made soils and other materials

TEXTURE CLASSIFICATION OF SOILS

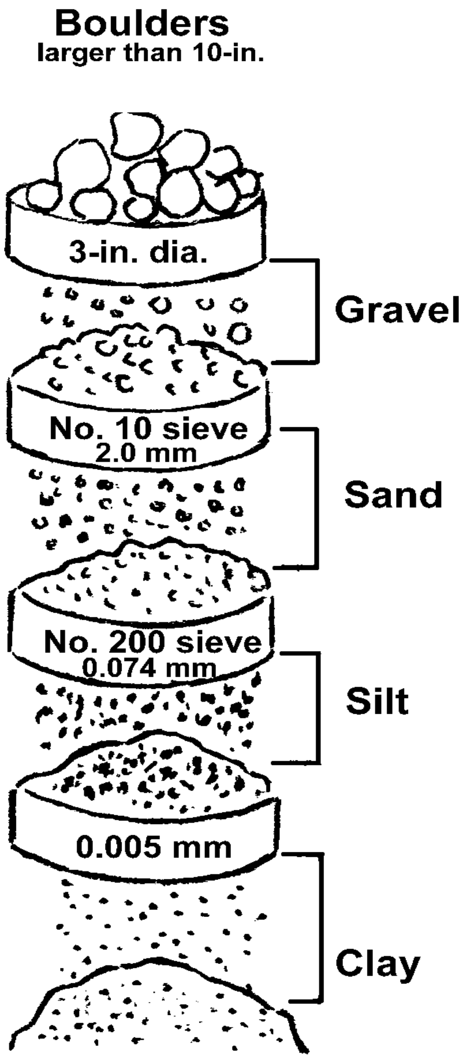
Soil Texture	Visual detection of Particle Size and general appearance of the soil	Squeezed in hand and pressure released: When Air Dry	Squeezed in hand and pressure released: When Moist	Soil ribboned between thumb and finger when moist.
Sand	Soil has a granular appearance in which the individual grain sizes can be detected. It is free-flowing when in a dry condition.	Will not form a cast and will fall apart when pressure is released.	Forms a cast which will crumble when lightly touched.	Can not be ribboned.
Sandy Loam	Essentially a granular soil with sufficient silt and clay to make it somewhat coherent. Sand characteristics predominate.	Forms a cast which readily falls apart when lightly touched.	Forms a cast which will bear careful handling without breaking.	Can not be ribboned.
Loam	A uniform mixture of sand, silt and clay. Grading of sand fraction quite uniform from coarse to fine. It is mellow, has somewhat gritty feel, yet is fairly smooth and slightly plastic.	Forms a cast which will bear careful handling without breaking.	Forms a cast which can be handled freely without breaking.	Can not be ribboned.
Silt Loam	Contains a moderate amount of the finer grades of sand and only a small amount of clay over half of the particles are silt. When dry it may appear quite cloddy which readily can be broken and pulverized to a powder.	Forms a cast which can be freely handled. Pulverized it has a soft flourlike feel.	Forms a cast which can be freely handled. When wet, soil runs together and puddles.	It will not ribbon but it has a broken appearance, feels smooth and may be slightly plastic.
Silt	Contains over 80% of silt particles with very little fine sand and clay. When dry, it may be cloddy, readily pulverizes to powder with a soft flourlike feel.	Forms a cast which can be handled without breaking.	Forms a cast which can freely be handled. When wet, it readily puddles.	It has a tendency to ribbon with a broken appearance, feels smooth.
Clay Loam	Fine textured soil breaks into hard lumps when dry. Contains more clay than silt loam. Resembles clay in a dry condition; identification is made on physical behavior of moist soil.	Forms a cast which can be freely handled without breaking.	Forms a cast which can be handled freely without breaking. It can be worked into a dense mass.	Forms a thin ribbon which readily breaks, barely sustaining its own weight.
Clay	Fine textured soil breaks into very hard lumps when dry. Difficult to pulverise into a soft flourlike powder when dry. Identification based on cohesive properties of the moist soil.	Forms a cast which can be freely handled without breaking.	Forms a cast which can be handled freely without breaking.	Forms long, thin flexible ribbon. Can be worked into a dense, compact mass. Considerable plasticity.
Organic Soils	Identification based on the high organic content. Muck consists of thoroughly decomposed organic material with considerable amount of mineral soil finely divided with some fibrous remains. When considerable fibrous material is present, it may be classified as peat. The plant remains or sometimes the woody structure can easily be recognized. Soil color ranges from brown to black. They occur in lowlands, in swamps or swales. They have high shrinkage upon drying.			

TABLE 1.—*Field Method for identification of soil texture.*

Table 2.4 Identification of principal soil type

Principal soil type	Particle size (mm)		Particle size (mm)
Boulders	>200		
Cobbles	60—200		
		coarse	20—60
Gravel	2—60	medium	6—20
		fine	2—6
		coarse	0.6—2
Sand	0.06—2	medium	0.2—0.6
		fine	0.06—0.2
Silt	<0.06		

Gradation



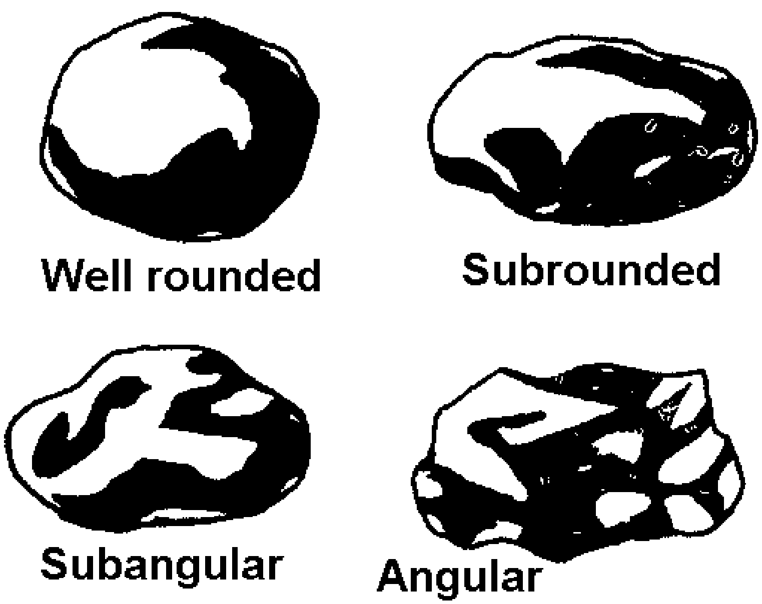
Soil gradation is the distribution, in percent (%) by weight, of individual particle sizes.

Soil Types

Organic Soils

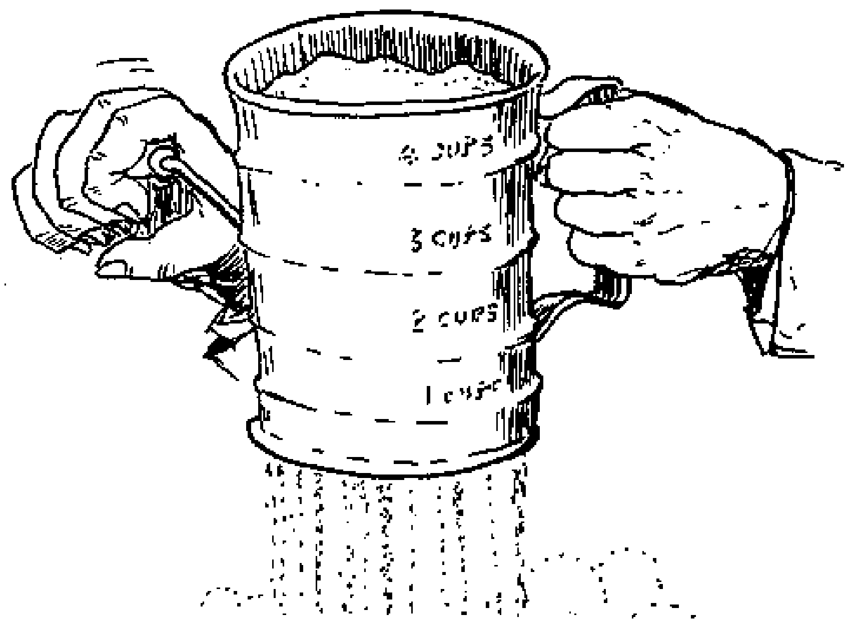
Will usually have to remove before building.

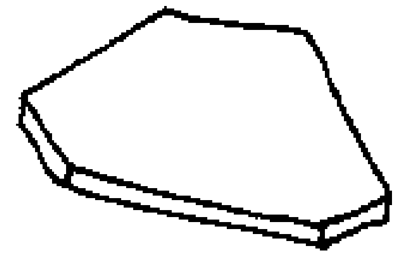
Bulky shaped soil grains



Soil Types

Cohesive



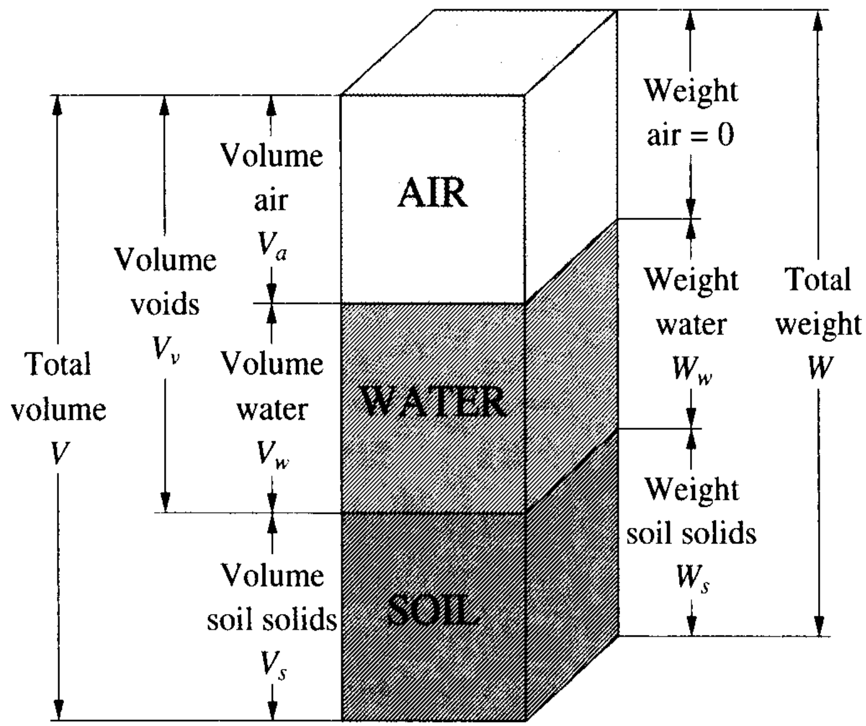


Platy shaped soil grains

Small grained < #200 Mesh sieve

Soil Mass

Composed of air, water, and solid particles.



Soil Weight-Volume Relationships

$$\text{Unit weight} \quad (\gamma) = \frac{\text{total weight of soil}}{\text{total soil volume}} = \frac{W}{V}$$

$$\text{Dry unit weight} \quad (\gamma_d) = \frac{\text{weight of soil solids}}{\text{total soil volume}} = \frac{W_s}{V}$$

$$\text{Water content} \quad (\omega) = \frac{\text{weight of water in soil}}{\text{weight of soil solids}} = \frac{W_w}{W_s}$$

Water Content

$$\text{Water content } (\omega) = \frac{\text{weight of water in soil}}{\text{weight of soil solids}} = \frac{W_w}{W_s}$$

$$\boldsymbol{\omega} = \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Dry Weight}}$$

Soil Weight-Volume Relationships

Dry weight is related to unit weight by water content,

$$\gamma_d = \frac{\gamma}{1+\omega}$$

when you move rock and dirt the only thing that stays constant is the weight of the solid particles.

Sub-soil exploration: For new structures

- Selection of type and depth of foundation
- Determination of bearing capacity of the selected foundation
- Prediction of settlement of the selected foundation
- Determination of the ground water level
- Evaluation of earth pressure against walls, basements abutments etc.
- Provision against constructional difficulties
- Suitability of soil and degree of compaction of soil.

Sub soil exploration: For existing structures

- Investigation of safety of the structure
- Prediction of settlement
- If structure is unsafe/will suffer detrimental settlement: Determination of remedial measures

Fig: Soil investigation

https://theconstructor.org/geotechnical/site-investigation-soil-exploration/312/

Scope of Soil Investigation

- Type and importance of Structure
- Existence of any previous knowledge of the sub-soil
- Cost of investigation relative to cost of proposed structure

<u>Soil-Investigation report contains</u>

- Nature and thickness of sub-soil strata
- Mechanical properties of each strata at least the strata and any other underlying strata that a structure is to be supported upon
- Density, natural moisture content (incl. any seasonal variation), compressibility bearing capacity and shear strength
- Chemical and physical properties
- Natural ground water level of the site (incl. seasonal variations)

Soil Investigation

- Report will help to get the soil behaviour during excavation
- Report will have major influence on the decision of type of foundation
- Access to different level of soil strata must be made
- Choice of test: nature of ground, topography of ground and comparative cost of available methods

Choice of exploration method

- Nature of ground
- Topography
- Cost

Soil samples

- Disturbed samples
- Undisturbed samples

Soil samplers

- Open drive sampler
- Stationary piston sampler
- Rotary sampler

Methods of site exploration

- Open excavations
- Borings
- Sub surface soundings
- Geo physical methods

Trial Pit/Open excavations

- Cheapest method
- Can be used in all types of soils
- Pits excavated & soil samples collected at each level.
- Investigation of Soil strata in their natural conditions
- Suitable for shallow depths up to 3m.
- Cost increases with depth.

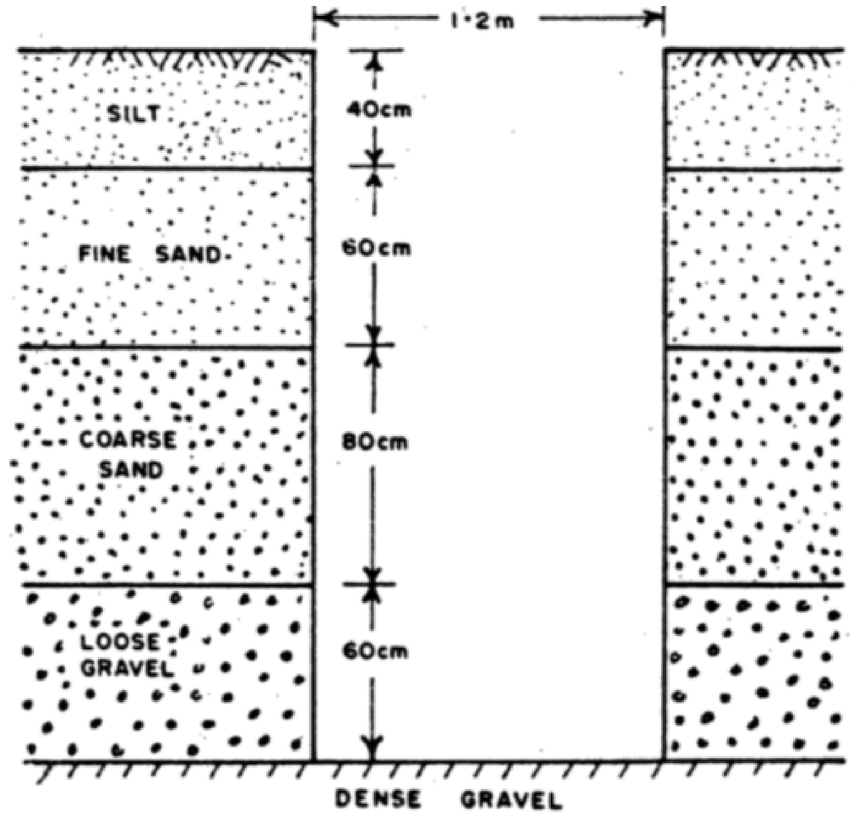
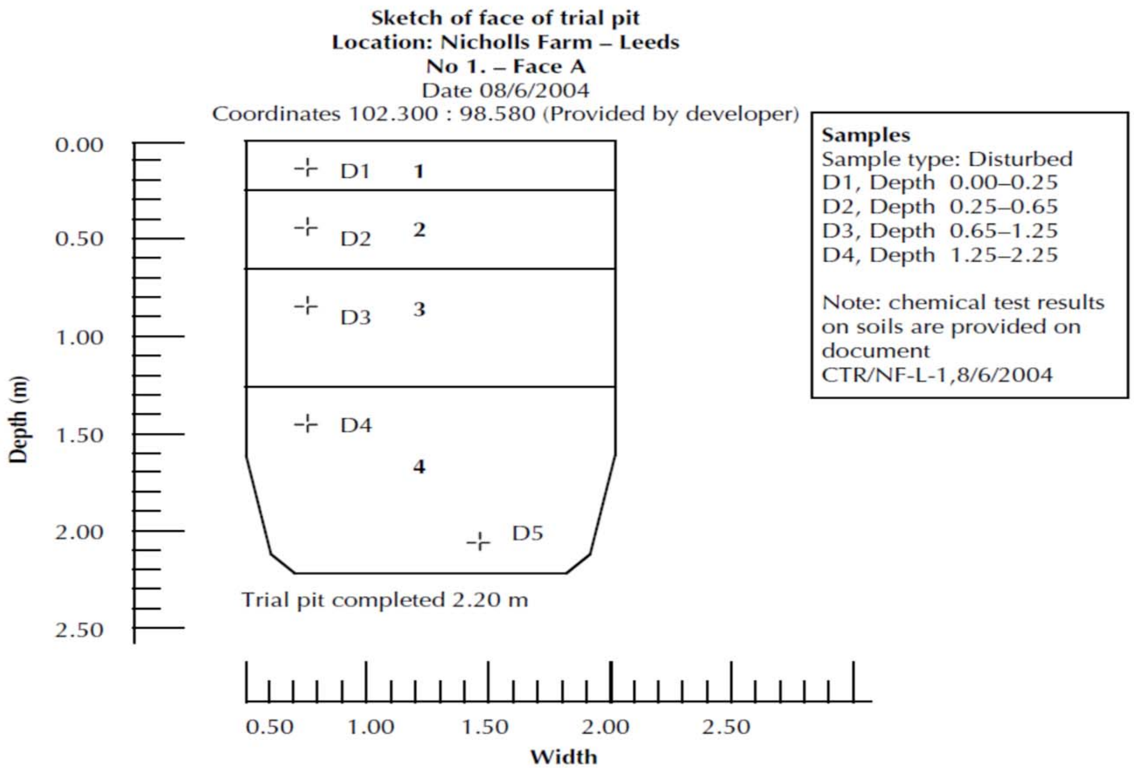


Fig: Trial pit

B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

Trial pits/open excavation

- Excavated by a mechanical excavator, or by hand tools, to a depth of 3–4 m.
- Nature of the subsoil is determined by examination of the sides of the excavations.
- Soil and rocks can be examined in situ on the faces of the excavated pit,
- Samples taken for further laboratory tests.
- Trial pit provides an indication of ease of dig (or excavation), trench stability & groundwater conditions
- For shallow depths (up to 3 m), Trial pits are economical than boreholes.
- Pits are rectangular, being approximately 1.2 × 1.2 m in plan.
- Excavated in the vicinity of the proposed structure;
- If pit is located under a proposed foundation - backfill the hole using material should be of sufficient strength and well compacted.



Strata

(1) Topsoil and grass 220 mm
(2) Made ground: firm to stiff orange brown sandy clay with a little gravel of limestone
(3) Made ground: soft to firm dark grey clay with occasional rootlets
(4) Medium dense dark grey clay

Notes:

(1) Groundwater: no groundwater encountered
(2) Variability of faces: all faces were similar
(3) Stability of faces: all faces were stable
(4) Weather: overcast

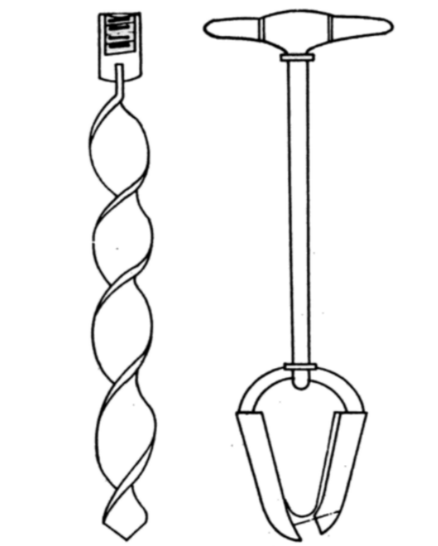
Figure 2.1 Trial pit log.

Trial pits

- Care to be taken during digging or inspection- unless sides are stables- shoring needed if unstable.
- Pit can not be dug in silts and sands below water table or in soft clays- sides will collapse
- Disturbed, undisturbed and hand-cut samples can be taken
- Variability conditions is much more apparent that boreholes
- Side can be photographed for permanent record

Boring methods

1. Auger boring
2. Auger and shell boring
3. Wash boring
4. Percussion boring
5. Rotary boring



(a) HELICAL AUGER (b) POST-HOLE AUGER.
FIG. 2.12. AUGER.

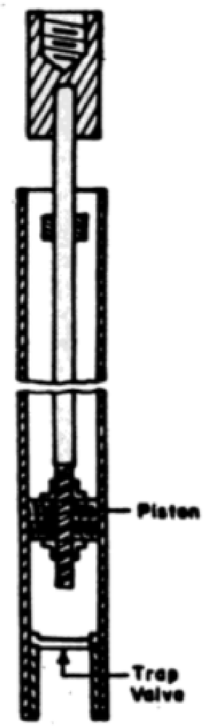


FIG. 2.13. SAND PUMP

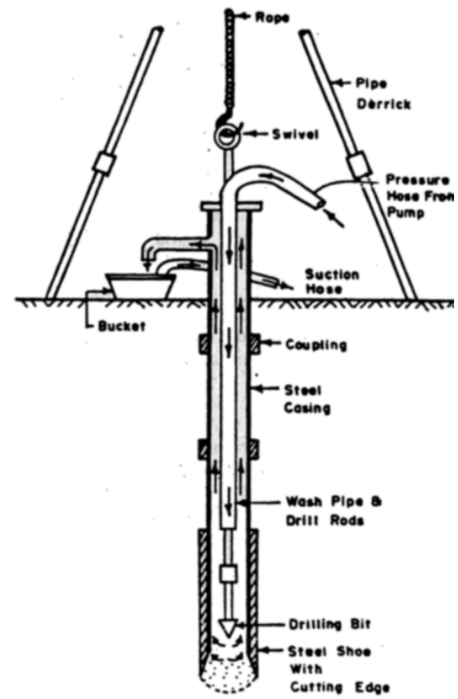


FIG. 2.14. WASH BORING.

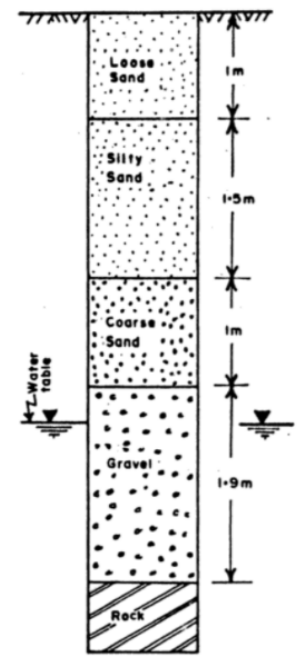


FIG.2.15. DETAILS OF BORING.

Fig: Boring methods

B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

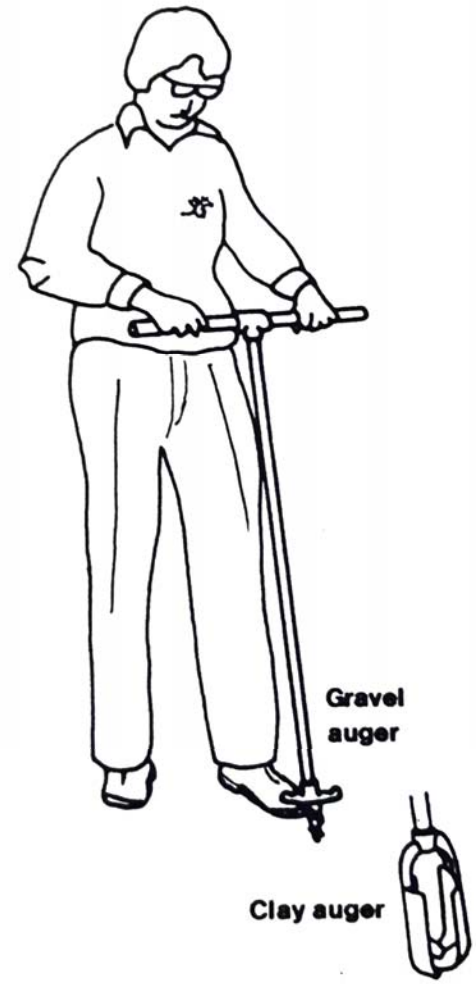
Boreholes

"Boreholes" represents various methods used to excavate and extract disturbed and undisturbed soil samples.

Samples from boreholes sealed immediately to minimise any loss of moisture before testing.

Post-hole:

- Hand augers useful for soft firm clays- up to 5 m depth- hole diameter: 50 to 100 mm
- Stopped by stones or ever gravel easily
- Power augers overcome this problem



Post-hole auger

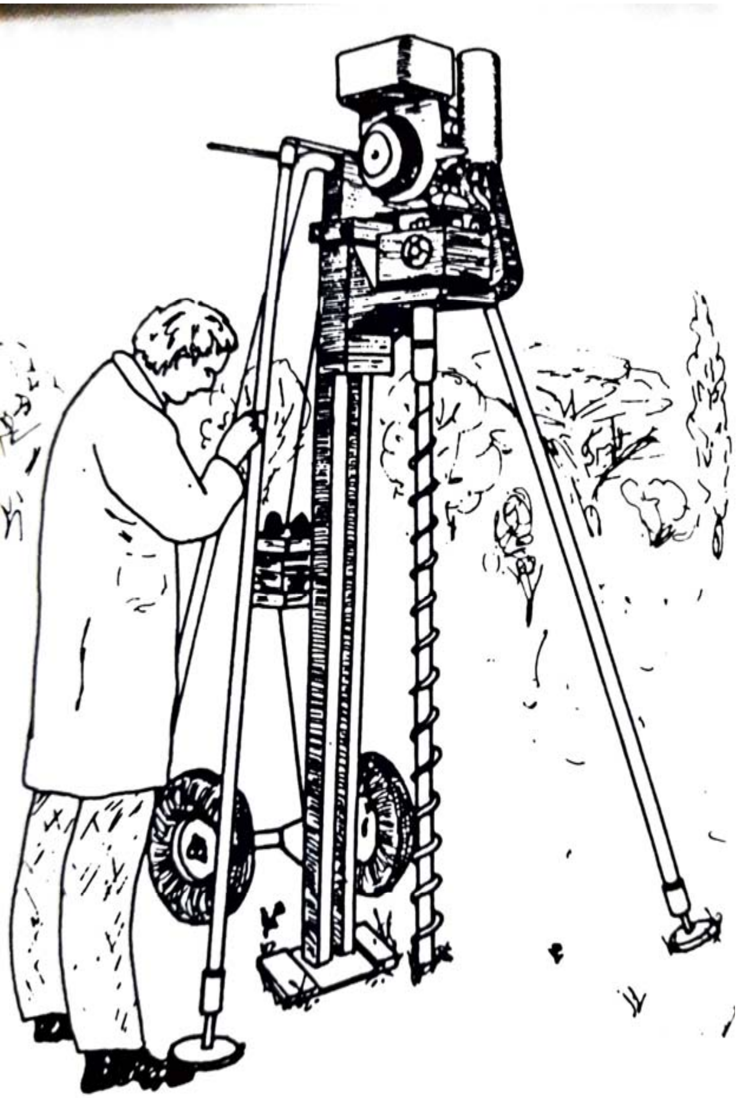
Boreholes: Auger boring – rotary boring methods

Hand or powered short-helical auger: Holes are made by into the ground.

- Auger holes: 75–150 mm in diameter.
- Disturbed samples of soil are collected as they are brought to the surface.

Rotary drilling - used where boreholes are being cut into very dense gravel or bedrock.

- Samples or bedrocks are recovered in seamless plastic tubes, logged by an engineer - taken for laboratory testing
- Power auger Truck/trailer-mounted- capable of penetrating up to 50 m
- Suitable for cohesive soils- rapid penetration is achieved
- Disturbed samples can be collected- difficult to identify depth at which changes in strata occur-
- Small undisturbed samples can be obtained by hand driving tubes into the bottom of the hole.
- Sample in-situ test can be done



Small power auger

Shell and Auger boring

- Uses Tripod legs with power winch
- Repeated dropping of auger consisting of steel tube to the bottom of bore hole
- After every few blows- lifted out of hole for cleaning (with a crow bar)
- Auger for clays, sand etc.,
- Sand and gravel Auger: Valve fitted at lower end of the tube- when dropped into bottom of a bore hole partly filled with water- soil and water are forced through the valve- trapping sediments inside

Shell and Auger boring

- Bounders &moderate depths of Rocks- penetrated by repeated dropping of drill bit or chisel down a hole.
- Steel lining tubes - inserted to support sides of bore hole
- With wide variety of tools- useful for all types of soil above & below water table.
- Skilled operator required
- Clay: undisturbed samples- using 100 mm dia. Open-drive sampler- but not possible sands and gravels – in-situ test to be done

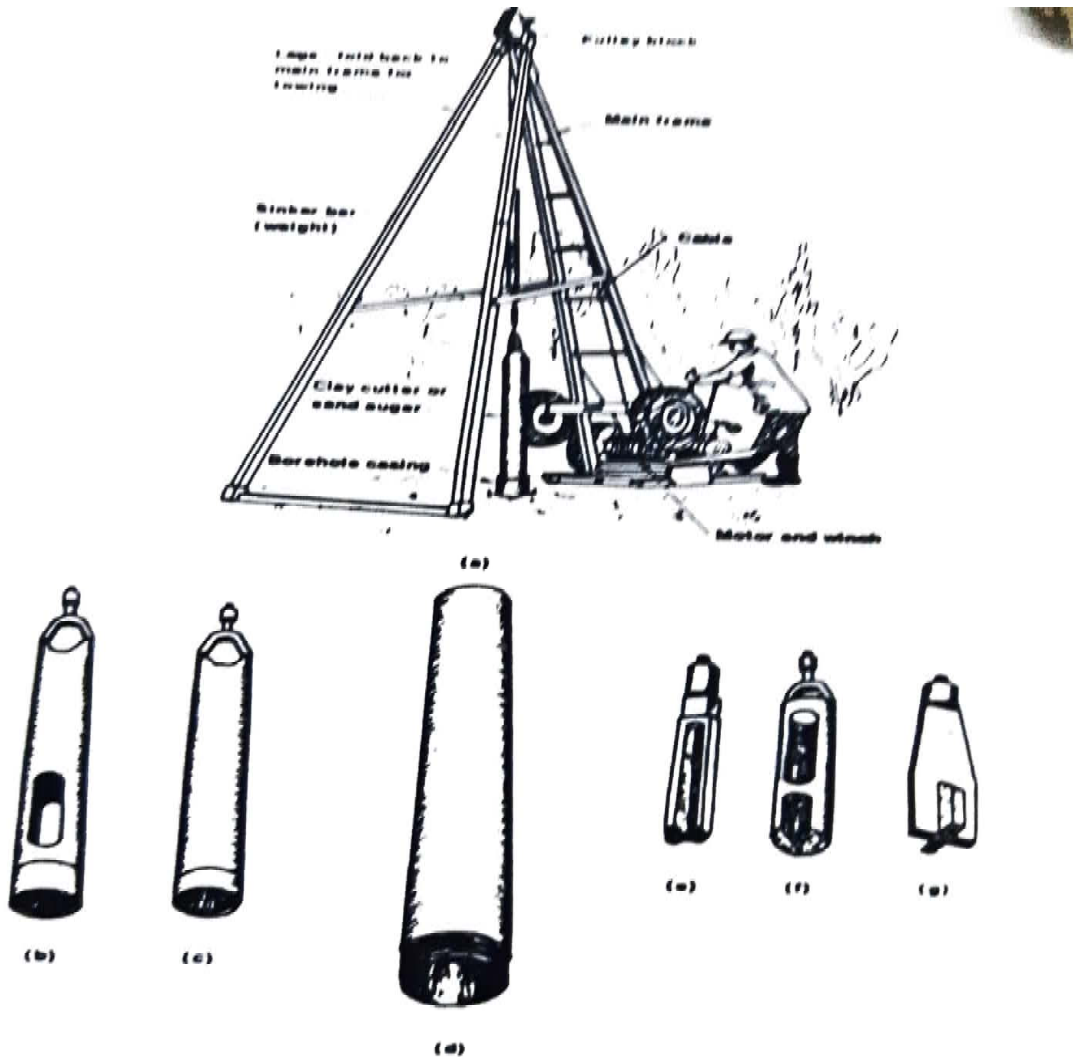


Figure 3.6 Shell and auger equipment: (a) rig; (b) clay cutter; (c) shell or sand auger; (d) borehole casing; (e) drilling bit or chisel; (f) clay auger (g) cross-head chisel.

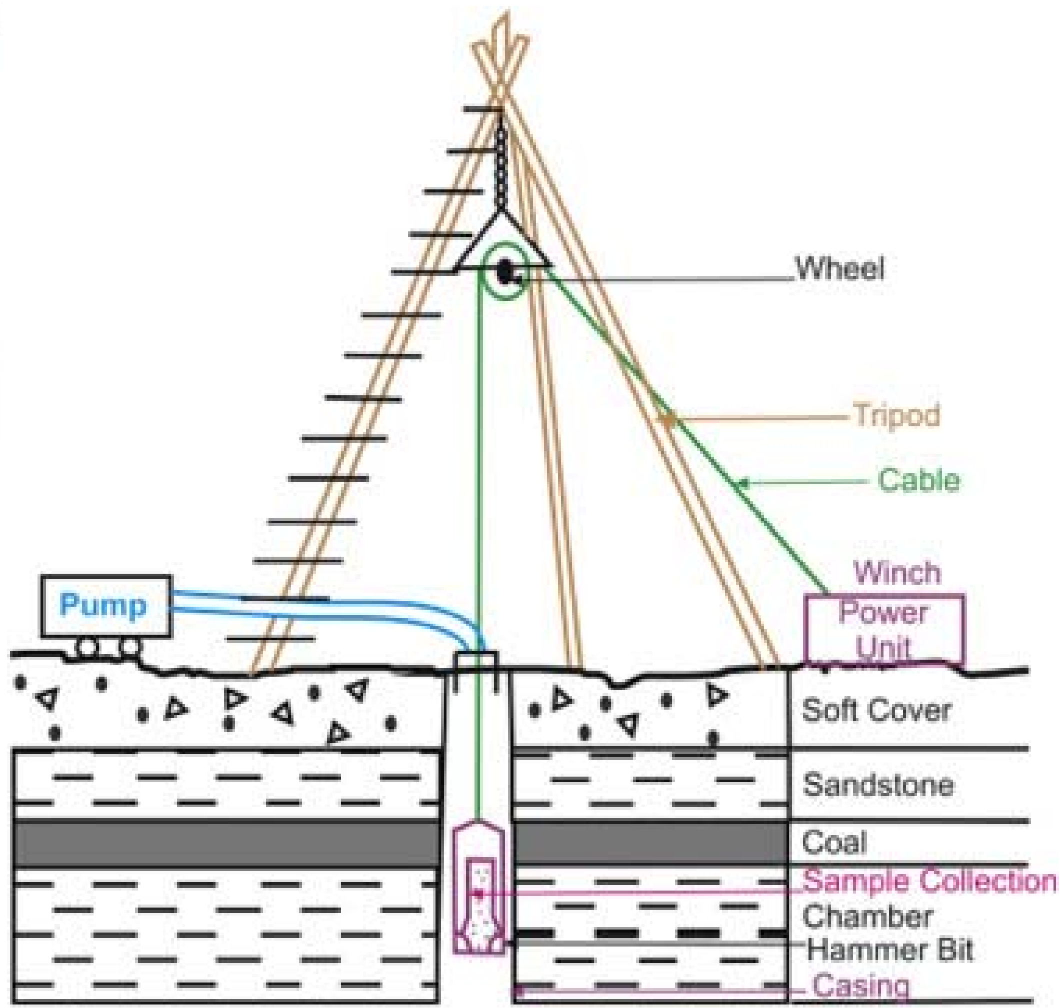
Window samplers

- A steel tube of about 1 m length, with a hole cut into the wall of the tube, allowing the disturbed sample to be viewed or soil samples taken from the tube.
- Tube is driven into ground - by lightweight percussion hammer and extracted with the aid of jacks.
- Tube diameter- wide range: Large tubes are driven in first and removed, leaving a hole for smaller tubes to be inserted and driven in further.
- Samples can be obtained down to a depth of 8 m.



Percussion boring

- Boreholes made using light percussion equipment.
- A weighted hollow tube of 150–200 mm diameter is dropped into the hole- soil becomes lodged within the tube.
- Tube is lifted to the surface - sample removed.
- Clay soils: Method relies on the cohesive properties of the soil to hold it in the tube (clay cutter).
- Granular soils: Hollow tube with a flap over its base is used (shell or bailer). Materials collected during the drilling and excavation -disturbed samples
- One day: Drilling up to 15 m
- Cohesive soils: Tube of diameter 100 mm can be dropped to the bottom of the hole to collect an undisturbed sample (undisturbed sampling is confined to cohesive soils). - Tube is then to the laboratory for further tests.
- Standard penetration tests (SPTs) and vane tests can be carried out in the borehole as the drilling and excavation process proceeds.


Wheel
Tripod
Cable
Winch
Power Unit
Pump
Soft Cover
Sandstone
Coal
Sample Collection
Chamber
Hammer Bit
Casing

Soil sample ready for logging

Exploratory investigation and foundation systems

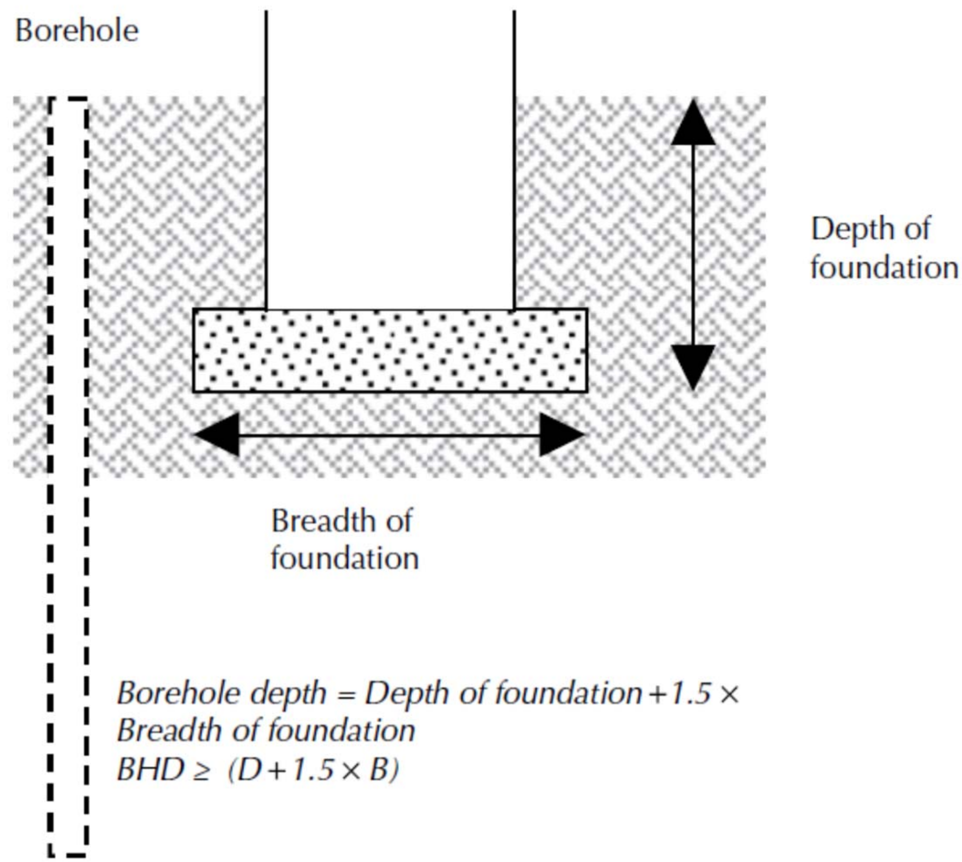
- Boreholes and trial pits will be used to design suitable foundation systems.

- Boreholes must penetrate through all unsuitable deposits such as unconsolidated fill, degradable material, peat, organic silts and very soft compressible clay.

- Once a suitable bearing stratum is reached, the depth of the borehole can be calculated.

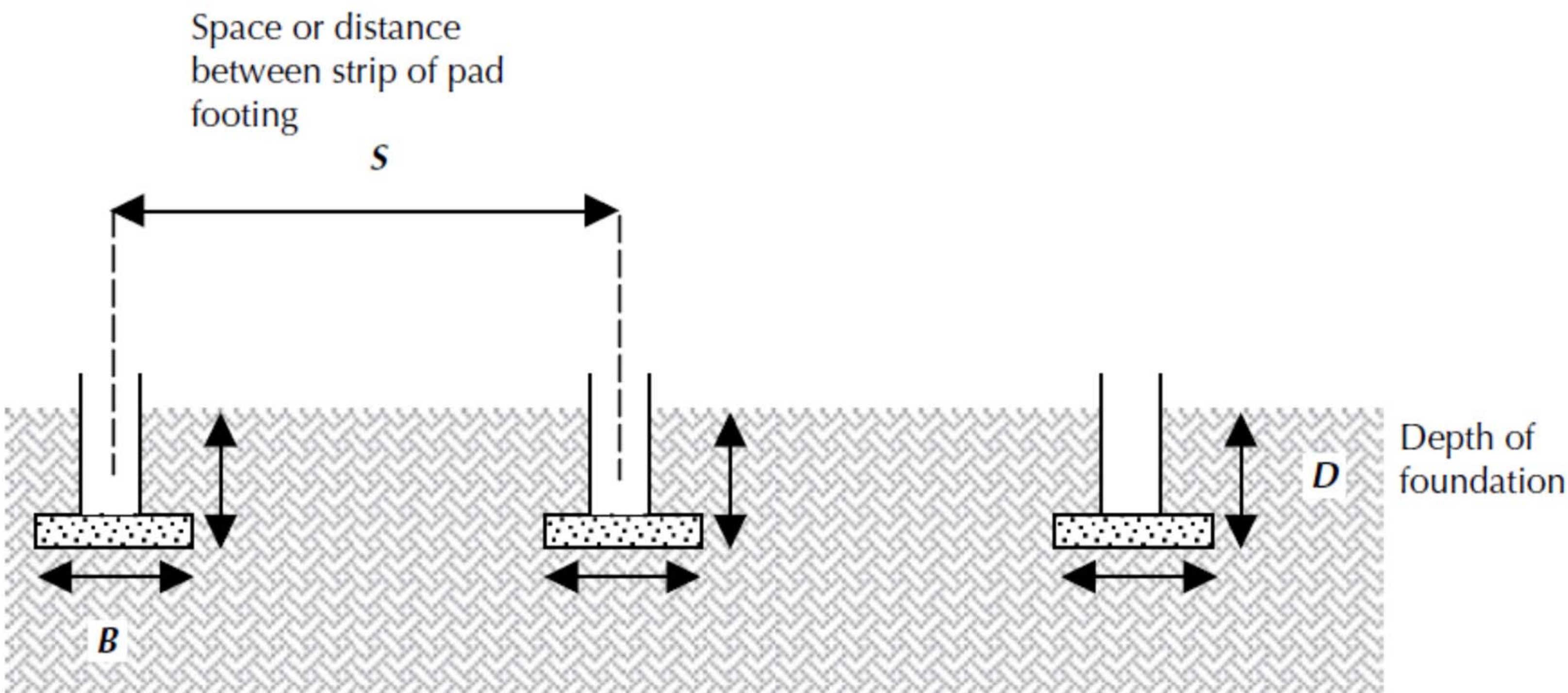
Isolated pad or raft foundations

Where the structure rests on an isolated pad or raft foundation



Depth of borehole for pad and raft foundations.

Closely spaced strip or pad foundations



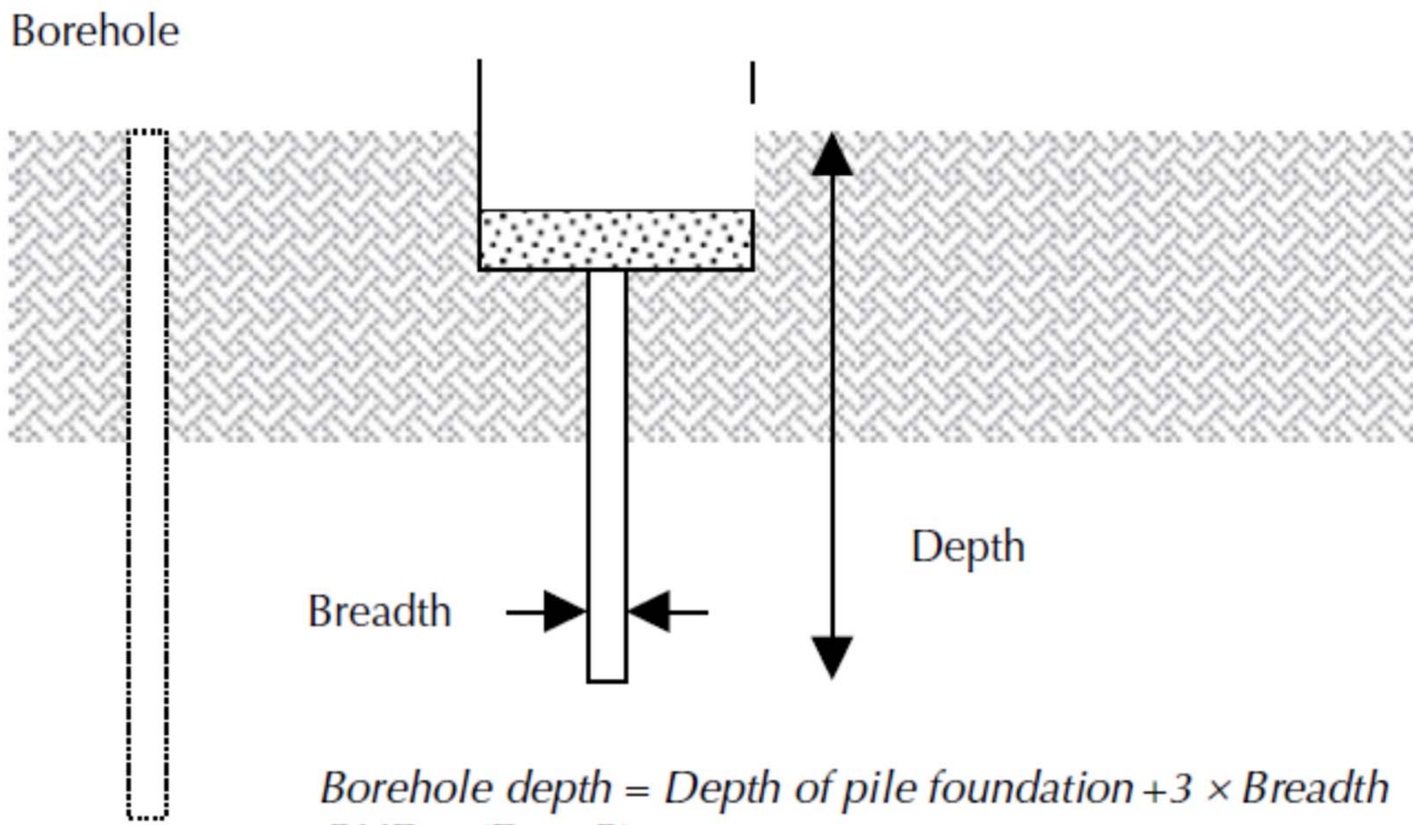
Borehole depth = Depth of foundation + 1.5 × (2 × Space between foundations + Breadth of foundation)

BHD ≥ D + 1.5(2S + B)

Used where S is less than 5 times B

Figure 2.3 Depth of borehole for closely spaced strip or pad foundations.

Structure on friction piles



$$\text{Borehole depth} = \text{Depth of pile foundation} + 3 \times \text{Breadth}$$
$$BHD \geq (D + 3B)$$

Figure 2.4 Depth of borehole for friction piles.

Site Investigation: Soil Testing

- Laboratory based tests
- Field tests

Laboratory Tests: Soil Classification Tests

- Moisture content: frequently used for determination of dry density, degree of saturation
- Liquid Limit and Plastic Limit (Atterberg limits): used to classify fine grained soil and as an aid for classifying fine fraction of mixed soils.
- Linear shrinkage/Volumetric shrinkage: to identify presence of expansive clay minerals
- Specific gravity: used for determination of other properties like voids ratio, particle distribution by sedimentation
- Particle size distribution by sieving: Sieve analysis for content of sand and gravel; Hydrometer test for content of clay and silt.
- Particle size distribution by sedimentation: Proportion of soil passing through finest sieve (64 micron) represent silt and clay fraction- can be determined only by sedimentation
- Laboratory vane shear Test: Useful for classifying silts and clays in terms of consistency

Laboratory Tests: Soil Permeability Tests

- A measure of rate of flow of water through soil

- Constant Head permeability test: water is forced by known constant pressure through soil specimen of known dimensions- rate of flow is determined; suitable for soil permeability range 10^{-4} to 10^{-2} m/sec.

- Falling head permeability test: water is forced by a falling head pressure. Suitable for soil having lower permeability

- Grain size analysis: Sieve analysis

Laboratory Tests: Soil Compaction tests

- Dry density/Moisture content relationship: Indicates the degree of compaction that can be achieved at different moisture contents and with different compactive efforts

Laboratory Tests: Chemical and Corrosivity on soils and groundwater

- Organic matter content: detects presence of organic matter which can

    i) interfere with hydration of cement in soil or cement paste,

    ii) influence shear strength, bearing capacity and compressibility,

    iii) promote microbiological corrosion of buried steel

- Sulphate content in soil (Total and sulphate ion content in ground water and aqueous soil extracts): Assess the aggressiveness of soil and groundwater to buried concrete and steel

- pH value: Assesses aggressiveness of soil and groundwater to buried concrete and steel

- Chloride ion content: Assesses i) aggressiveness of soil to buried concrete and steel, ii) suitability of fine aggregate for use in concrete

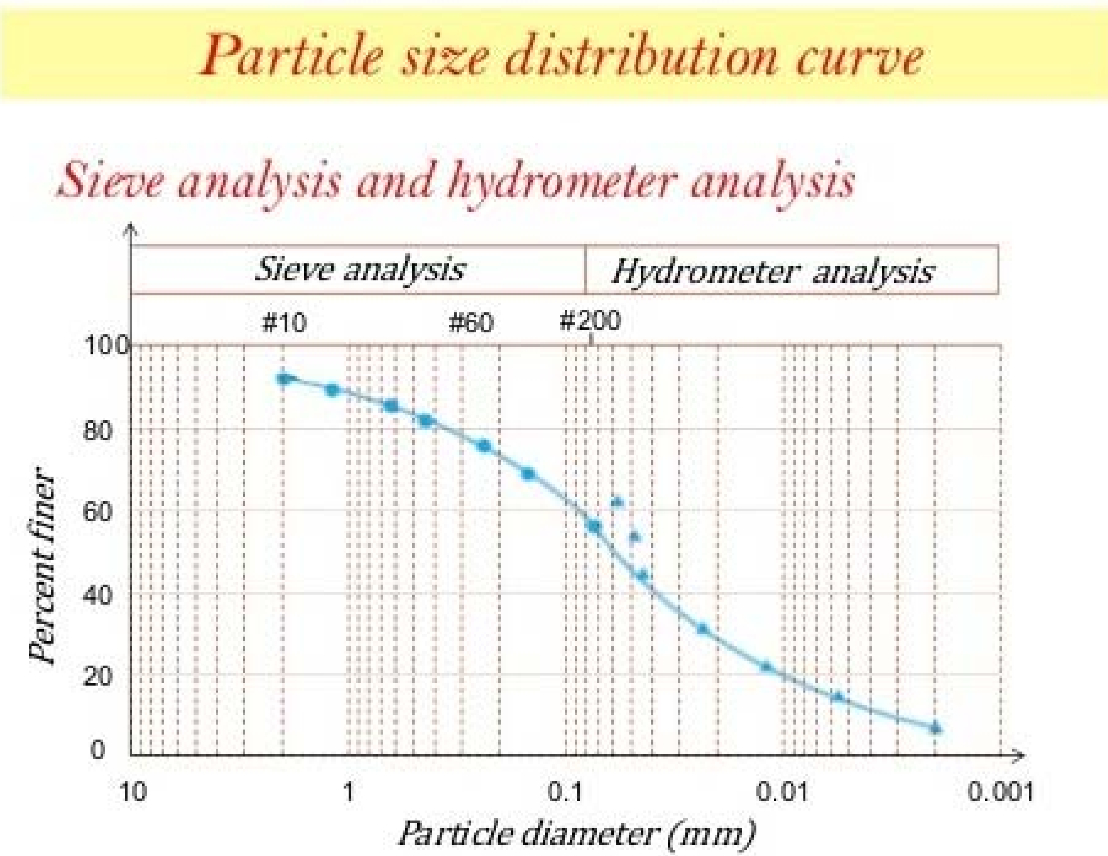
Laboratory Tests: Soil Strength Tests

- Unconfined compression test/Unconsolidated undrained Triaxial compression test/ Consolidated undrained triaxial compression test with pore pressure measurement/ consolidated drained triaxial compression test with volume change measurement: Stress-strength relations

- Direct shear test: useful and practical alternative to consolidated undrained triaxial test. Specimen can be oriented to measure shear strength on a pre-determined plane

- Soil deformation Test: One-dimensional /triaxial consolidation tests: Significant settlement can occur due to consolidation of soil under imposed load; test provides soil parameters from which the amount and time-scale of settlement can be evaluated

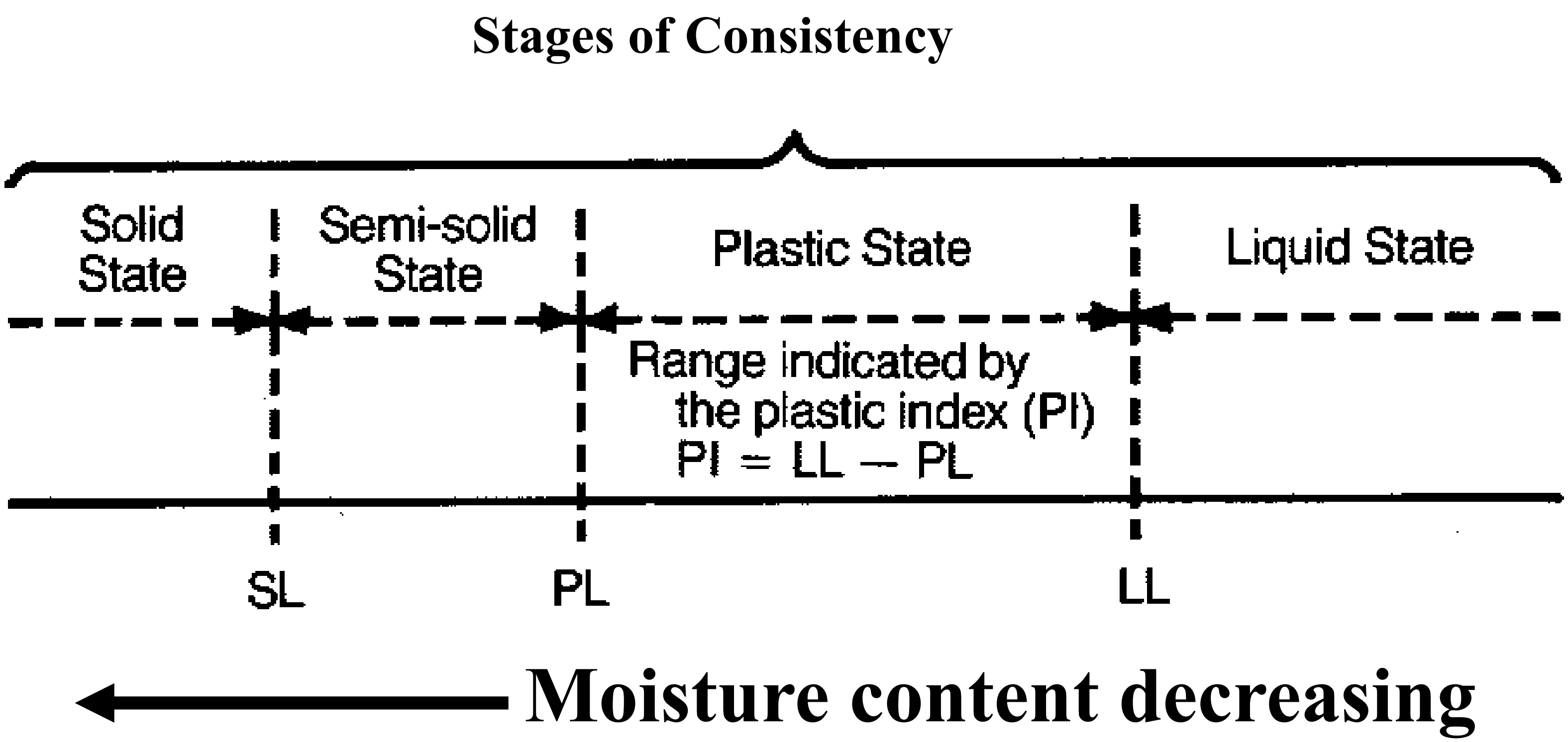
Soil Testing



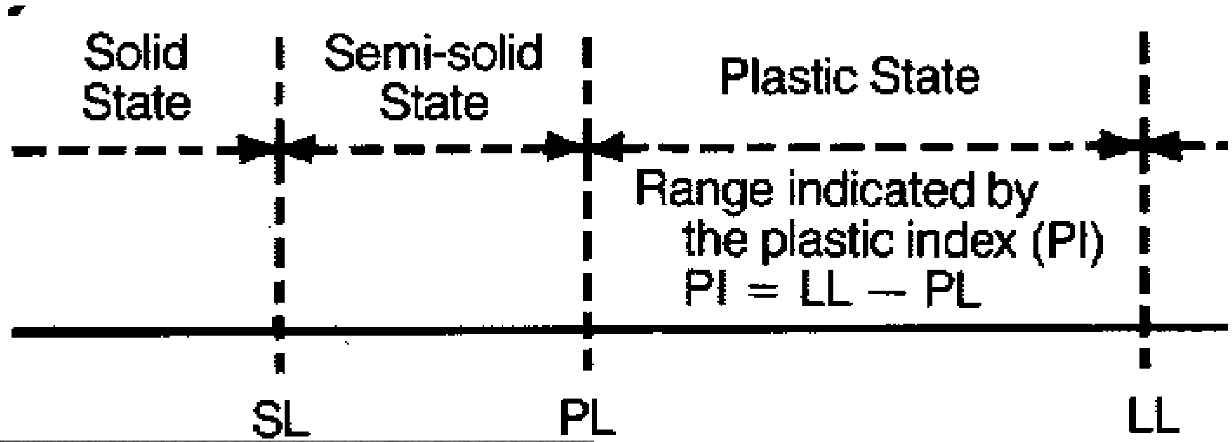
Soil Testing: Laboratory Tests

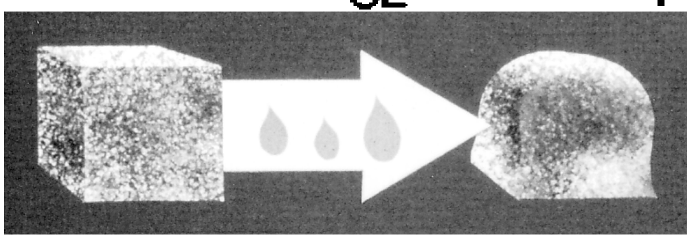
- Soil Limits: Atterburg Limits
- LL - Liquid limit
- PL - Plastic limit
- PI - Plasticity Index

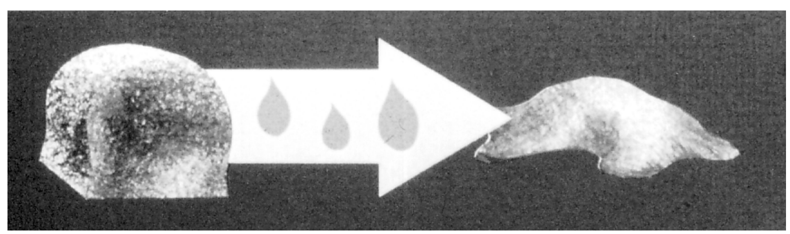
Soil Limits


Stages of Consistency
Solid State
Semi-solid State
Plastic State
Liquid State
Range indicated by the plastic index (PI)
PI = LL – PL
SL
PL
LL
Moisture content decreasing

SOIL LIMITS


Solid State
Semi-solid State
Plastic State
Range indicated by the plastic index (PI)
PI = LL − PL
SL
PL
LL



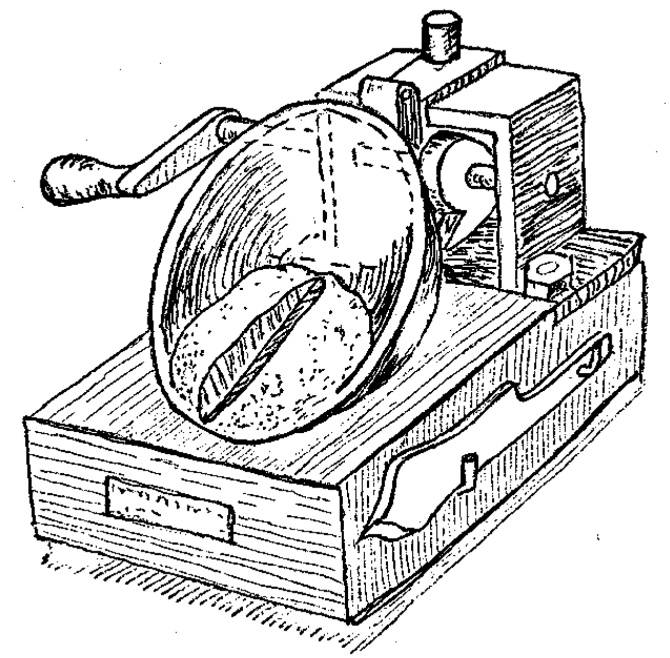


SOIL LIMITS

LL - Liquid limit is the water content of a soil when it passes from the plastic to liquid state.

Non-cohesive or sandy soils have low LLs -- less than 20.

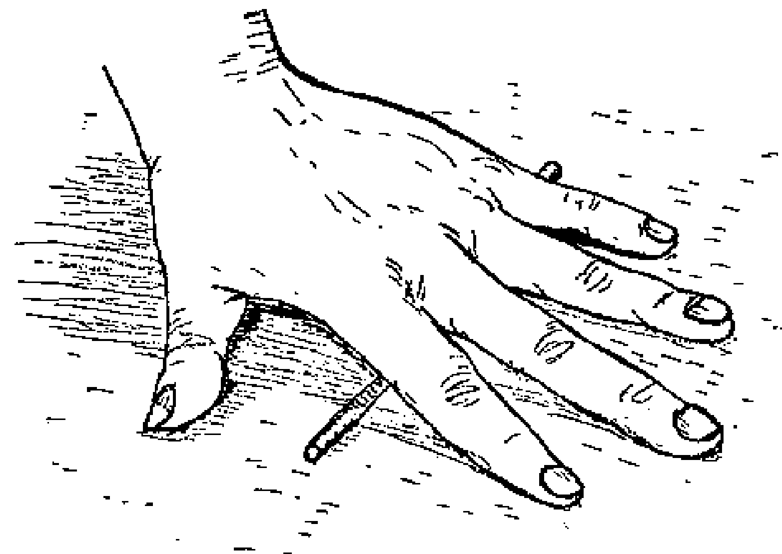
Clay soils have LLs ranging from 20 to 100.



Soil Limits

PL - lowest water content at which a soil remains plastic.

3 mm diameter thread



PI - Plastic Index   PI = LL – PL

The higher the PI the more clay that is present in the soil.

Field Tests: Sub-surface soundings

- Measuring the resistance of soil with depth by means of penetrometer.
- Done under static and dynamic loading
- Penetrometer consist of sampling spoon, a cone or other shaped tool.
- Resistance of penetration is related to density Index, consistency, bearing capacity etc

Useful for

- Exploration of erratic soil profiles
- Depth to bed rock or stratum
- Have an appropriate induction of strength and other properties of soil.

Two tests:

- Standard penetration test
- Cone penetration test

Methods for estimating bearing capacity

- Analytical methods involving the use of soil parameters
- Plate load test on soil
- Penetration test
- Presumptive bearing capacity values from codes

Field Tests: Standard Penetration test

- Assessment of in-situ properties of granular soil which can not be samples in undisturbed state
- Also used for cemented soils and some clays
- Clean bottom of borehole & remove any disturbed materials
- Standard split spoon sampler is driven 450 mm into the soil (where sampling is made by repeated blows from a hammer of standard dimension
- Ignore No. blows required to produce first 150mm penetration (seating blows)
- Record No. Blows required to drive next 300 mm as N value (every 75 mm - value noted)
- Gives variation in soil profile across depth.
- Yields small disturbed sample

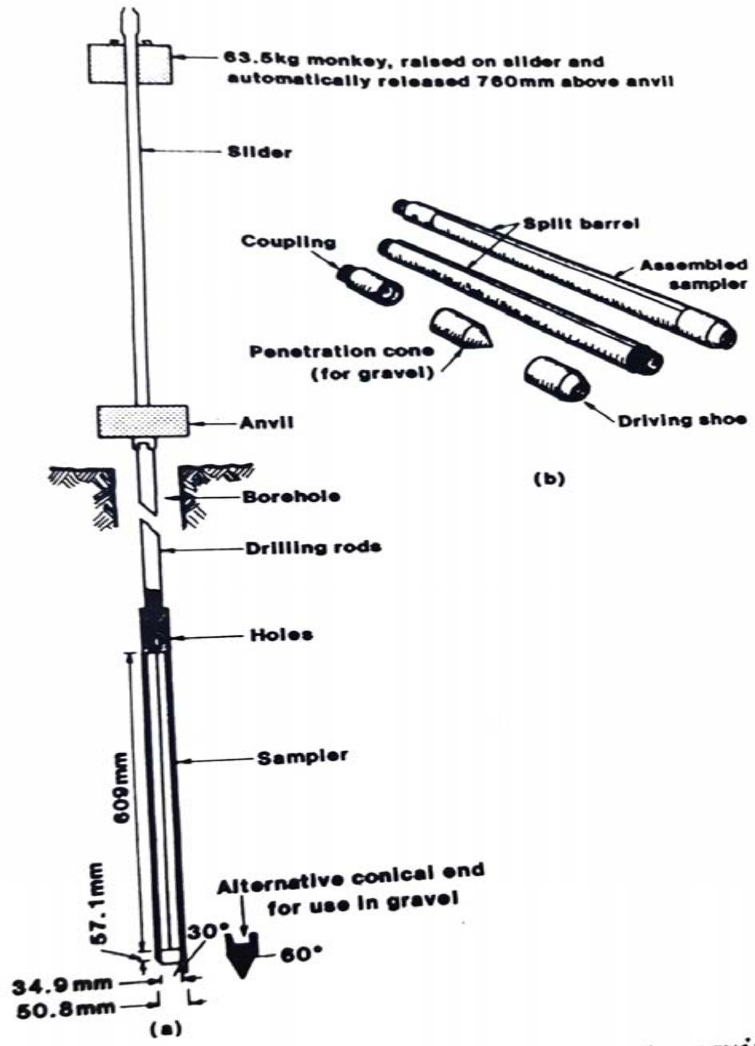


Figure 3.10 Standard penetration test equipment: (a) basic features and general arrangement; (b) details of the split-spoon sampler.

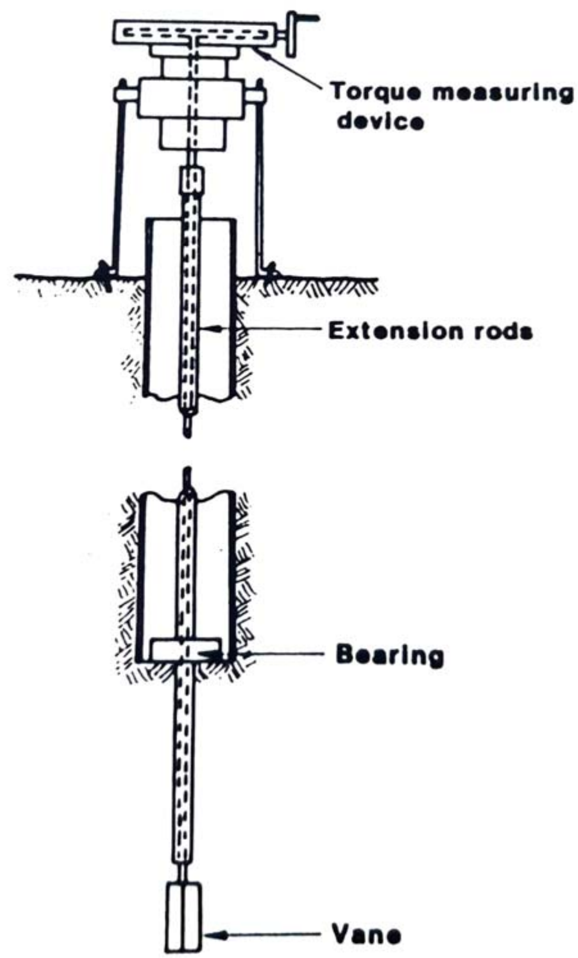


Figure 3.13 Borehole vane test.

Vane shear test

- Used to measure in-situ undrained shear strength of clay –
- suitable for soft or sensitive clays or silts which are difficult to sample- or whose properties of which are significantly altered by normal sampling methods
- Consists of 4-blade vane length 2times its width
- 150 mm long- 75 mm wide- for soft clays
- 100 mm long and 50 mm wide for firm clays
- Vane is inserted into ground on end of rod and slowly rotated- torque required for rotation is measured
- Types for use at bottom of bore hole or for direct penetration into ground

Penetrometer test

- Consists of a rod which is pushed slowly into the ground up to certain mark
- Force is applied through a spring so that the required load can be measured by compression of the spring
- By calibration of results with lab test- approx. value of undrained shear strength is established
- Small hand version is also useful for site engineers quick assessment
- Due to small size of plunger- several readings to be taken to obtain reliability of data

Plate load test

- Square circular plate is seated on the stratum to be tested- bottom of trial pit- and loaded
- Load is applied in increments and maintained until full- settlement has taken place at each increment
- Can be done at the bottom of the borehole
- Particularly suitable for coarse granular material which can not eb tested by normal means or penetration tests
- Limitation: Zone of soil stressed is much smaller than that beneath larger foundation- plate should be as large as possible.

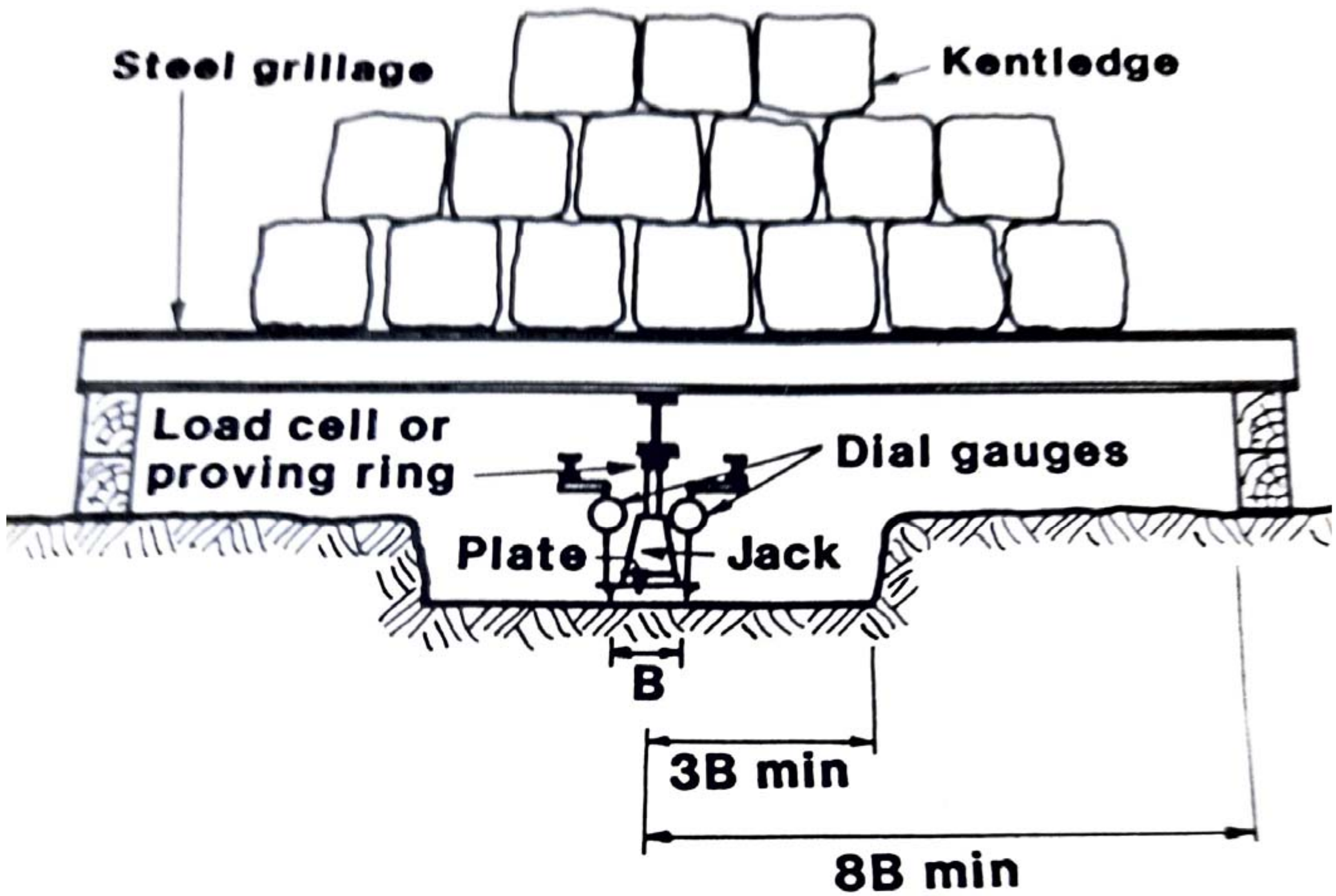


Figure 3.15 Plate bearing test, general arrangeme

Geo Physical methods: Seismic refraction method

- Shock waves created into soil at ground level/certain depth
- Waves are picked up by vibration detector
- Depth of strata evaluated from the time of travel of waves.

FOUNDATIONS—1 : GENERAL 41

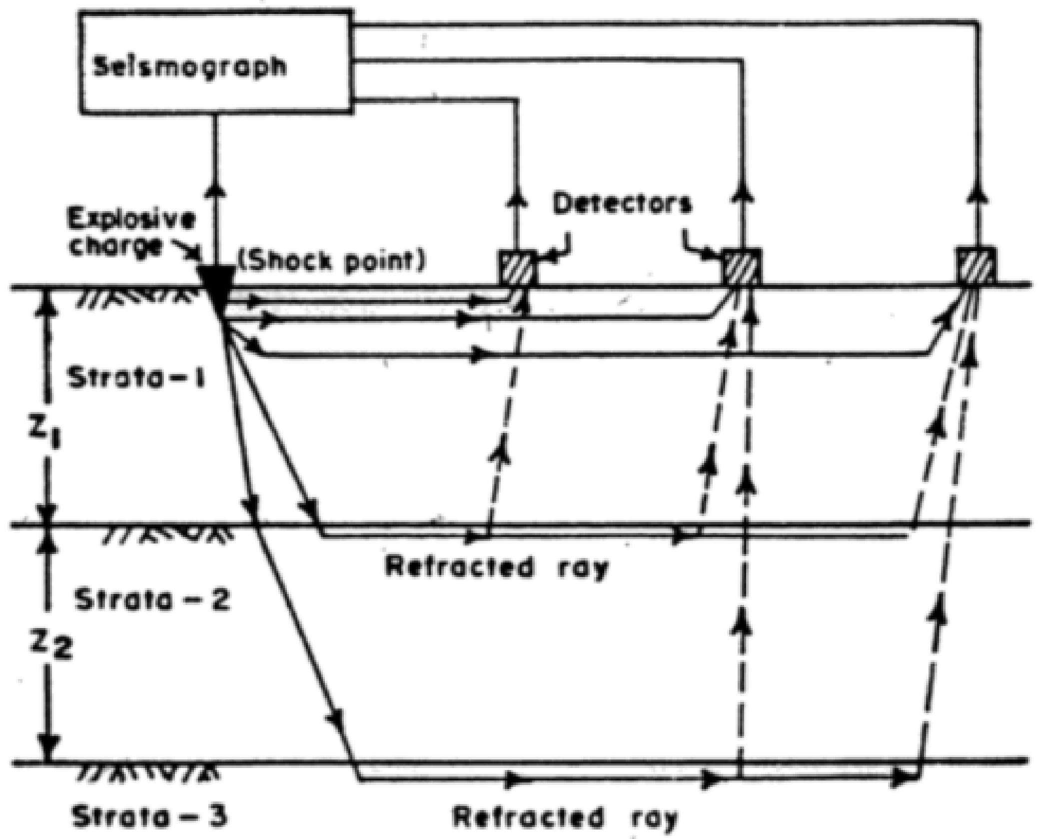


FIG. 2.16. SEISMIC REFRACTION METHOD.

❑B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

Geo Physical methods: Electrical Resistivity method

- Based on measurement & recording of changes in mean resistivity of various soils
- Resistivity depends on water content, compaction & composition
- 4 metal spikes electrodes driven along straight line at equal distance in soil
- Voltage is applied on 2 outer electrodes & potential drop is measured
- Mean resistivity computed

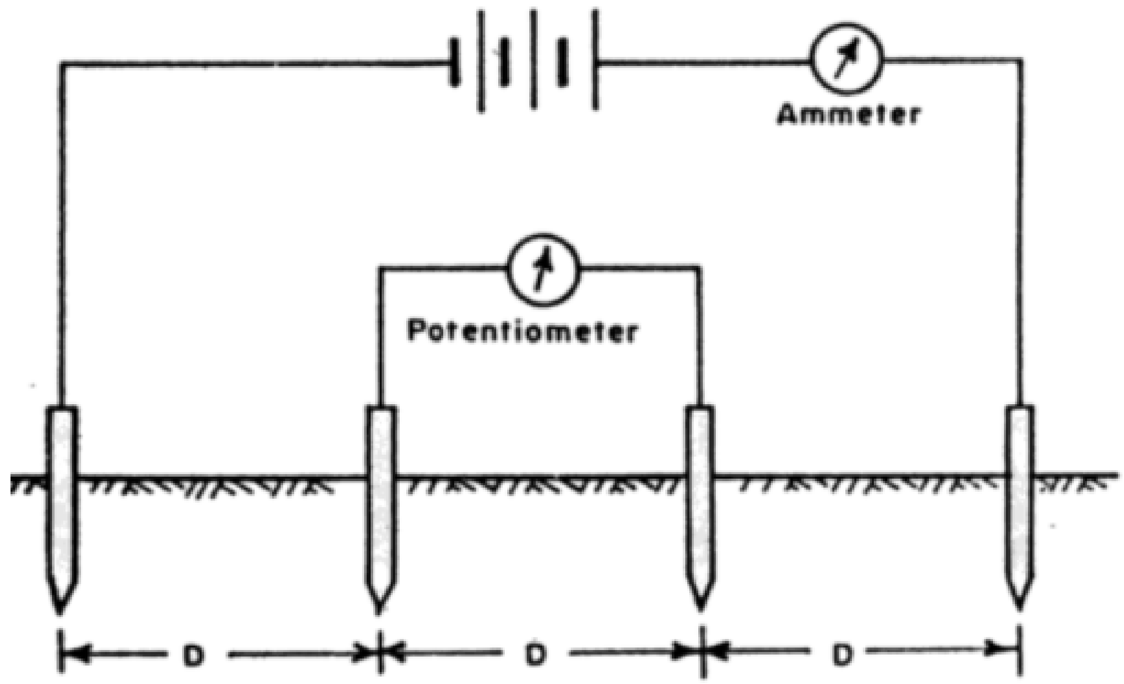


FIG. 2.17. RESISTIVITY METHOD.

❑B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

Methods of improving safe bearing pressure of soils

- Increase depth of foundation
- Compaction of soil
- Ramming moist soil
- Rubble compaction into soil
- Flooding of soil
- Vibration
- Vibro-floatation
- Compaction by pre-loading
- Using sand piles

Setting out

1

Baselines

Baselines: A straight line whose terminal are fixed in relation to some other detail. Baselines are in a variety of forms.

Building Line: A line laid down by a local authority, usually a distance from a nearby road, over which no part of the building may encroach

Site centreline: Base line used for industrial type complexes such as sewage works where the distances between various plants are defined in relation to each other.

2

Baselines

Road centreline: A series of straight lines connected by horizontal curves. These become the baselines for setting out buildings.

Coordinated Baseline: Defined from the Primary setting out network. Rectangular coordinates define the terminals and are set out from coordinated control points.

Checked for length both by calculation and site measurement.

3

Location of building from a Baseline

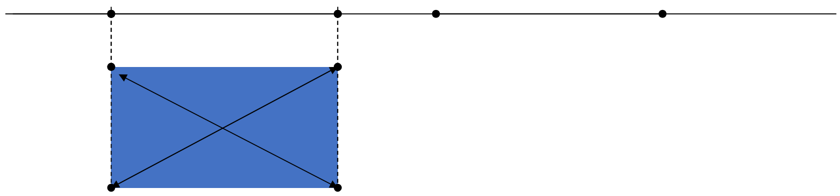
After setting out of baselines- building can be located by the use of rectangular offsets

- Locate pegs along baseline from where the offsets are to be measured.
- Distances measured as a series of RUNNING MEASUREMENTS and then individual peg distances checked.
- Difficult to do over long distances or sloping ground with a steel tape but use of Total Station makes this easier and possibly more accurate.

4

Location of building from a Baseline

- Survey instrument-theodolite is used for the determination of right angles.
- Squareness to be checked for by comparing diagonals with calculated value.



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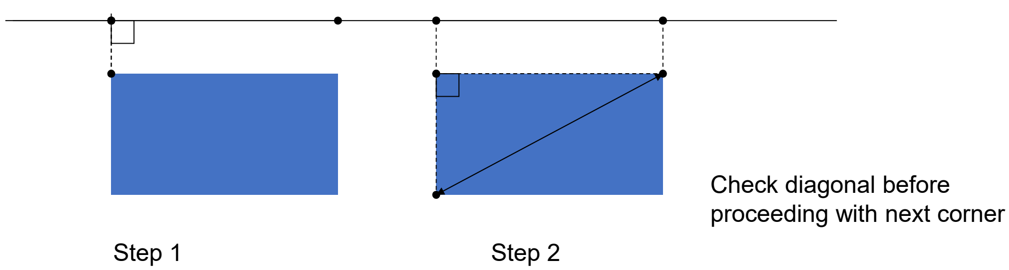
Location of building from a Baseline

- An alternative approach is to set out the first line of the building and then this line checked.
- Remainder of the building is then set out from this tertiary baseline.
- Allows corrections to be made immediately, if found to be necessary.



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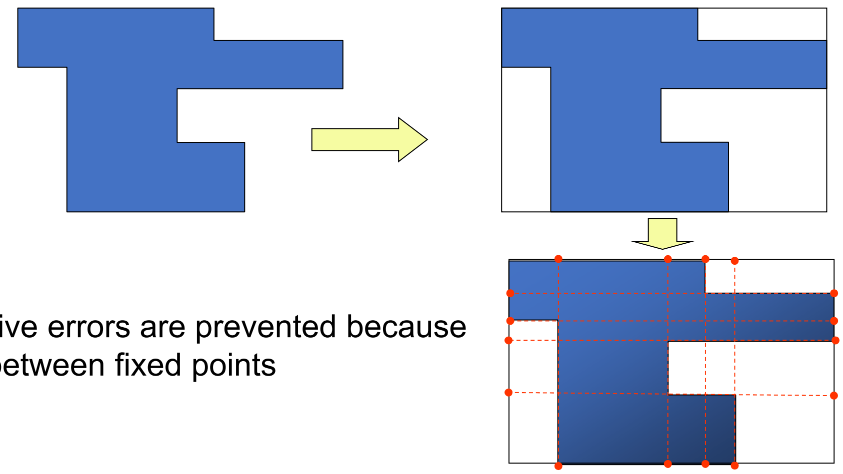
Irregular shaped buildings

- Turn into rectangle if possible



Accumulative errors are prevented because they fit in between fixed points

7

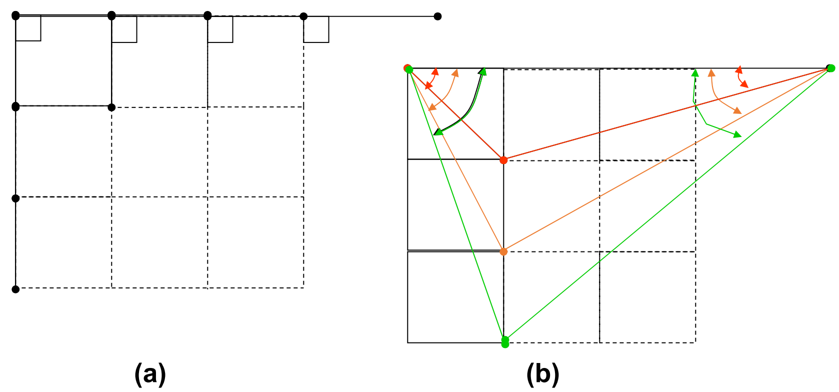
Site Grid

- A system of lines set out parallel and square to each other and a set distance apart.

Methods of setting out grids depending on the nature and complexity of the site:

- By Setting out from a coordinated baseline with offsets.
- By Intersection from the terminals of the base
- By calculating the coordinates of all grid intersections and setting out from site Primary controls.

8



9

Location of Buildings from a Site Grid

- Each grid line now becomes a separate base line and the building corners can be set out by rectangular offsets as previously described.
- Once again the building corners must be checked for accuracy and squareness.

Rectangular coordinates:

- The location of building corners by rectangular corners has been dealt with in setting out using radials.
- Primary control points as reference stations should be used if possible
- Again the distances between corner pegs must be checked and corrected if necessary.

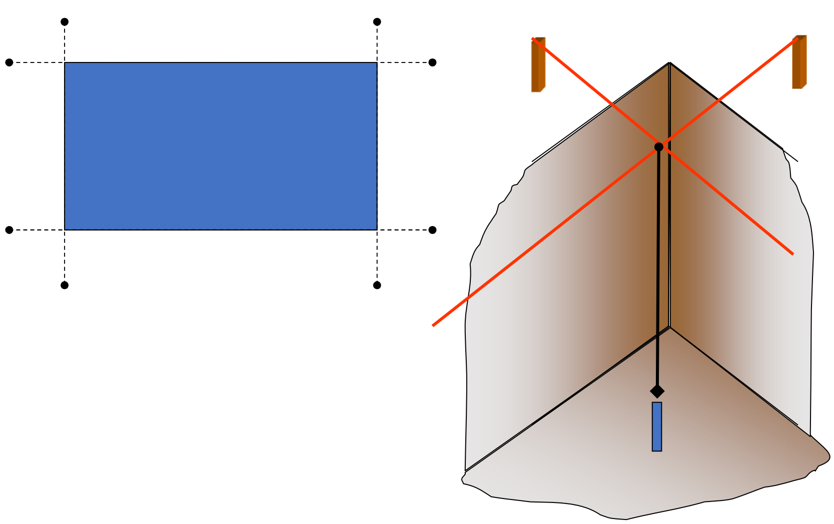
10

Control of Line and level

- Once the corner pegs have been located offset reference pegs or Profile boards need to be located as the corner pegs will be lost once excavation commences.
- Offset Pegs need to be put in at a standard offset (2m – 3m) and have been fully described in the section on drainage.
- Relocation of the corner pegs may be completed by stringlines between offset reference pegs.
- A plumb line dropped from the stringline intersection will locate the corner peg in an excavation.

11

Locating peg at bottom of excavation



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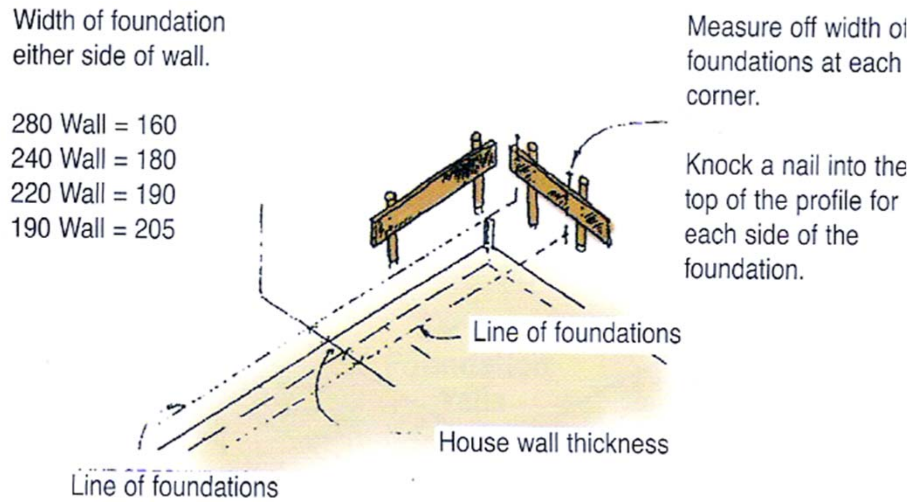
MINIMUM SIZES FOR FOUNDATIONS



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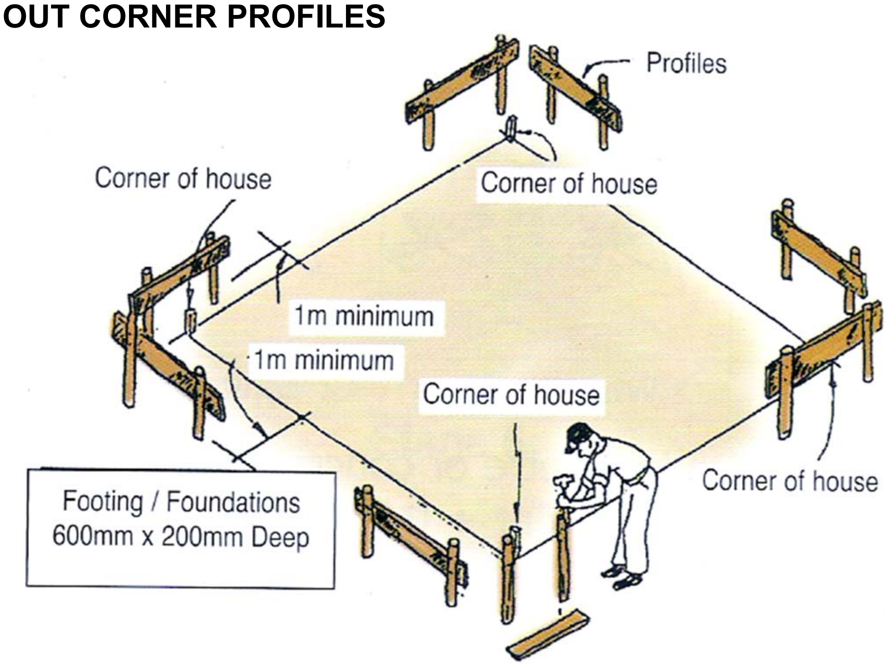
SETTING OUT CORNER PROFILES



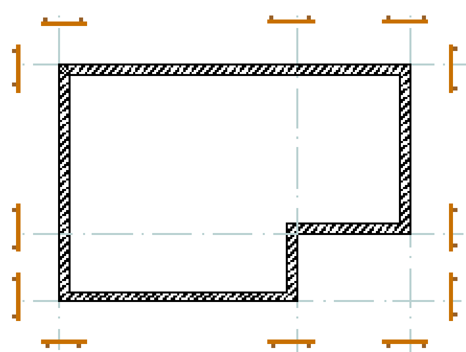
14

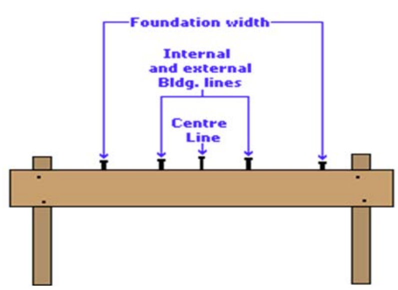
Profile Boards

- Used for referencing a building - superior method to the use of offset pegs.
- Building Lines are produced on to the boards where they are marked either by a saw cut or a nail.
- Profile Boards should be as close to the ground as possible.
- Should all be set to the same level if possible and relative to FFL (Finished Floor Level)
- Boards must be set Parallel to the building lines and a reasonable distance from them to allow access for plant.

15

Profile Boards





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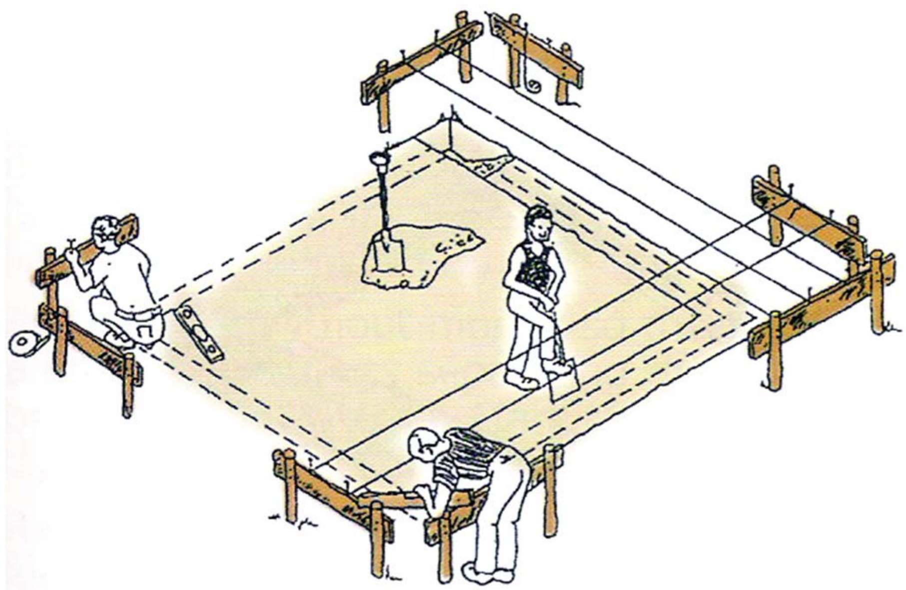
MARKING OUT FOUNDATION AND WALL THICKNESSES



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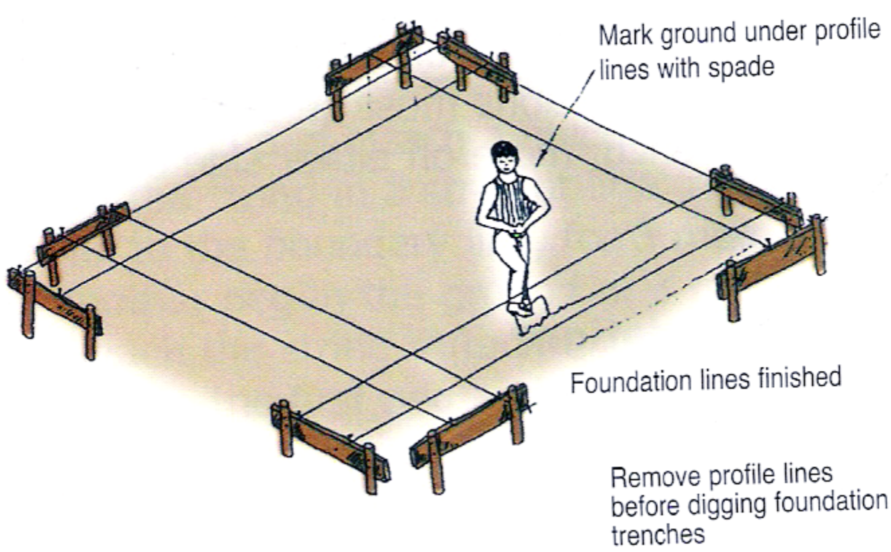
MARKING OUT ON THE GROUND FROM THE PROFILES



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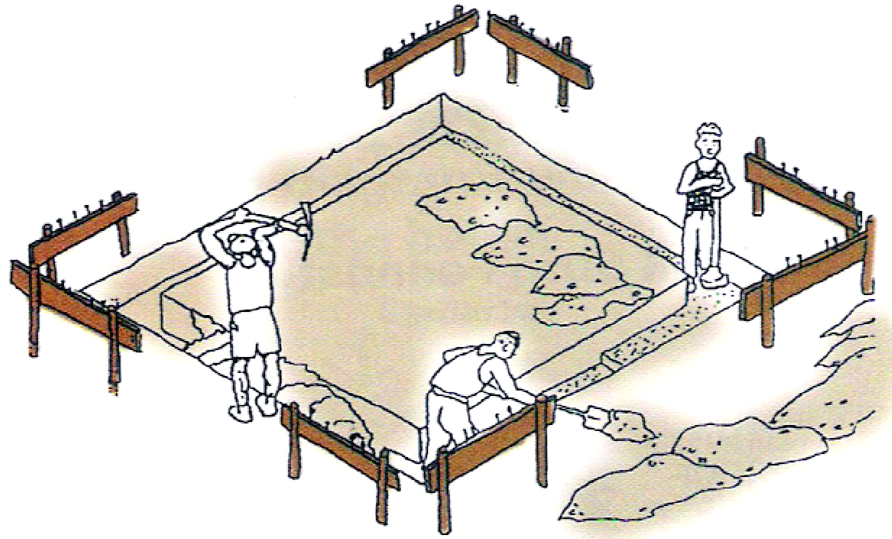
EXCAVATION OF FOUNDATION



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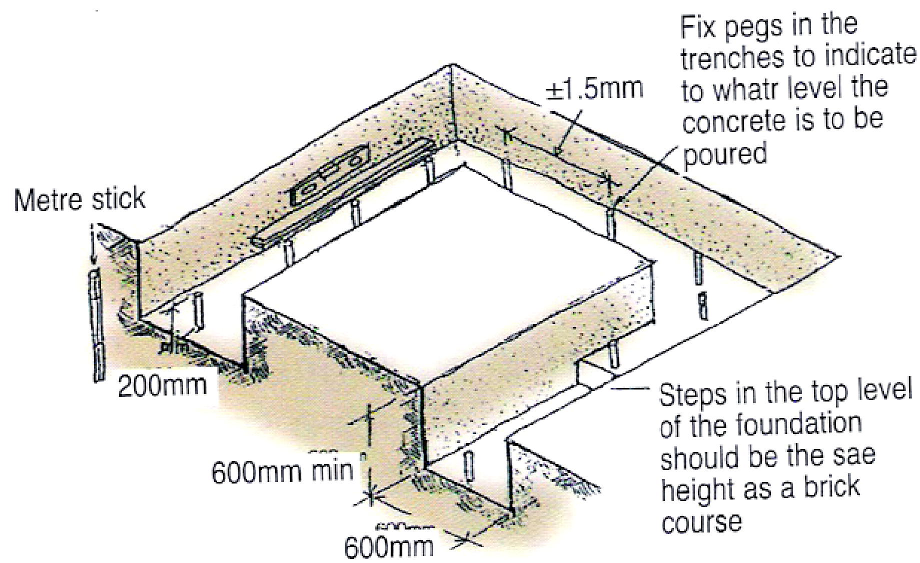
Controlling Level of Trench Bottom

- Depth of foundation trench will be fixed by design.
- Sight rails or profile boards are used.
- A traveller length is determined bearing in mind the depth of trench and the height of the rails above ground level.
- Excavation is controlled in the usual way.

20

SETTING OUT LEVELS FOR THE HEIGHT OF THE CONCRETE



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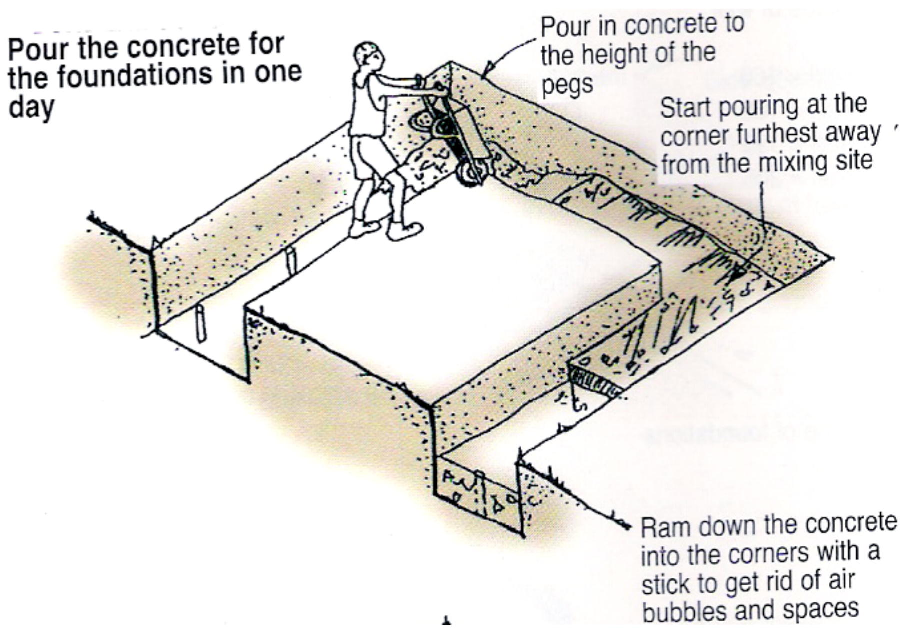
POURING CONCRETE FOR THE STRIP FOUNDATION



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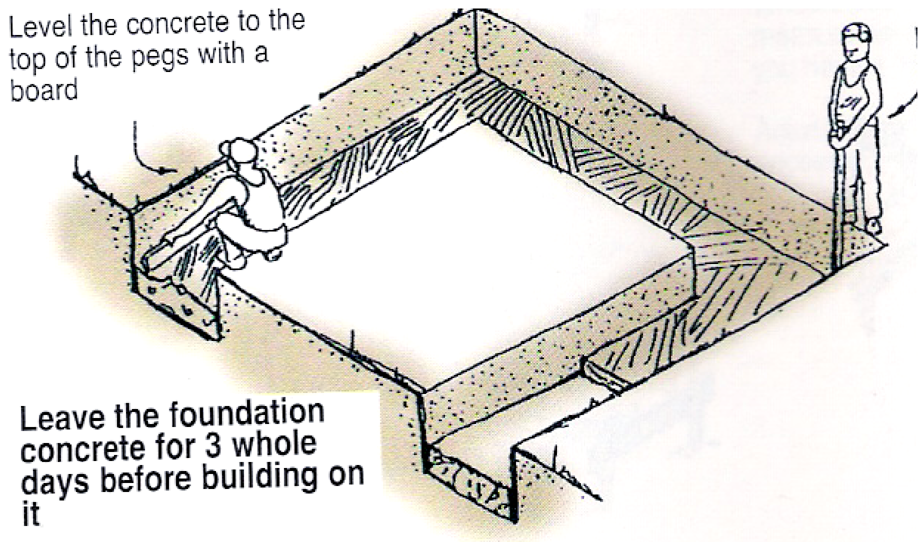
COMPACTING AND LEVELLING OUT CONCRETE



23

Earthwork/Excavations for foundation

1

Earthwork- ground water control

Ingress of surface/ground water

- Flooding
- Undermining supports to sides
- Work delay/cost
- Problem with working in waterlogged condition

Control of Ground and surface water- Geotechnical process

- Lowering of ground water
- Changing physical characteristics of sub-soil
- Freezing the ground water
- Use of compressed air

Site investigation on

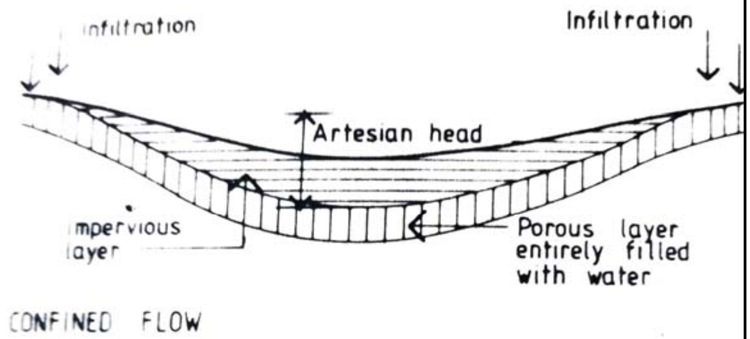
- Soil profile
- Ground water condition
- History of other excavation work carried out in the area, if available

2

Two types of ground water problems

Confined ground water:

- When the Layers in which GW lies has along its upper boundary a layer of low permeability
- If source of Ground water is above the level of the area of investigation- water head in pervious layer at this point may be above GL
- This condition is "Artesian"

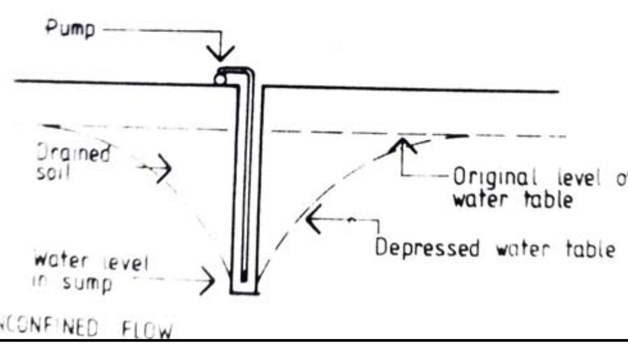


3

Two types of ground water problems

Unconfined ground water:

- When Upper flow boundary of GW is not confined by a layer of low permeability
- GW pressure at boundary = Atmospheric pressure
- Required to measure the water pressure in pervious strata at intervals-
- Check whether GW pressure exceeding limits which could cause damage to temp. or permanent works



4

Choice of Ground water control or treatment

Exclusion of Groundwater:

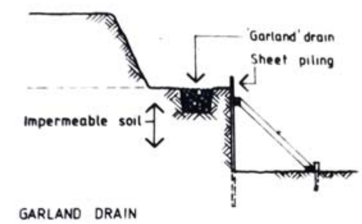
Temporary exclusion: Water table is lowered so that work can be carried out in excavation or in temporary situations

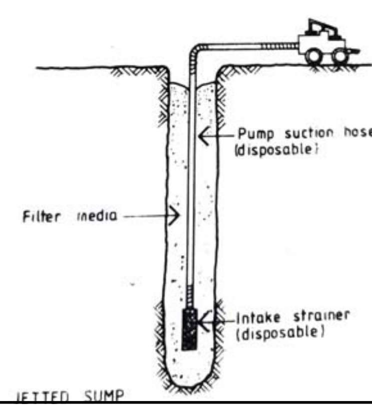
Permanent exclusion: when the water is excluded from the working area by surrounding it by an almost water-proof barrier

5

Methods of temporarily excluding groundwater

- Pumping from Sumps:
    - Normal situation- Sump is sited within the area of excavation
    - When large quantity of water to be pumped- convenient to form Sump outside excavation area
    - Will avoid risk of damage to supporting timbers in the excavation by erosion of soil at the formation level
    - Small sites- one sump; large sites- at least 2 sumps





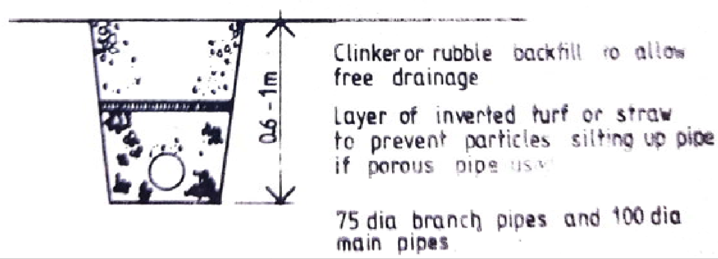
6

Methods of temporarily excluding groundwater

Land Drains:

- Used in construction sites to control surface water over the site and to prevent surface run-off entering an excavation
- Open jointed porous clay, concrete, vitrified or polyethylene pipe
- Laid in a trench
- Porous pipes- problem of being silted up- correct backfilling required

C/s through a typical land drain

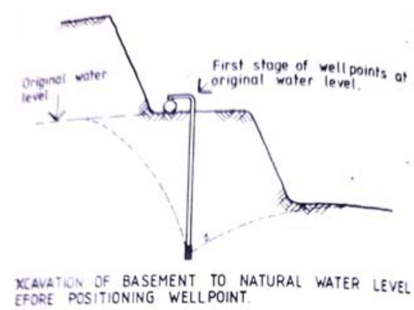


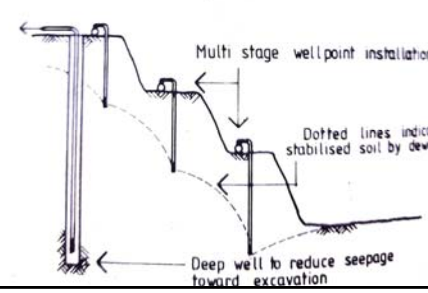
7

Methods of temporarily excluding groundwater

Pumping from wellpoints:

- Mechanical device used as a small well which can be readily installed in the ground and withdrawn
- Wellpoint system consists of a number of wells installed around an excavation
- Connected at top to a header main which is connected to a pump
- Water is taken away from the excavation by the action of pump thereby stabilises sides of excavation
- Advantages: System can be installed quickly- cheaper- Suitable for trench work
- Limitation: suction limit- 5 m below pump level- for deeper excavation- wellpoints installed in 2 or more stages



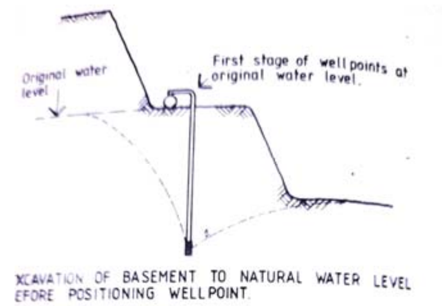


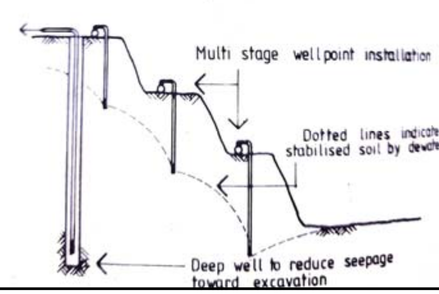
8

Methods of temporarily excluding groundwater

Pumping from wellpoints:

- Spacing of wellpoints- 0.3 to 1.5 m depending on permeability of soil
- Installed in the ring or progressive system-
- Single pump can serve multiple wellpoints
- Ring system: wellpoints installed around perimeter I an excavation and connected to a header main and pump- ideal for large rectangular excavations (ex: basement)
- Progressive system: used for trench excavations with the header main laid along the sides of the trench and pumping is continuously in progress in one length





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Methods of Permanently excluding groundwater

Cast-In-situ diaphragm walls:

- Water can be prevented from entering excavation by surrounding them with an impermeable wall constructed in-situ
- Wall with- 450 mm to 1m; depth- up to 45 m
- Trench for the wall panel is excavated using mechanical grabs mounted on crane rigs.
- As trench is excavated- bentonite slurry is pumped in to ensure the trench is stable
- As the concrete is poured- bentonite slurry rises in the trench and is progressively removed for reuse or disposal.

10

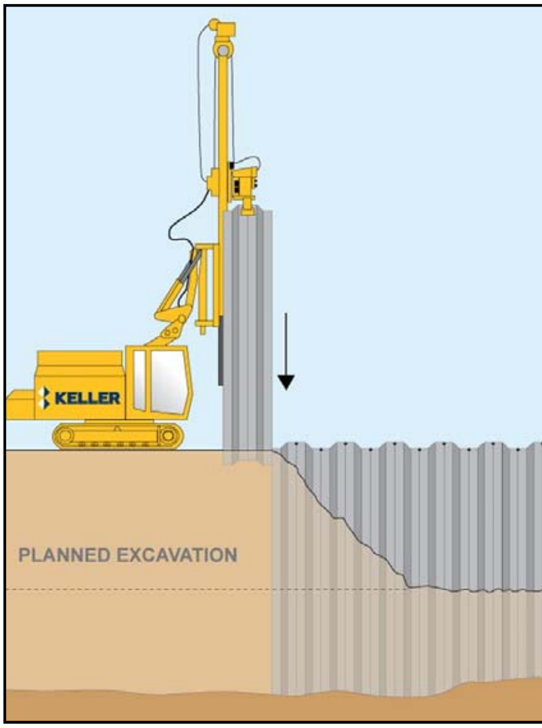
Methods of Permanently excluding groundwater

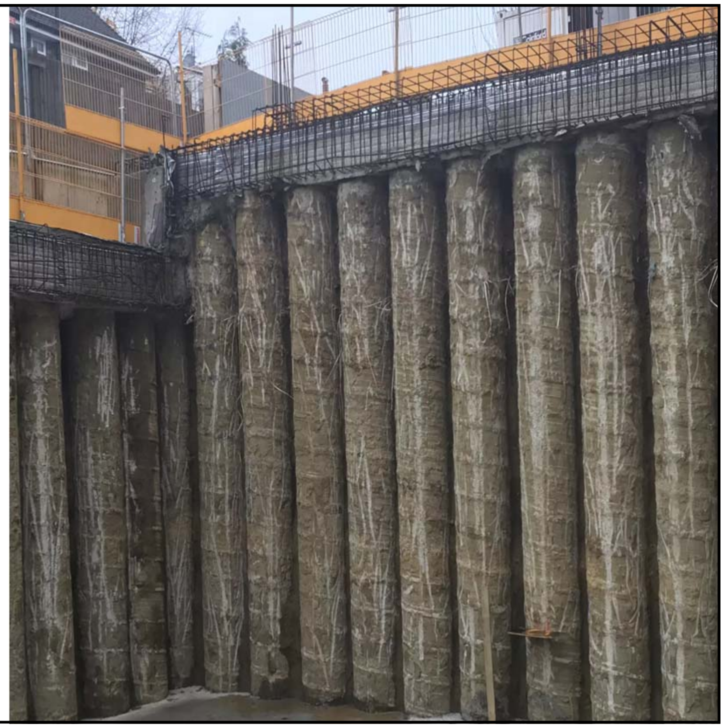
Sheet piling:

- To form barrier to the ingress of ground water
- Sheet piling designed as a retaining wall or a temporary enclosure for excavation work
- Use of a dop hammer
- Leads to noise and vibration- careful about use in places close to existing structures

Contiguous piles:

- Alternative to diaphragm walls
- Concrete bored piles installed in a line- piles tough each other over their total length
- May be required to inject group between piles to exclude water ingress
- Used as a permanent retaining or basement wall and is completed by addition of a RCC wall terminated with a capping beam





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Excavation: General precautions

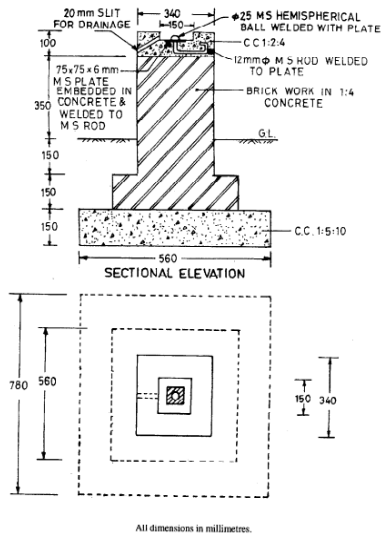
- Ensure that excavation operation does not affect adjacent building
- Excavation should not be done below foundation level of adjacent buildings until Underpinning, shoring etc are done
- Trenches and foundation pits are to be securely fenced and posted with proper precautionary signs.
- Marked with red lights at night to avoid accidents.

Fig: Shoring of excavation

https://theconstructor.org/structural-engg/shoring-underpinning-building-construction/323/

14

Surface Excavation



Type design and temporary site benchmark

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15

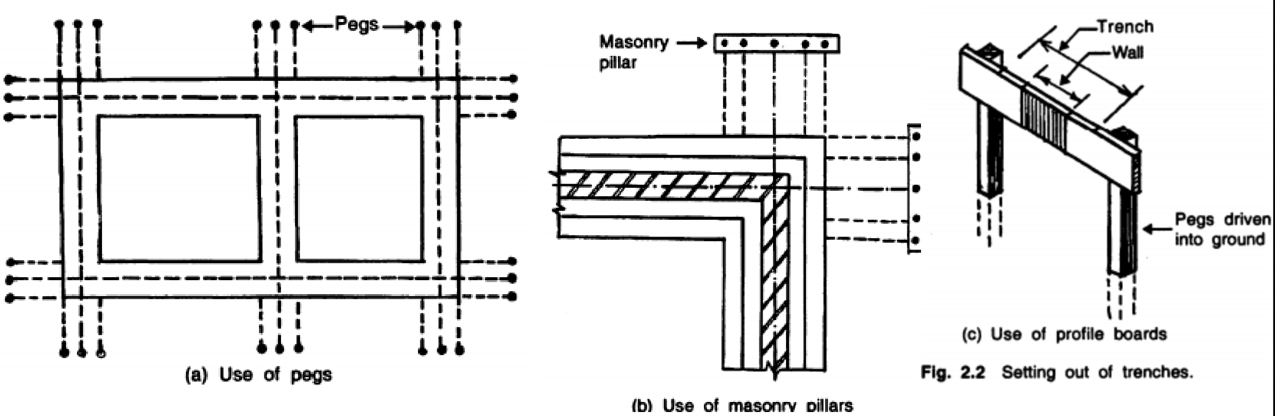

Fig: Setting out of trenches

16

P.C. Varghese, Building Construction, Prentice-Hall of India, New Delhi, 2008

16

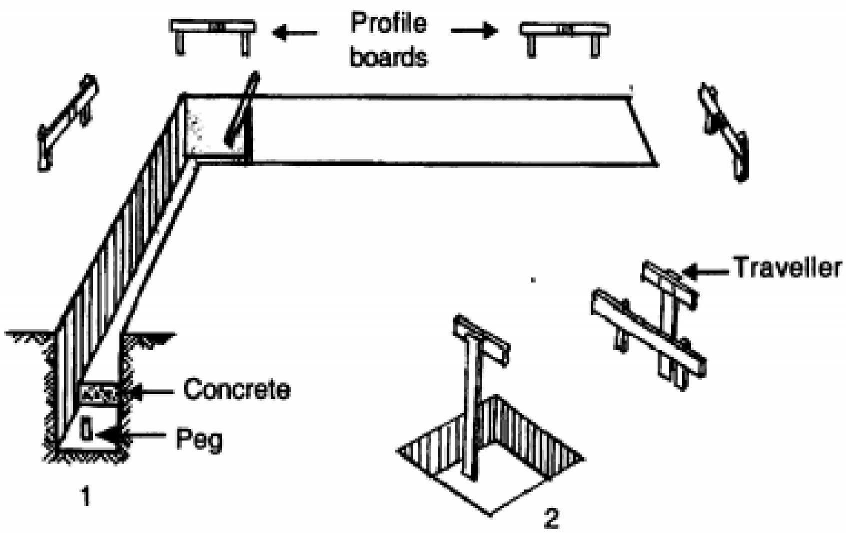

Fig: Determining of depth of excavation by boning rod or traveller and profile boards 1-strip foundation 2-coloumn footing

17
P.C. Varghese, Building Construction, Prentice-Hall of India, New Delhi, 2008

17

Filling

- Earth from cutting can be used for filling
- Filling earth - free of roots, grass, rubbish & lumps of soil/clay
- Filling- in regular horizontal layers- layer thickness ≤ 20 cm
- Each layer; Consolidate by ramming & watering.
- Finish top surface area neatly dressed.
- Keep finished formation level considering future settlement
  - Hand consolidation - 10% higher depth.
  - Consolidation by machinery- 5 % allowance
  - Compaction by mechanical equipment under Opt. Moisture Condition- No allowance

18

Timbering of excavation

Will depend on

- Depth of the trench
- Nature of the soil
- Season and period for which the work last

- Traditionally done in timber and hence called *timbering of excavations*
- Excessive timbering should also be avoided.

Fig: Excavation timbering

https://civilsnapshot.com/timbering-and-strutting-for-foundation-trench/

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Shoring and timbering

- Shoring & timbering essential for all trenches > 2.0m in depth.
- Vertical sides shored in sloping trenches and extends at least 30 cm above vertical sides.
- Toe board is provided in open spaces sheathing to prevent material rolling down the slope
- Carried out along with the opening of a trench.
- Approved quality of SAL wood used for shoring and timbering a trench or any material with same strength.

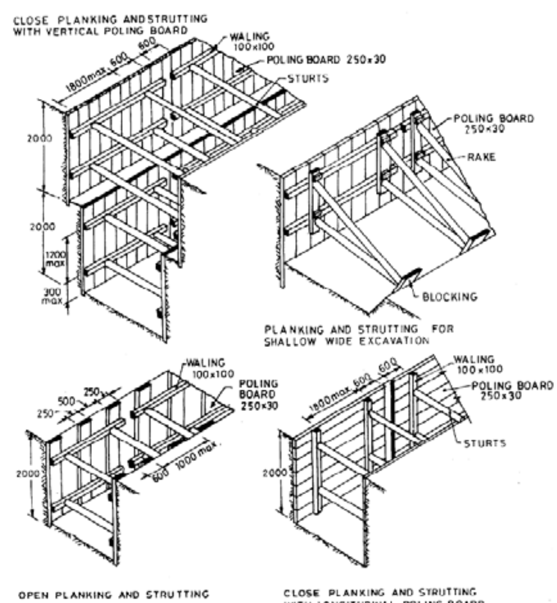

Fig: Close and open planking and strutting

IS SP 62

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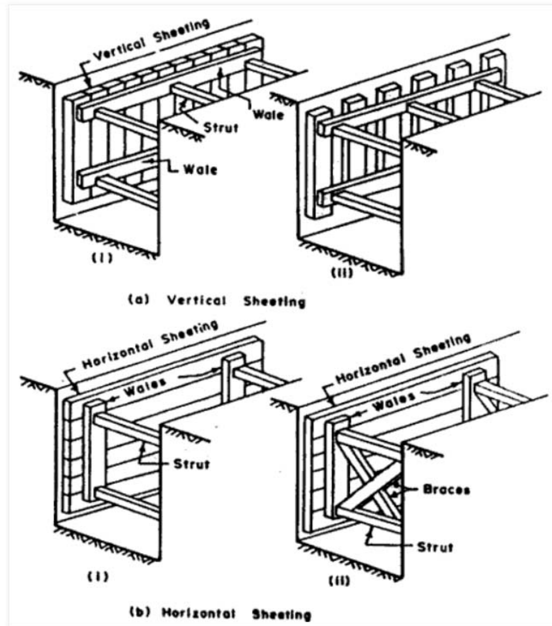
Sheathing and struts

- Placed against the side of the trench so that the length of each piece of sheathing is vertical.
- Held securely in place against the wall of the trench by wales.
- Each piece driven into the bottom of the trench to be firmly held in place wherever necessary.
- Lower pieces overlap the lowest wales supporting the pieces next above it where more than one is used.
- Pieces are firmly driven into the soil and securely supported by wales and struts as the trench is made deeper.



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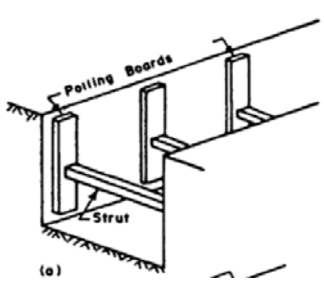
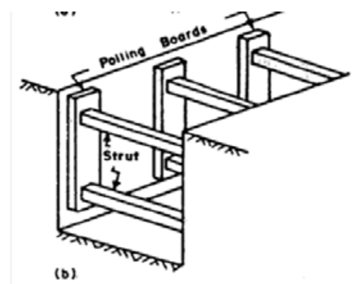
Struts

- Horizontal and at right angles to the wales or sheathing supported thereby.
- Cut to the proper length required to fit in tightly between the wales.
- Where necessary, held securely in place by wedges, driven between struts and the wales.
- Placed on cleats spiked or bolted to posts supporting wales.





http://www.abuildersengineer.com/2012/10/timbering-of-trenches-soils.html

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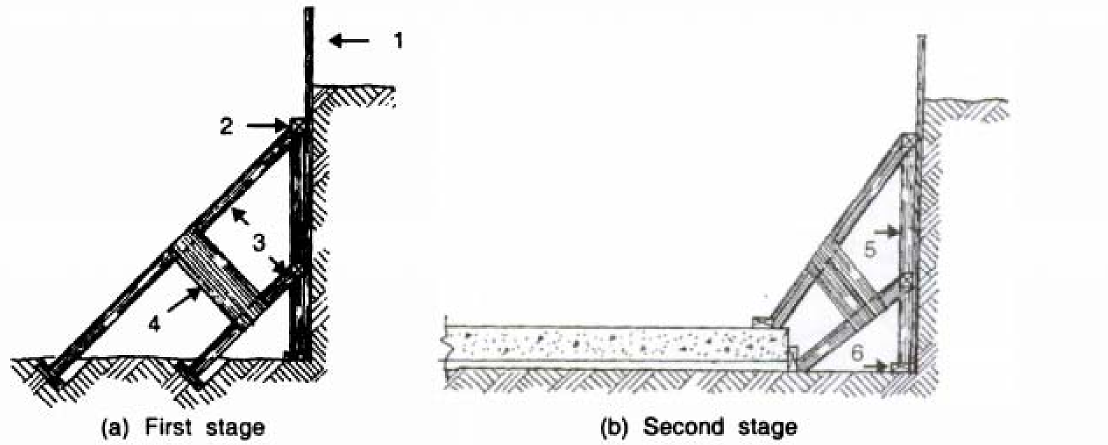

Fig. 3.3 Timber excavation for basements: 1. Vertical face timbering projecting above G.L. for safety of work 2. Horizontal waling, 3. Raking struts, 4. Binders to struts provided on both sides, 5. Vertical punchions at 2 m centers, 6. Sole plate.

P.C. Varghese, Building Construction, Prentice-Hall of India, New Delhi, 2008

Fig: Timbering of Basement excavations

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Earth filling and sand filling in basement

- Filling is done till plinth level in layers.
- Done along with the construction so that fill is also consolidated by the people walking on it.
- Done in layers of not more than 15cm to a height of at least 75mm more than the required height.
- After consolidation, sufficient quantity removed to the level required for laying the flooring.
- For rooms, it is made level and for verandas, a slope of 1 in 48 towards the edge is usually provided for drainage.

Fig: Earth filling and sand filling compaction

https://www.youtube.com/watch?app=desktop&v=rbH_QsK0img

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Sand filling

- Sandfill on original earth work required before flooring concrete.
- **Thickness**-30cm for very clayey soils
- -15cm for soils other than sand
- Compacted in layers by flooding.
- It breaks the upward movement of capillary water under the floors.
- Reduces settlement of floors in expansive soils such as black cotton soils.
- The sand should be as coarse as available.
- Greater part filled with a quarry dust and a coarse sandfill provided for the last 10 to 15cm at least immediately below the floor if sand availability is less.

25

Termites in buildings

Ground nesting or subterranean termites

- Common in India
- Presence indicated by swarms of winged reproductions flying from the soil or wood lying around the site at the beginning of monsoon.

Wood nesting or non subterranean termites

- Lives in dry wood inside buildings
- Recognised by their pellets of digested food or blisters on the wood as wood is eaten.
- Damage wood, rubber, plastic, underground cables etc.

Both can be terminated by same anti-termite chemicals.

Fig: a) Ground nesting, b)wood nesting termite

https://www.housemanpest.com/major-difference-between-drywood-and-subterranean-termites%E2%80%A8/

26

Anti-termite treatment of foundations

Anti-treatment of buildings comprises of three parts:

- Pre-construction measures to be taken
- Pre-construction treatment
- Post-construction treatment

Fig: Anti termite spray https://helpr.in/blog/anti-termite-treatment-in-building/

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Recommended chemicals for treatment

Purpose of the treatment is to create a chemical barrier between the ground and woodwork.

- Chloropyrifos concentrate 1.0% by weight
- Heptachlor concentrate 0.5% by weight
- Chlodane concentrate 1.0% by weight.

- Ex of brand name: for one of the chloropyrifos: Durmet & Dustan TC- available in in various concentrations.
- Dilute in 1% concentration as desired in water (soil treatment) or kerosine oil (wood treatment)
- Solution is toxic and should avoid contact with skin.

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Pre-construction treatment with Durmet

Considerations

- Hand pump used for spraying at specified rates.
- Graduated containers used to facilitate right dose.
- Treatment should not be carried out when its raining or soil is wet with subsoil water.
- Done just before concreting of foundation.
- Treated barriers for termites should not be disturbed after treatment.

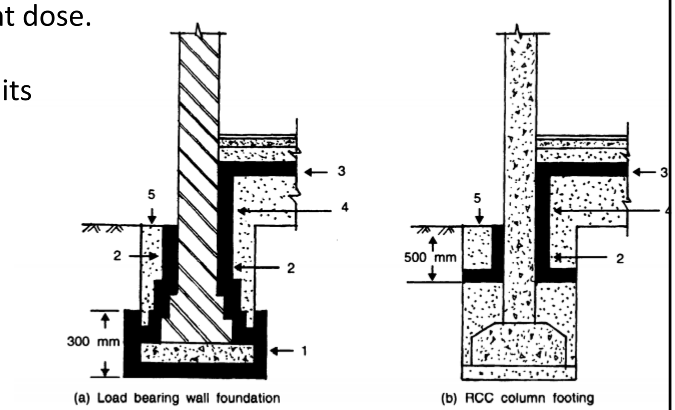

Fig: Anti-termite treatment of foundation and earthfill below ground floor

P.C. Varghese, Building Construction, Prentice-Hall of India, New Delhi, 2008

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- **First stage:** Treatments of wall trenches and basement excavation
- **Second stage:** Treatment of refill in contact with foundation
- **Third stage:** Treatment of soil below floors.
- **Forth stage:** Treatment of junction of floor and wall
- **Fifth stage:** Treatment of soil along the external perimeter of building.
- **Sixth stage:** Treatment of other locations
- **Seventh stage:** Treatment of wood surfaces

30

30

oundations: Functions of foundations

- Reduction of load intensity
- Even distribution of load
- Provision of level surface
- Lateral stability
- Safety against undermining
- Protection against soil movements.

https://civilblog.org/2015/01/26/what-are-the-functions-of-foundation/

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Table 3.2 Bearing capacities

Group	Types of rocks and soils	Bearing capacity (kN/m²)
I Rocks	1. Strong igneous and gneissic rocks in sound condition	10 000
	2. Strong limestones and strong sandstones	4 000
	3. Schists and slates	3 000
	4. Strong shales, strong mudstones and strong siltstones	2 000
	5. Clay shales	1 000
II Non-cohesive soils	6. Dense gravel or dense sand and gravel	>600
	7. Medium-dense gravel or medium-dense gravel and sand	>200–600
	8. Loose gravel or loose sand and gravel	<200
	9. Compact sand	>300
	10. Medium-dense sand	100–300
	11. Loose sand	<100
III Cohesive soils	12. Very stiff boulder clays and hard clays	300–600
	13. Stiff clays	150–300
	14. Firm clays	75–150
	15. Soft clays and silts	75
IV	16. Peat and organic soils	Foundations carried down through peat to a reliable bearing stratum
V	17. Made-up ground or fill	Should be investigated with extreme care

Source: Based on BS 8004:1986.

32

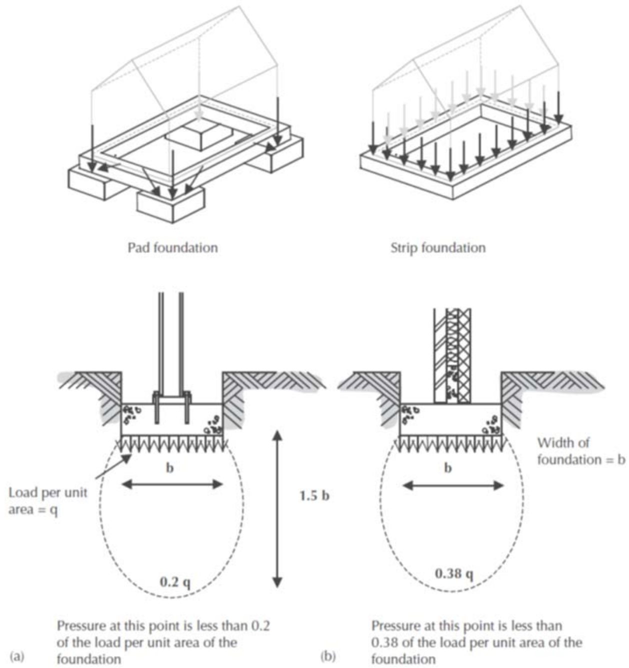

Figure 3.5 Bulb of pressure exerted under pad (a) and strip (b) foundations.

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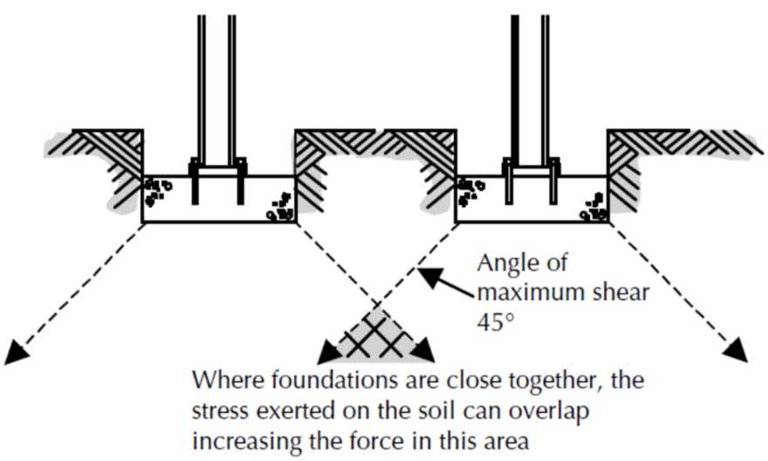
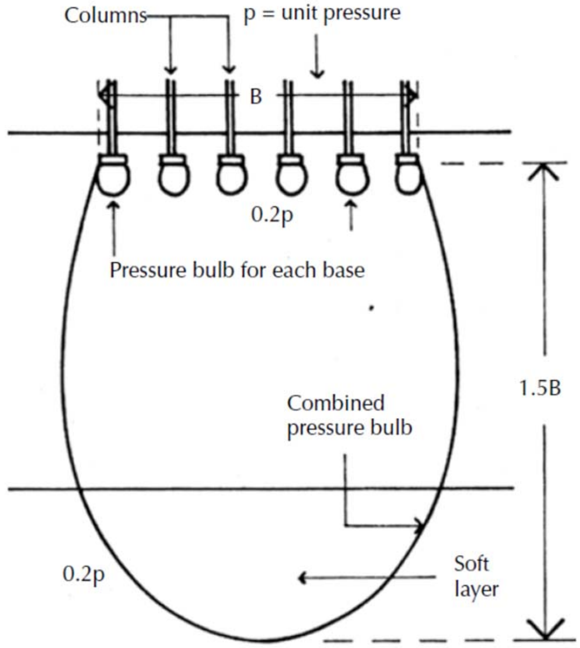


Figure 3.6 Combined stress exerted on subsoil from foundations in close proximity.

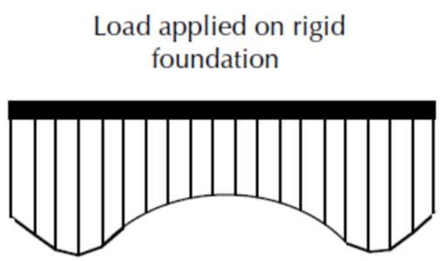
34



Combined pressure bulb.

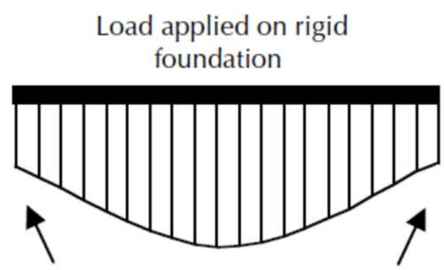
35

Contact pressure in practice



As foundation load is applied, the clay yields, such that the stresses at the edge decrease, and those at the centre increase

Cohesive soil



If the edge of the foundation is below the ground, the edge stresses are not zero

Cohesionless soil

36

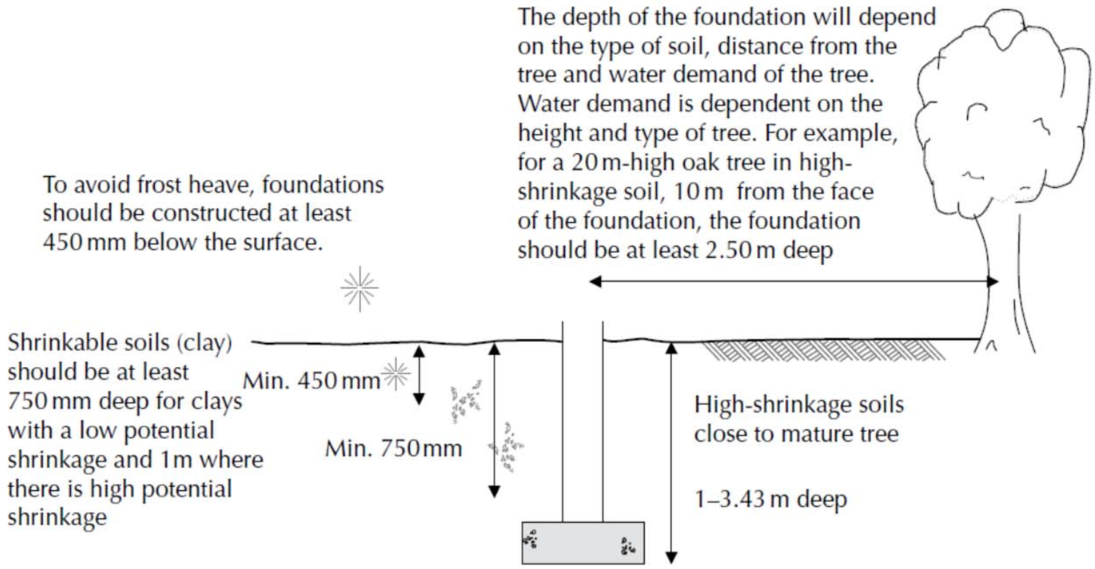


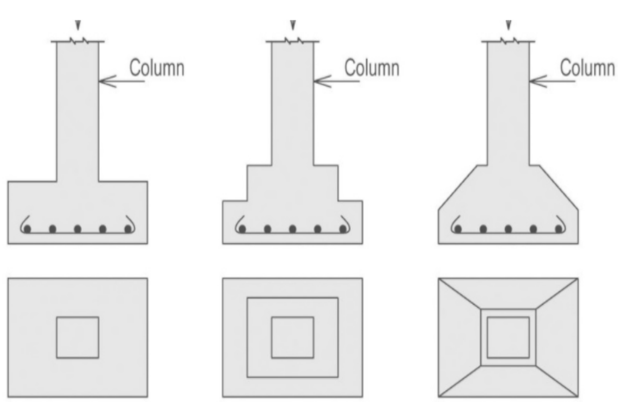
Figure 3.14 Depth of foundations and stability (information adapted from NHBC, 2000).

37

Types of foundations: Shallow foundations

Load transfer through shea resistance to the soil and normally laid to a depth of 3m.

- Spread or Pad
- Strip
- Raft



https://gharpedia.com/blog/shallow-foundation/

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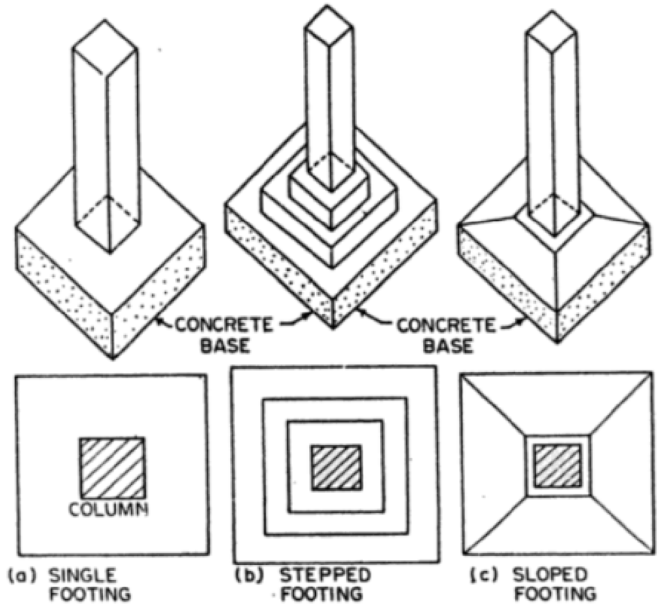


Fig: Spread footings for columns

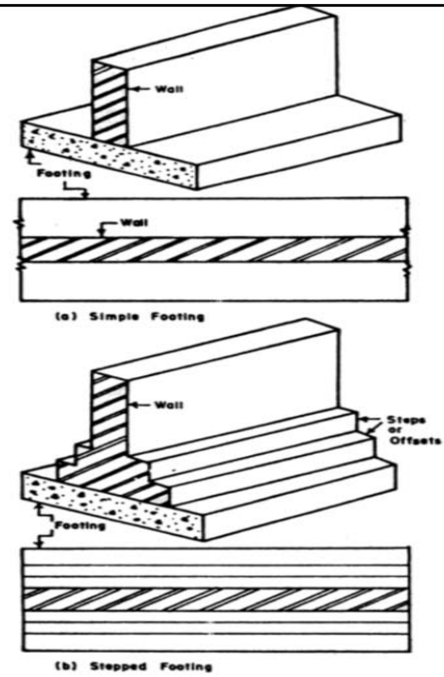
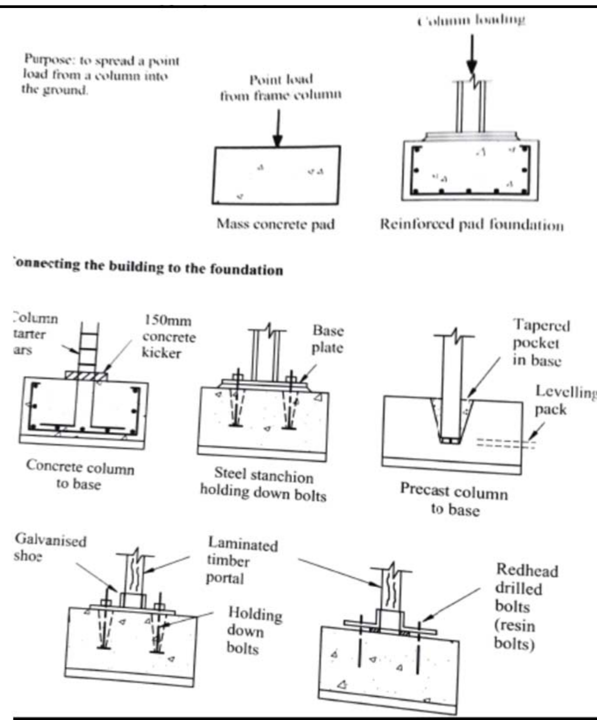


FIG. 2.3. SPREAD FOOTING FOR WALLS : STRIP FOOTING.
B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

39



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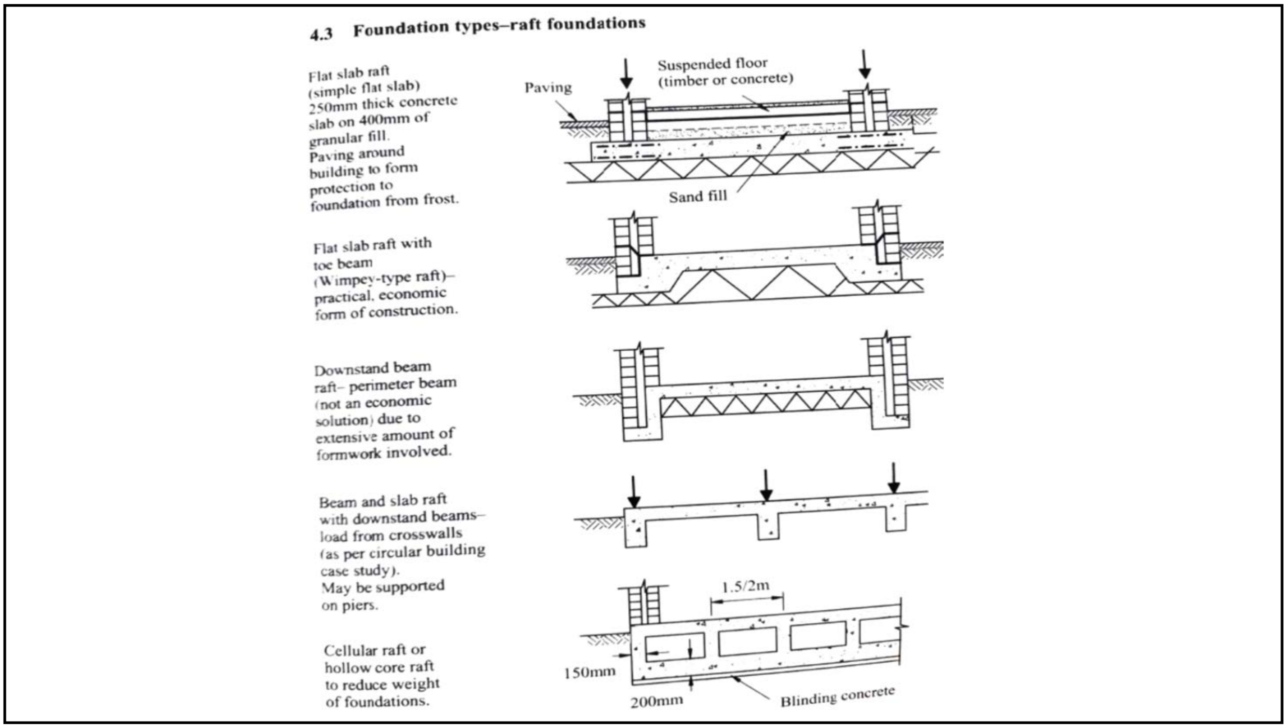

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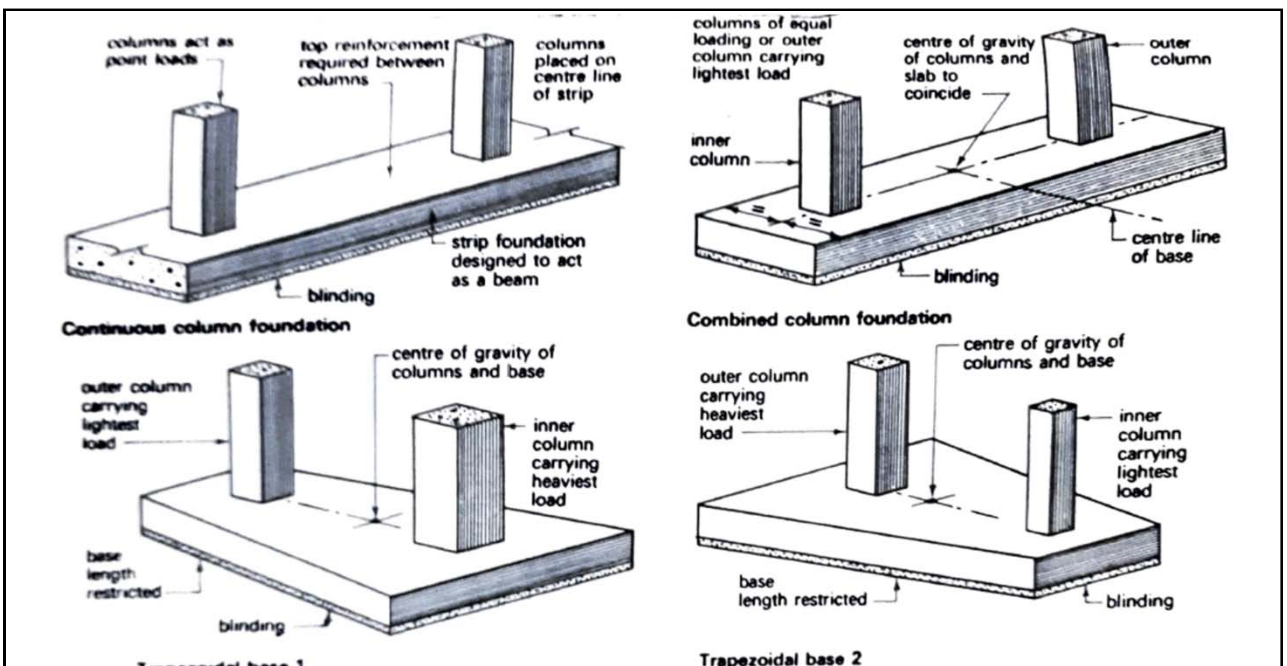


Fig. III.11 Typical combined foundations

42

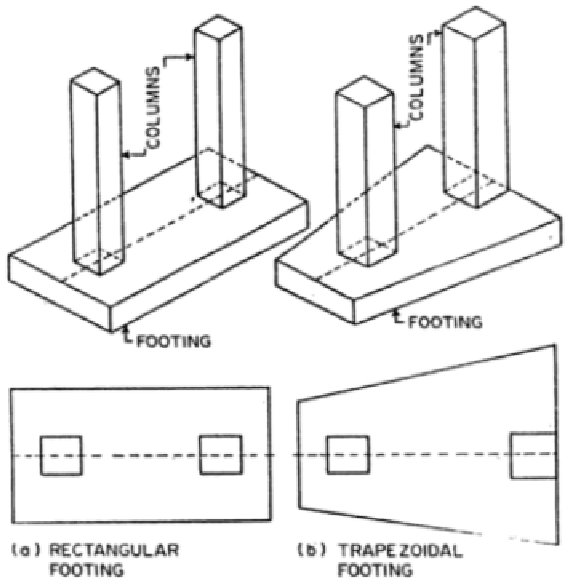


Fig: Combined footings for columns

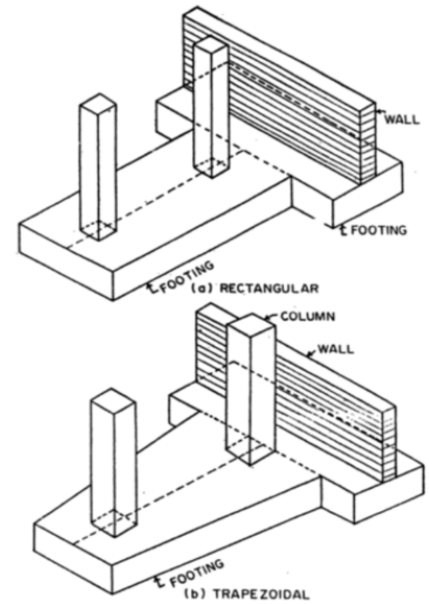
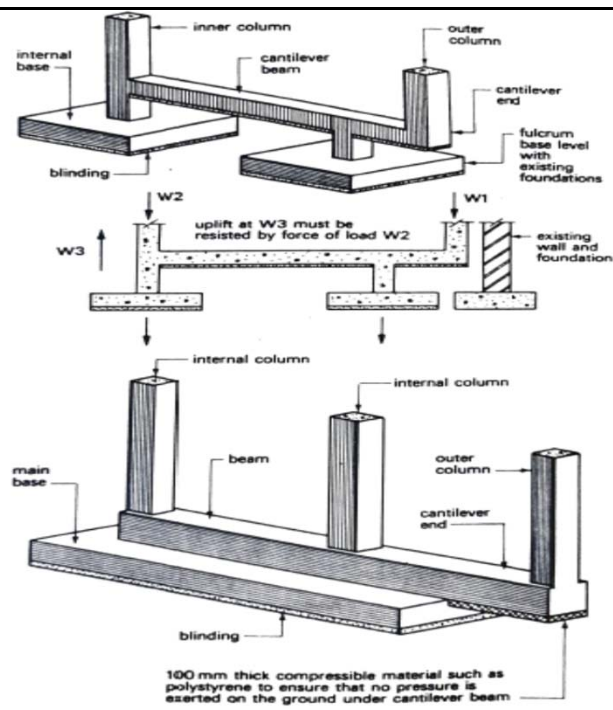


Fig: Combined footings for columns and wall

B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

43



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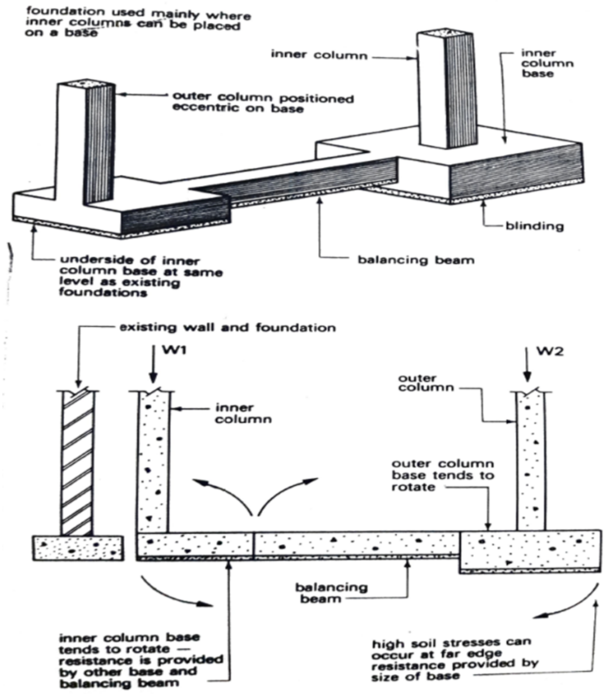

Fig. III.13 Typical balanced base foundation

45

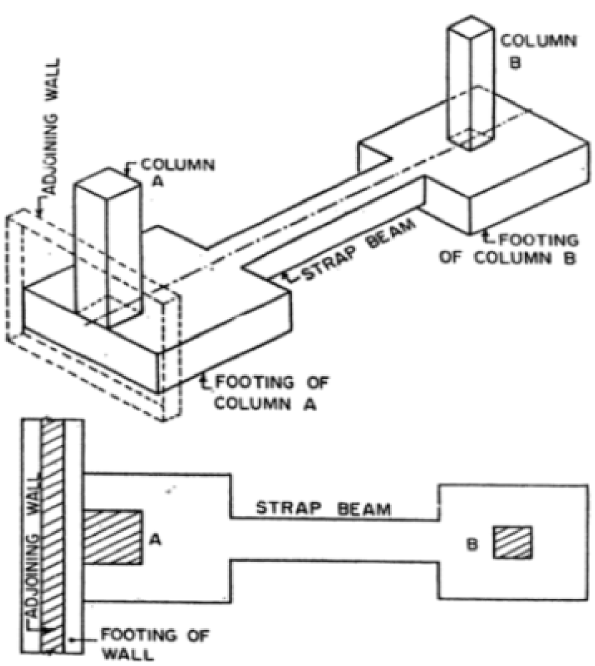

Fig: Strap footing

B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

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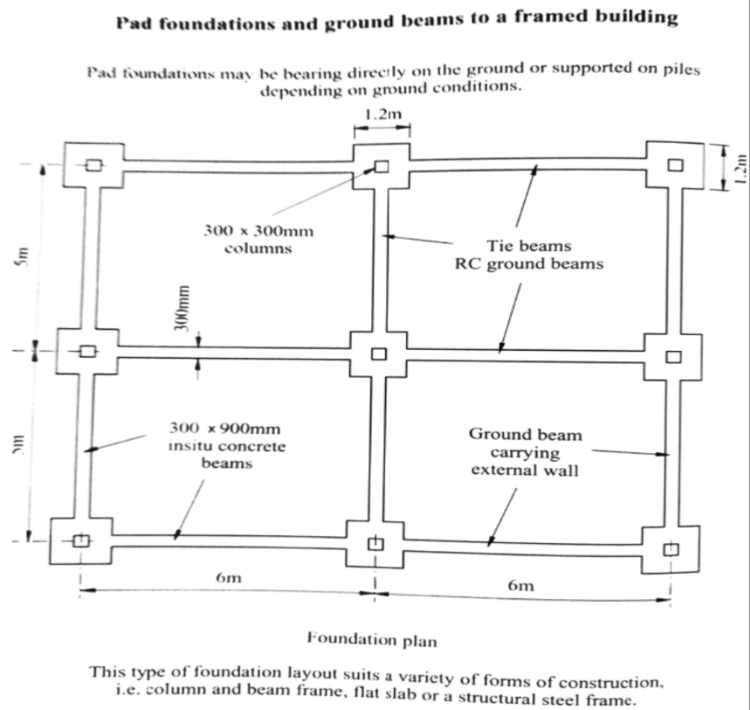

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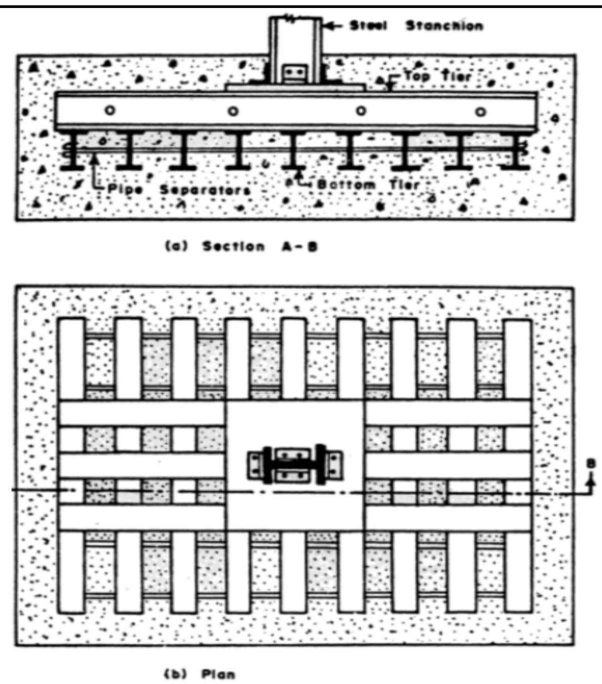

FIG. 2.4. GRILLAGE FOUNDATION.

B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

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Deep Foundation

- In the form of piles, caissons, diaphragm walls, used separately or in combination to transmit the loads to a deeper load bearing strata.
- Transfer of load may be through friction, end bearing or a combination of both.

Types of Deep foundation:

- Pile foundations
  a. Driven cast in situ
  b. Bored cast in situ
  c. Timber
  d. Under reamed
- Diaphragm walls
- Combined foundations-
- Two or more of the above

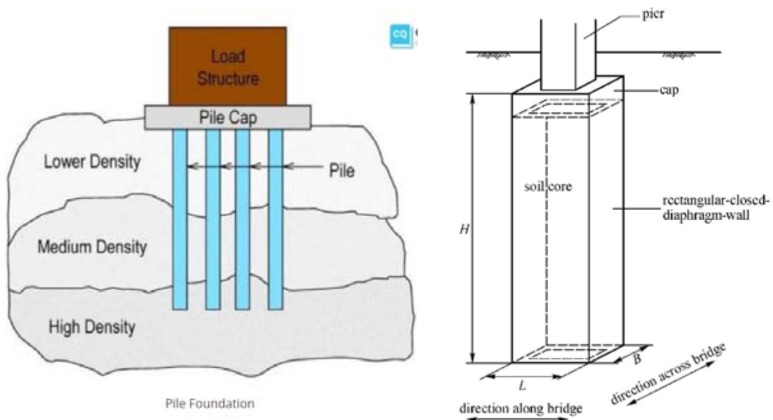

Fig: a)Pile foundation b) diaphragm walls

https://www.civilquery.com/types-of-deep-foundation-and-their-uses-in-construction/
https://www.researchgate.net/publication/245464375_Diaphragm_wall-soil-cap_interaction_in_rectangular-closeddiaphragm-wall_bridge_foundations/figures?lo=1

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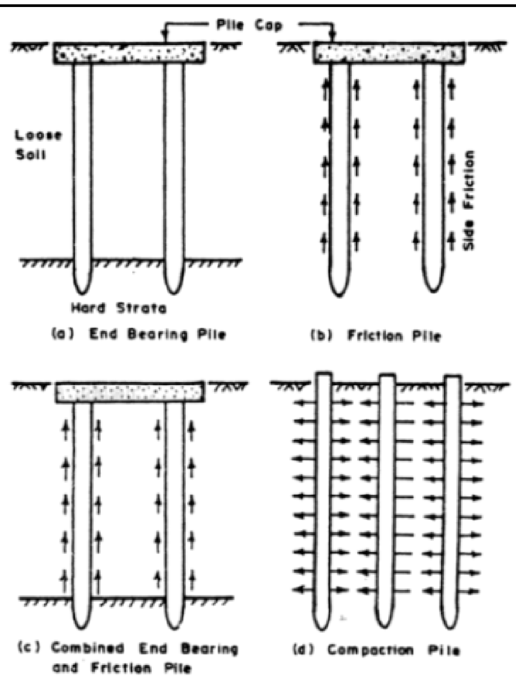

Fig: Pile foundations

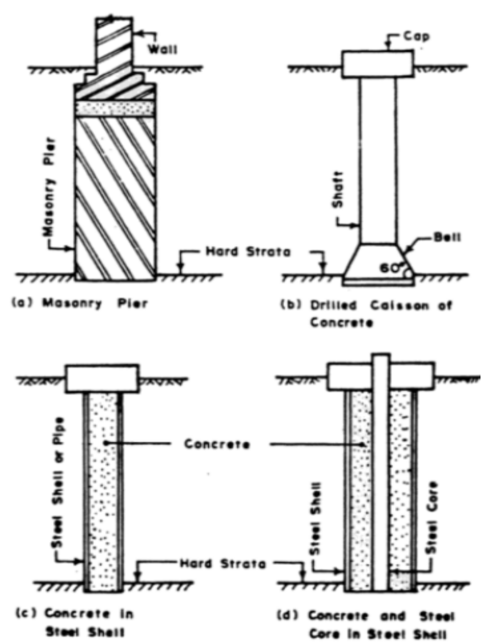

Fig: Pier foundations

B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

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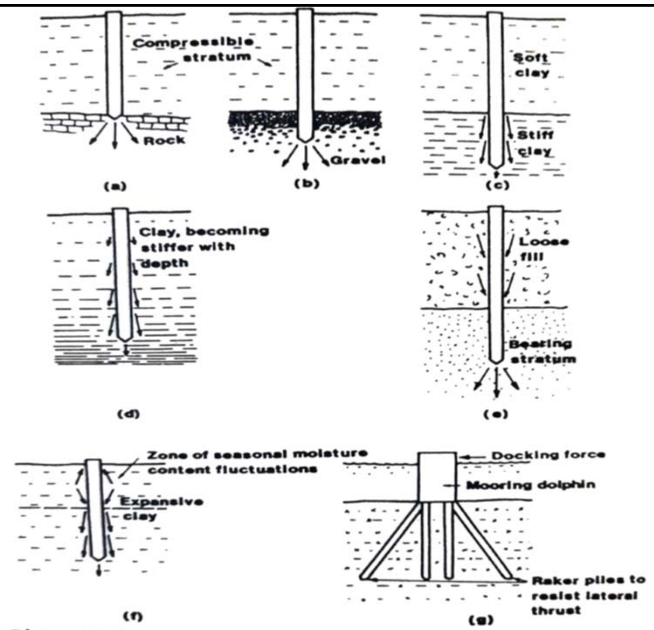

Figure 2.9 How loads are transmitted from piles to the surrounding ground: (a) and (b) end-bearing piles which terminate in rock or granular soil; (c) and (d) friction piles which terminate in clay; (e) and (f) the effects of loose or expansive soils; (g) raker piles to resist lateral thrust.

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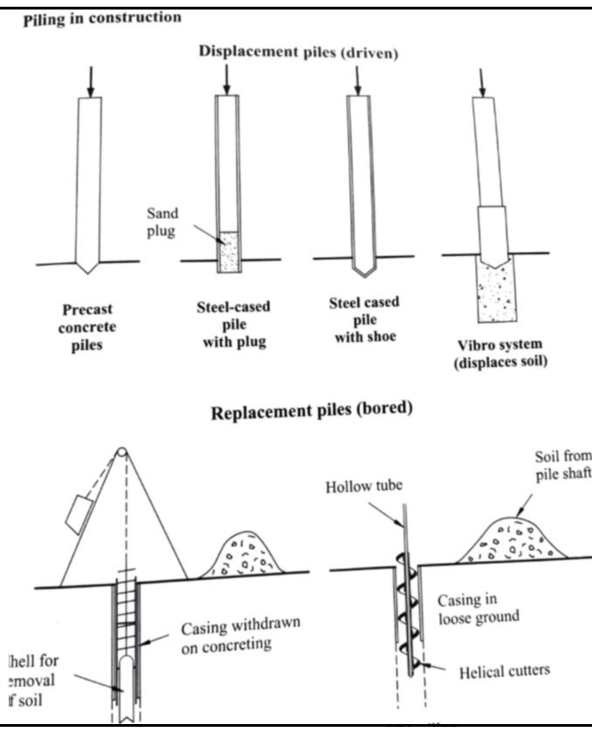

52

Under reamed foundations

- Under reamed piles, though listed under deep foundations also are used for foundations up to 3m depth.
- Bored cast in-situ and bored compaction concrete types
- Has one or more bulbs formed by suitably enlarging the bore hole of the pile stem.
- Substantial bearing or anchorage is available with provision of bulb.

53

Application of under-reamed foundation

- To avoid undesirable effect of seasonal moisture content changes as in expansive soils
- To reach firm strata
- To obtain adequate capacity for downward, upward and lateral loads and moments
- To take the foundations below scour level.
- No vibration & noise caused during construction of piles
- Can resist uplifts as they can used as anchors, increased bearing surface also becomes available

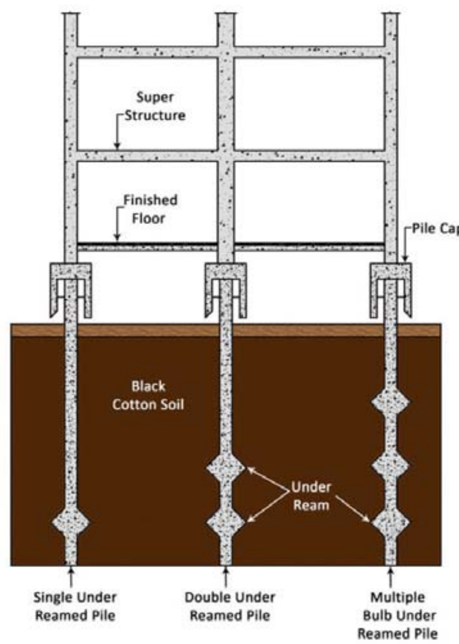

Fig: Underreamed foundation

https://gharpedia.com/blog/under-reamed-pile-uses-advantages-disadvantages/

54

Equipment used for manual operations

- Auger/ Under-reamer/Boring guide/Accessories
- Portable tripod hoist with manually operated winch is required for deeper and larger size greater than 30 cm piles.
- For piles in high ground water table and unstable soil conditions, boring and under-reaming shall be carried out using suitable equipment. Tremie pipe shall be used for concreting.
- For compact piles, the additional equipment required are drop weight for driving the core assembly and pipe or solid core.

Fig: Auger

Fig: Under reamer

https://www.harborfreight.com/gas-powered-earth-auger-56257.html

55

Precast piles: Bored precast piles

- Constructed in a casting yard and subsequently lowered into pre bored holes and the space grouted.
- In situ extensions are avoided
- Casting yard is well drained.
- Longitudinal reinforcement of one length. If any joints, they are staggered.
- Hopes and links of reinforcement is fitted by welding or tying tightly against longitudinal bars.
- Permanent spreader forks at 1.5m apart for holding bars.
- constructed by suitable choice of boring and installation techniques based on subsoil conditions.
- Bottom end have arrangements for cleaning and grouting.

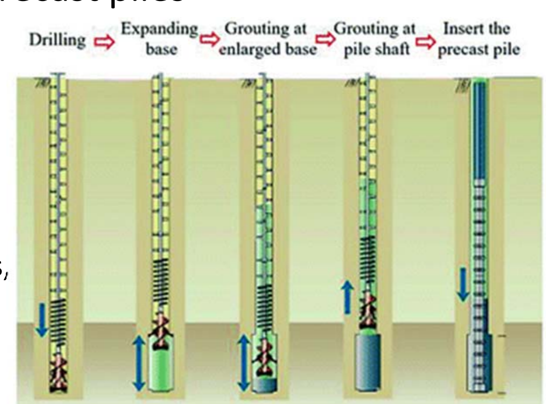

*Fig: Bored precast **piling***

https://aarsleff.co.uk/solutions/driven-precast-concrete-piling/

56

Driven precast piles

- Transmit the load of the structure by resistance developed either at the tip or by end bearing or along the shaft by friction or by both.
- They are cast in a yard and subsequently driven into the ground with or without jetting.
- Used for structures, such as, wharves, jetties, etc., or where conditions are unfavorable for use of cast in-situ piles.

Fig: Driven precast concrete piling

https://aarsleff.co.uk/solutions/driven-precast-concrete-piling/

57

Bored piles

- Transmit the load to soil by resistance developed either at the tip by end bearing or along the shaft by friction or by both.
- Driven by suitable choice of installation techniques.
- Sub soil conditions details necessary to predetermine the details of installation.
- Temporary casing inserted in each bored pile based on conditions. marine sites require permanent casing.
- Bottom of hole is cleaned before concreting work is taken up.
- Periodic testing to ensure consistent specific gravity of drilling mud (should be less than 1.2).
- Concreting done by tremie method or specially designed underwater placer.
- Ensure good concreting at the cut off level before capping.
- Defective piles should be replaced with additional piles
- Pneumatic tools should not be used until 7 days for chipping
- Quantity of concrete used should be noted and compared.

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Cast in situ piles

- Transmit load to the soil by resistance developed by the toe of the pile or by end bearing or by friction along their surface or by both.
- Materials used: steel and concrete

Equipment

Dolly: A cushion of hardwood to receive hammer blows.

Drop hammer**:** raised by a winch and allowed to fall under gravity

Single or double acting hammer**:** operated by steam or compressed air

Kentledge**:** Dead weight used for applying a test load to a pile;

Pile rig**:** A fabricated movable steel frame.

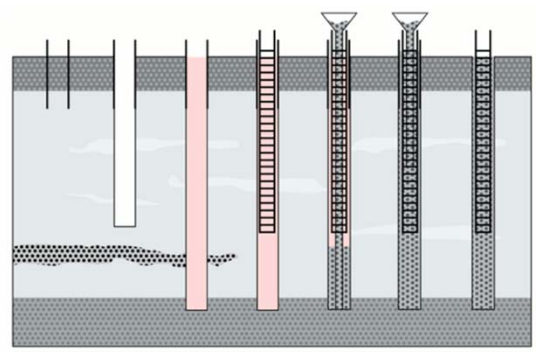


Fig: Stages of driven cast in situ piles

https://civilblog.org/2014/02/15/4-phases-involved-in-bored-cast-in-situ-pile-construction-work/

59

Machine foundations: Criteria for construction

Specialized structure: To Suit type of machines, namely, rotary, impact, reciprocating, etc.

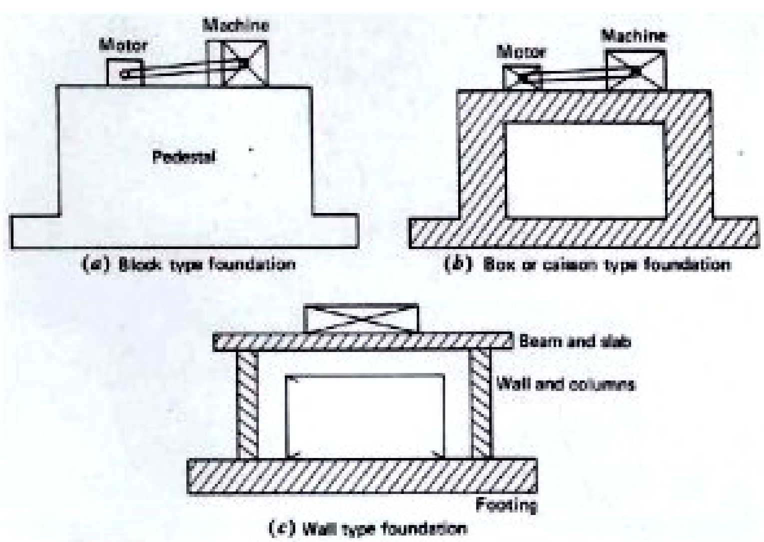


Fig: Types of machine foundations

https://civilengineersforum.com/machine-foundations/

60

❑ISSP 62
❑P.C. Varghese, Building Construction, Prentice-Hall of India, New Delhi, 2008
❑B. C. Punmia, Building Construction, Laxmi Publications, New Delhi, 1993.

Note: All the images used are for demonstration purpose only and are sourced from internet.

Masonry Construction

1

Classification based on Material of construction

- Early days- Masonry- Adobe, brick and stone
- Present day- Masonry -includes a host of other manufactured products.

Definition of Masonry: "An assemblage of small building units held together with mortar".

Classification:
- Adobe/mud-wall/Stabilized Soil block Masonry
- Stone masonry of various types
- Brick masonry
- Concrete block masonry
- Hollow clay and concrete block masonry
- Grouted, reinforced, prestressed masonry
- Accelerated masonry construction- interlocking- mortarless

2

Classification of Masonry construction

Based on

- Type of basic masonry unit
- Type of material used for masonry unit
- Type of mortar
- Type of finish (plastered/un-plastered-exposed masonry)
- Type of structural form

3

Suitability of load bearing masonry construction

- Low-rise buildings- any type of building
- Load bearing masonry MS buildings - suitable in which there is a fixed pattern of division of floor spaces by aligning the walls one over the other in different floors
- Ex: Hotels, Hostels, Apartments, Dormitories etc.
- Different types of masonry elements are integrated to get the desired form.
- Classification of Elements/Structural forms and non-structural forms

4

Single leaf wall

- May be of any thickness provided the masonry units are bonded together
- Use: internal / external load bearing walls, boundary walls and retaining walls

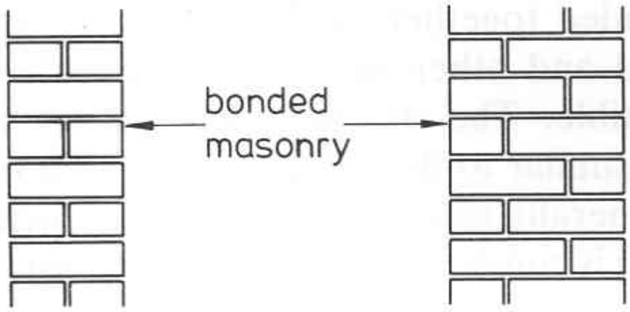


Figure 9.1 Single-leaf walls

5

Double-leaf collar-joined wall

- Use: Internal & external, where a double leaf thickness is required structurally, and stretcher bond is required architecturally
- Caution: Due to inherent weakness of collar joints design is to be done similar to a cavity wall.
- By use of metal ties or mesh reinforcement, strength is improved to that of solid wall (main improvement- ability of joints to take vertical shear)

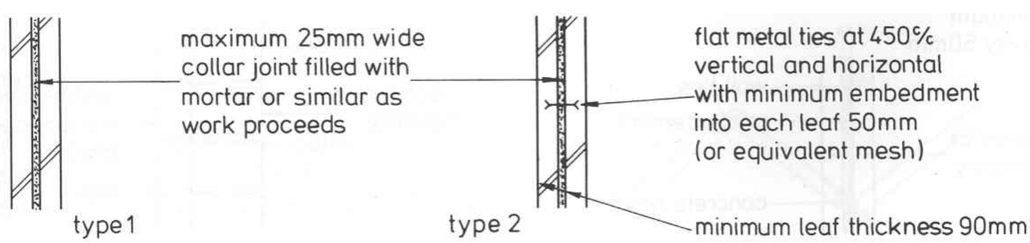


Figure 9.2 Double-leaf collar-jointed walls

6

Double-leaf cavity wall

- Use: External wall, with cavity to prevent damp penetration
- Two leaves are tied together with metal ties
- Ties transfer some horizontal forces but not capable of transferring vertical shear.
- Design as two separate leaves carrying vertical loads applied to it
- Other leaf provides resistance to buckling & transfers horizontal forces such as winds across cavity
- Cavities filled with (non-structural) insulation materials improve thermal insulation.

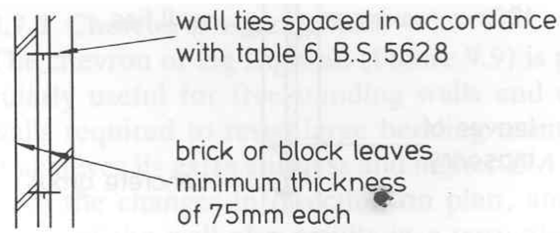


Figure 9.3 Double-leaf cavity wall

7

Double-leaf grouted cavity wall

- Designed as a solid wall (provided cavity = 50 mm and tied with metal ties and grouted)
- Also reinforced to resist tensile forces developed due to lateral loads
- Caution: But filling of cavity reduces resistance to damp penetration

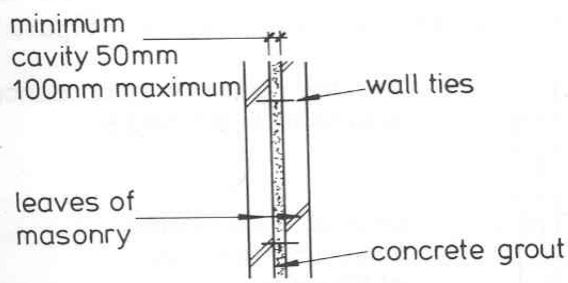


Figure 9.4 Double-leaf grouted cavity wall

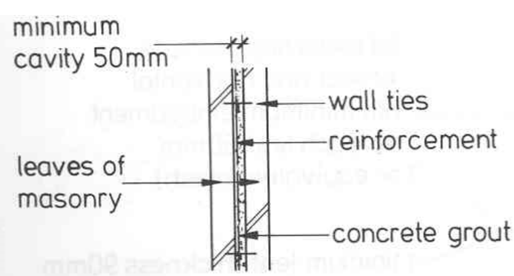


Figure 9.5 Reinforced grouted cavity wall

8

Faced wall

- Wall consists of two types of masonry units bonded together to provide a particular facing to wall
- Use: When solid wall is necessary – but facing must have properties not required for the backing.
- Caution: Shrinkage, thermal and other movements of units should be compatible.
- Design: Full thickness is assumed to be made up of weaker units.

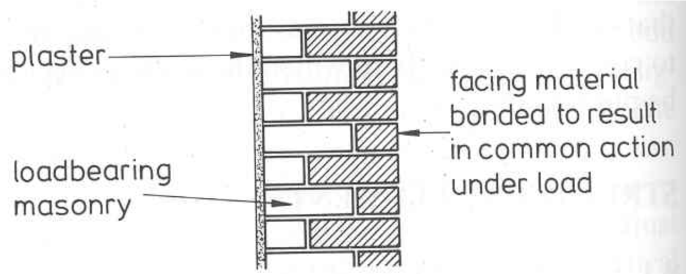


Figure 9.6 Faced wall

9

Veneered wall

- Facing attached to the backing – but not bonded to it in such a way to induce composite action under load
- Use: When expensive facing is required/ Veneer has little load carrying capacity/ Facing likely to be replaced within life of the structure
- Design: Include dead load of veneer neglect structural effect of veneer
- Caution: Differential vertical movements from shrinkage, thermal & other effects -to make sure that loosening of ties and or buckling of veneer will not occur

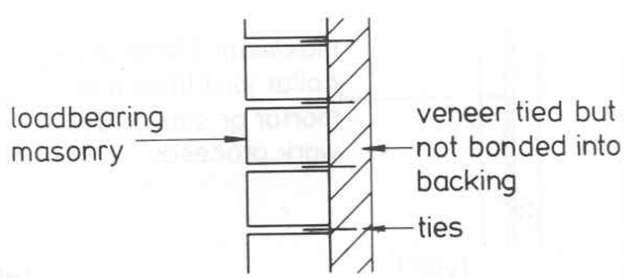


Figure 9.7 Veneered walls

10

Walls with improved section modulus

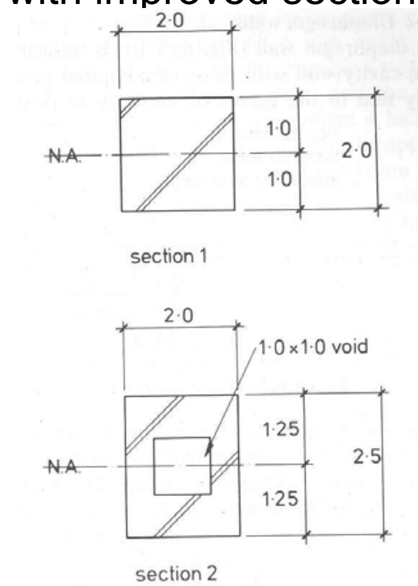
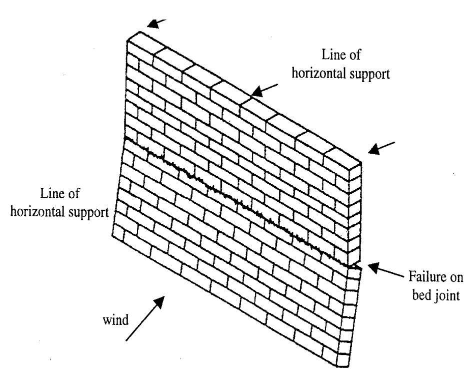


Figure 9.8

11

Masonry subjected to lateral load normal to wall

- Free standing wall
- Curtain wall
- Partition wall
- Panel wall



Wall spanning vertically

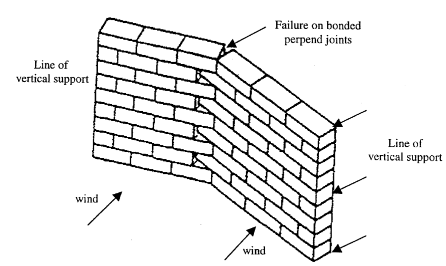


Figure 5.7 : Horizontal bending failure : toothed failure

Wall Spanning Horizontally

12

Zig-zag or serpentine wall

- Use: Free standing wall & other walls to resist large B.M. (External walls of buildings/ boundary walls etc.)
- Achieves extra stiffness & higher Z/A ratio from changes in direction on plan & shape
- Pleasing appearance
- External walls of buildings, fencing walls

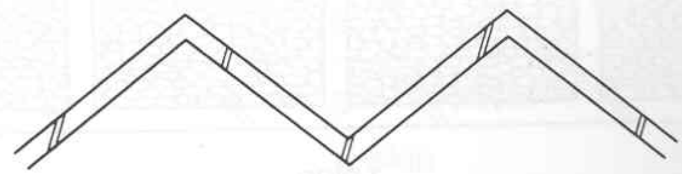


Figure 9.9 Chevron or zig-zag wall

13

Diaphragm wall, open, or mass filled

- Wide cavity wall with cross ribs bonded or specially tied to two leaves of masonry, which provides vertical shear resistance at joints.
- Use: Tall single storey buildings enclosing large open areas (sports, drama halls, factories)
- Design: width of leaves increased to suit design typical widths 500 to 1100 mm overall width.
- Retaining walls – with or without mass filled (rubble or other material) to provide stability. Sometime grouted to provide monolithic mass.

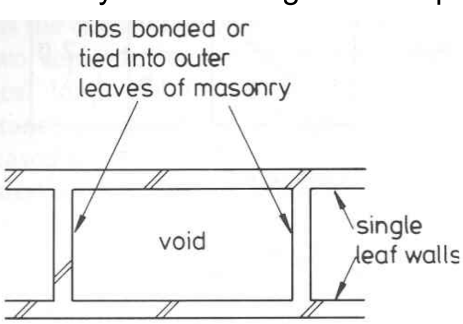


Figure 9.10 Diaphragm wall

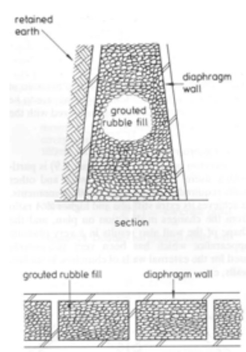


Figure 9.11 Typical mass filled diaphragm

14

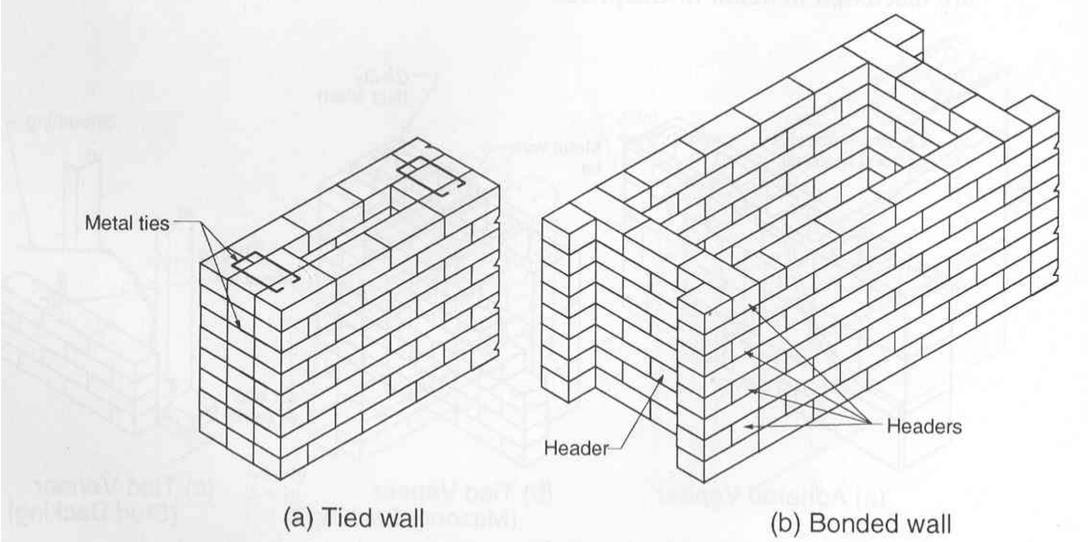


Figure 2.7 Diaphragm walls.

15

Piered wall

- Stiffened by piers bonded into wall at regular centres
- Use: Local strengthening under concentrated load/ External walls of single storey (3 to 5 m high) to resist lateral loads
- Design: Increases effective thickness, reduces slenderness Ratio: enables higher load carrying capacity.
- Caution: Due to unsymmetrical geometry- in one direction bending resistance is higher. Not suitable for sit

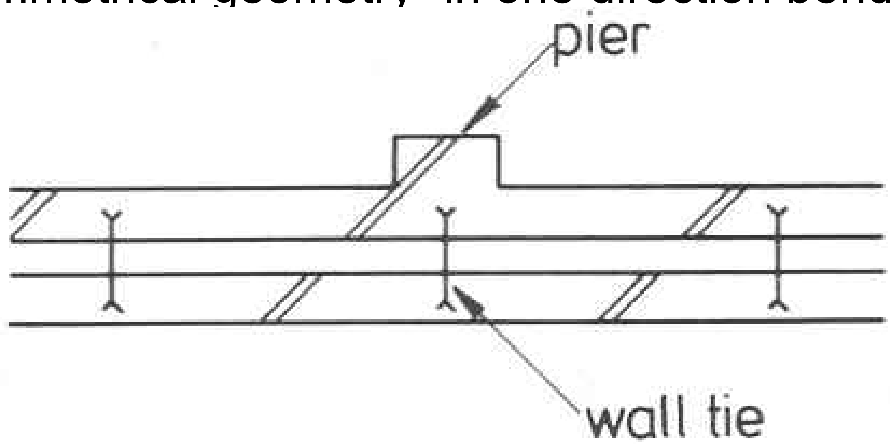


Figure 9.12 Piered wall

Fin wall

- Piered wall with piers extended to more slender proportion
- Design: Fin is designed as T-section bonded to the intersecting leaf of masonry
- Caution: Boundary between piers and fins
- Use: Retaining walls, sports stadia, factories multistorey buildings, Auditoria.

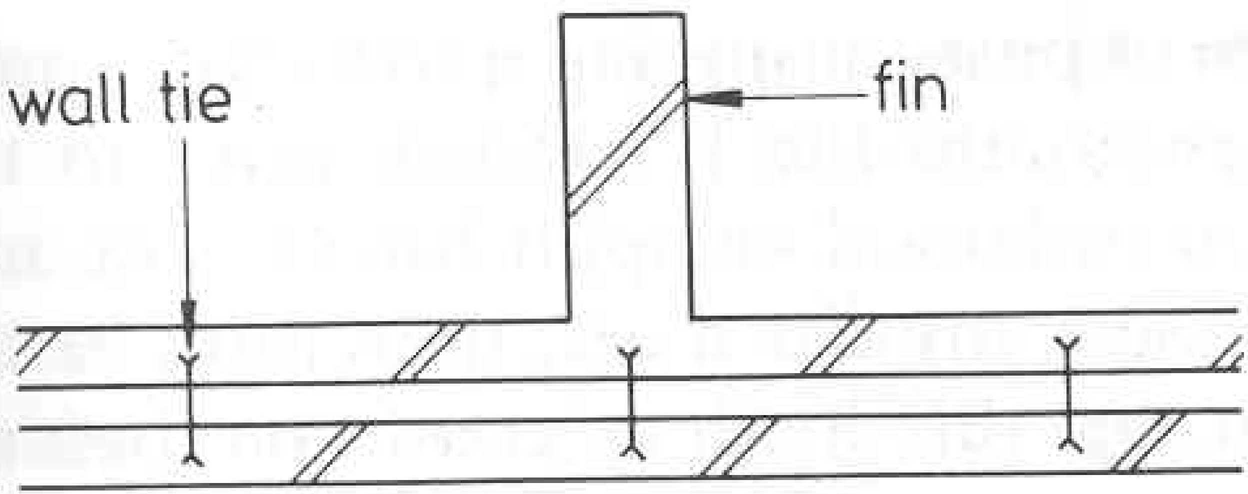


Figure 9.13 Fin wall

Reinforced wall

- Improved resistance to tensile stresses
- Walls constructed with reinforcement contained in cavity (also through holes, ducts in masonry)
- Voids around reinforcement is grouted or mortar filled to provide bond
- Reinforcement located at tension face of wall
- Design: Similar to RCC. Masonry in compression zone to resist compressive stresses & Reinforcements in tension face to resist tensile stresses

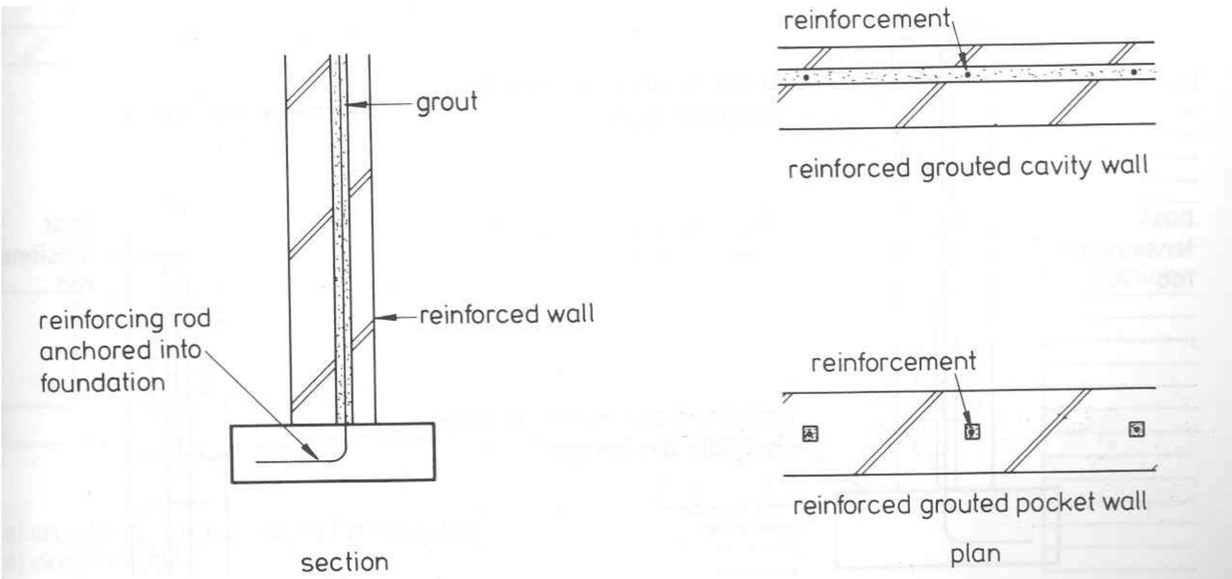


Figure 9.14 Reinforced walls

Reinforced wall

- Resistance is increased by employing suitable reinforced piers, diaphragms, or fins.
- Use: Retaining walls/large lateral loads/earthquake resistance
- Caution: Adequate protection against corrosion (quality of masonry, mortar and cover)

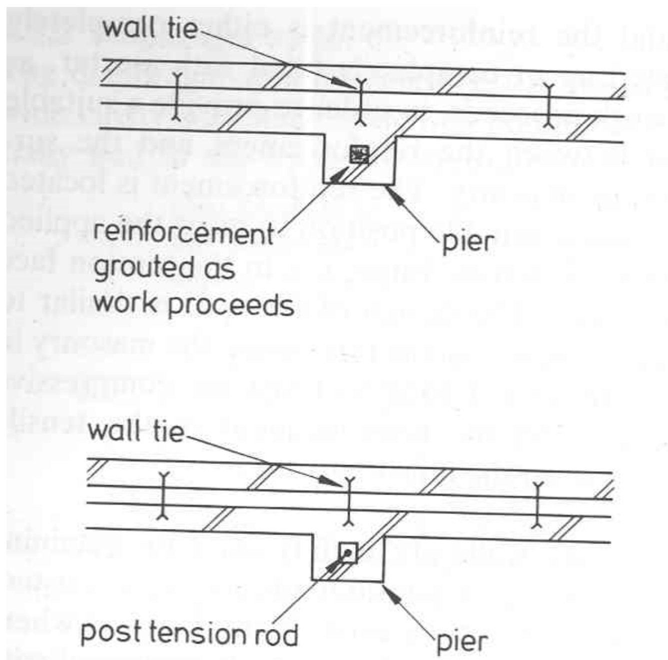


Figure 9.15 Reinforced and post-tensioned pier

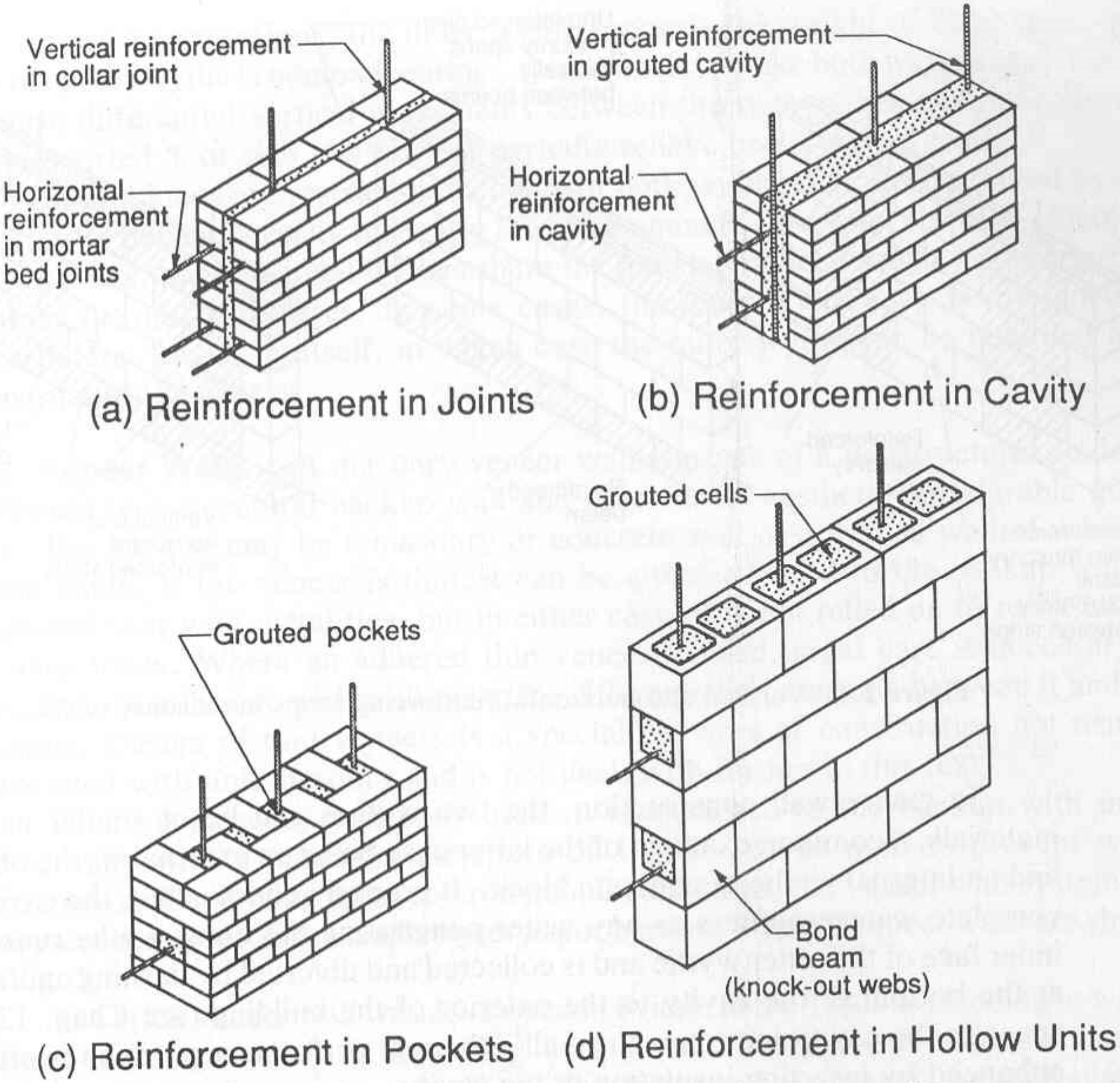


Figure 2.3 Reinforcement locations in masonry walls.

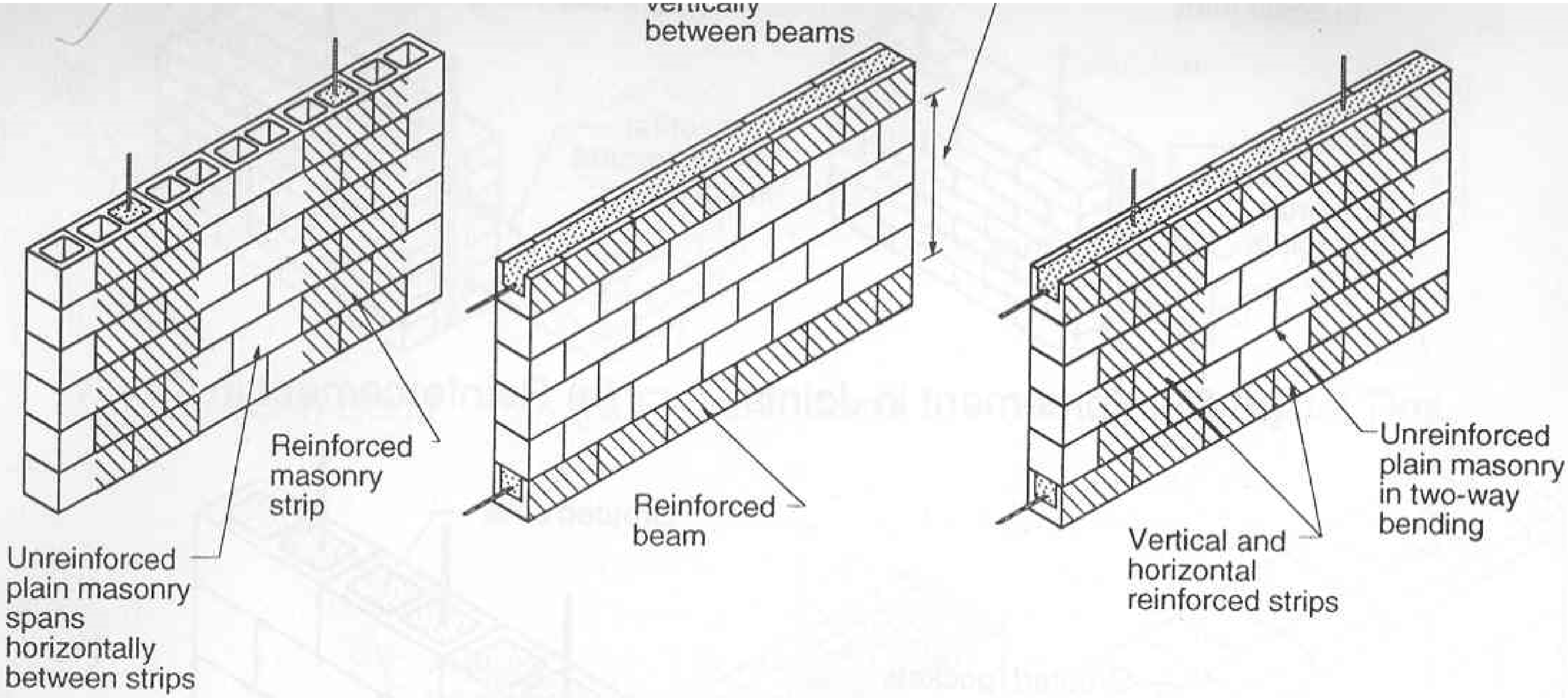


Figure 2.4 Vertical and horizontal reinforcing strips in masonry walls.

Column

- Short length of wall
- Isolated vertical load bearing member: width not greater than 4 times thickness
- Columns can be built with cavities- facilitating grouting, reinforcing/ prestressing

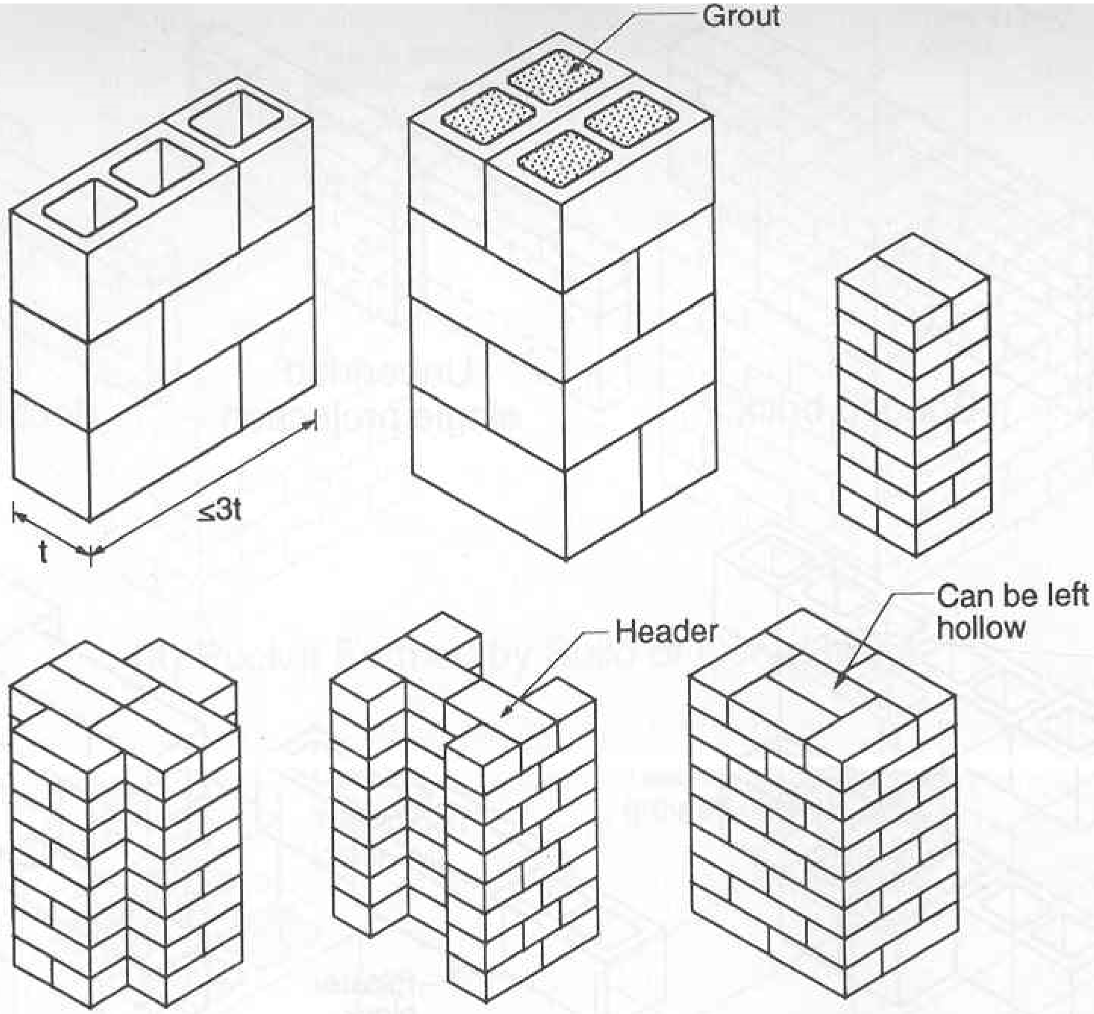


Figure 2.8 Columns.

Arch

- Efficient method of forming a support with materials having good compressive resistance & low tensile resistance.
- Graceful and visually attractive structural form
- But not being used frequently (Reduction in craftsman availability)

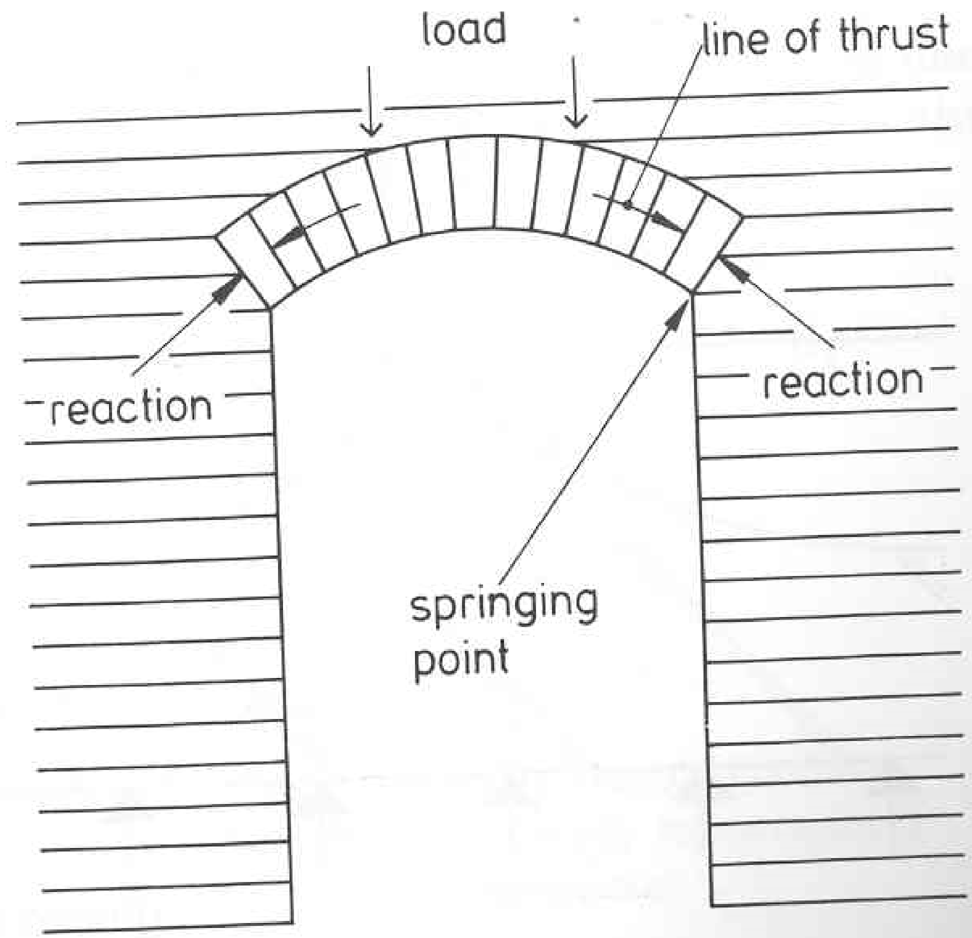


Figure 9.19 Arch

SPINE WALL CONSTRUCTION

- Suitability: Flexible open plan arrangement where several main walls, such as corridor walls, lift shafts, toilets (partitions can be temporary)

- Structural action: Spine walls & external walls are main load bearing walls (should line up vertically through out the height)

- Sufficient walls to resist wind at right angles – needed

- Floors serve as horizontal plate members transferring wind reactions from external walls to the shear walls resisting lateral loads.

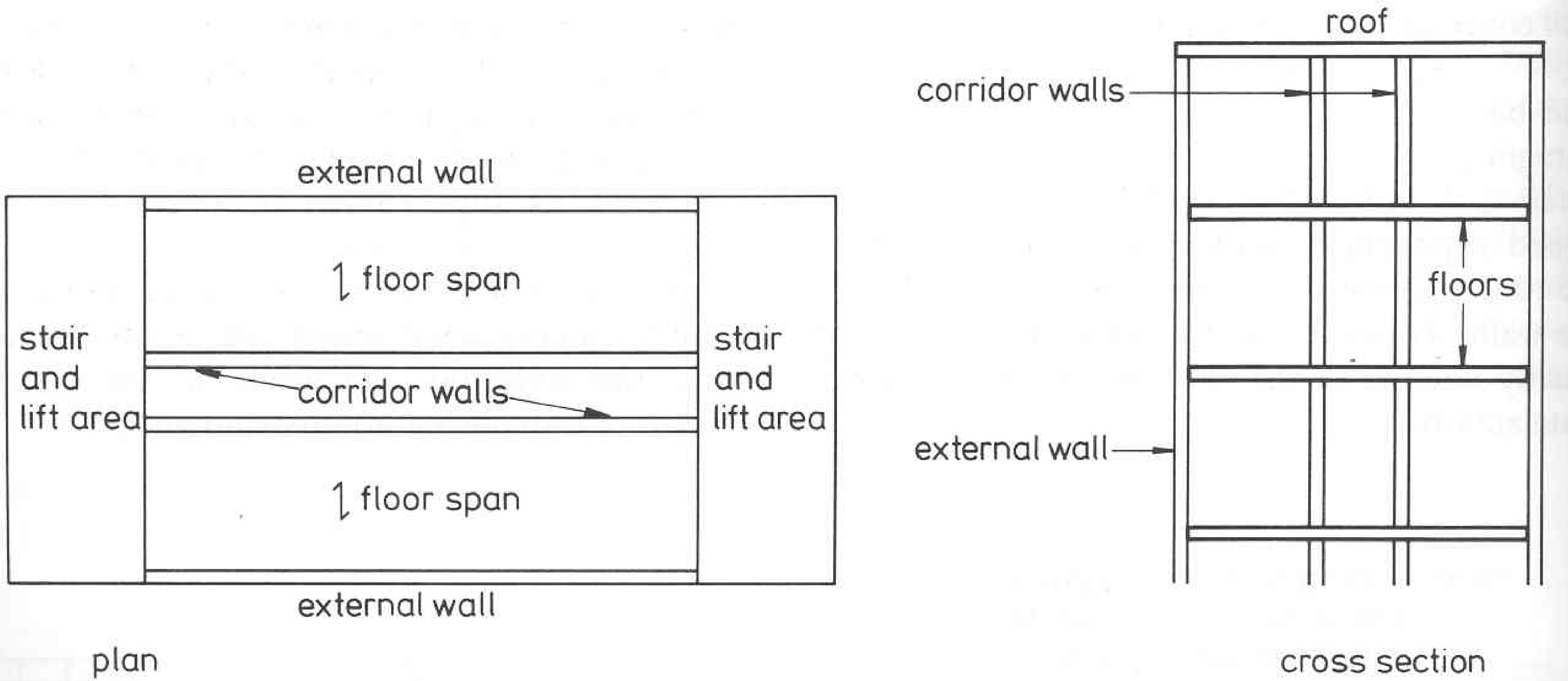


Figure 9.40 Spine wall construction

CROSS WALL CONSTRUCTION

- Suitability: Multistorey buildings with fixed pattern of division of space in all floors (Hotels, Hostels, Schools etc)
- Satisfies both functional and structural requirements
- Resist wind loads from main elevation
- Corridor walls, lift & stair wells resist wind load from right angles

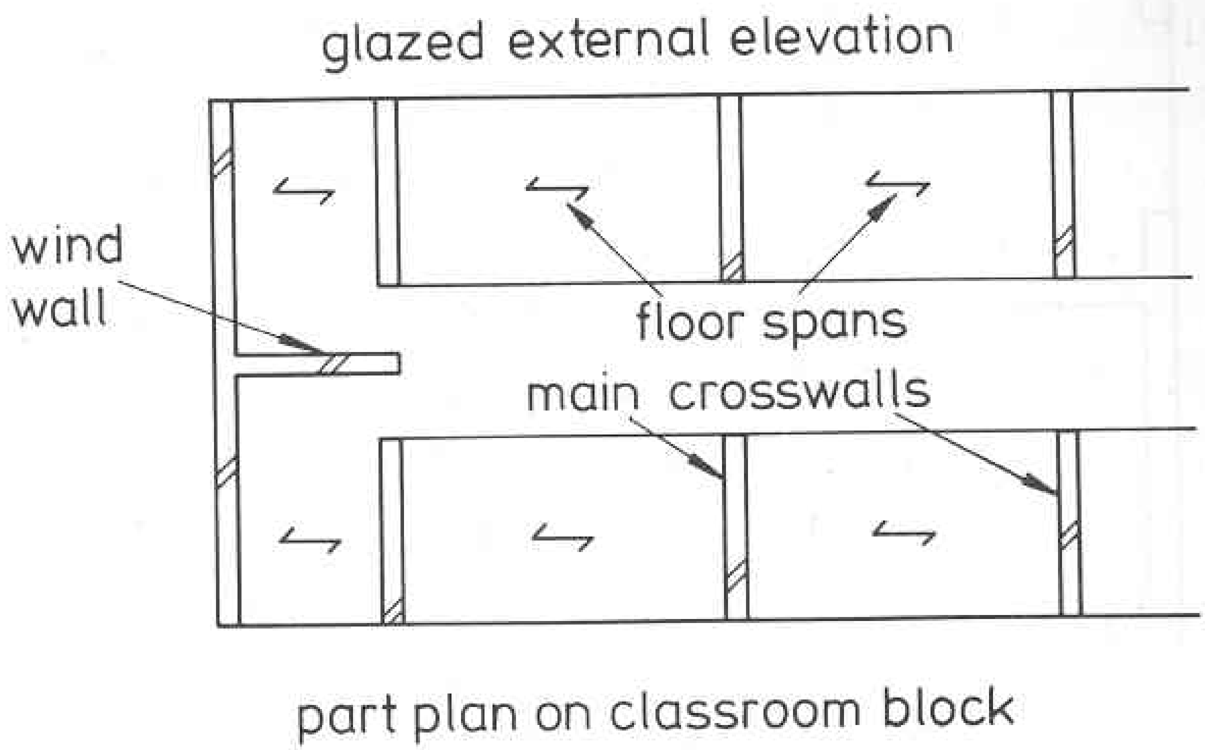


Figure 9.31 Crosswall classroom blocks

CELLULAR WALL CONSTRUCTION

- Suitability: Multistorey buildings with small rooms (domestic buildings, small offices etc.)

- Note: Rooms for a number of cells & all separating walls are used for main structure are lined up from bottom to top

- All walls are load bearing except toilet partitions and other minor room dividing walls.

- Similar to cross wall construction, but easier to achieve similar stiffness in all wind directions because of cellular arrangement.

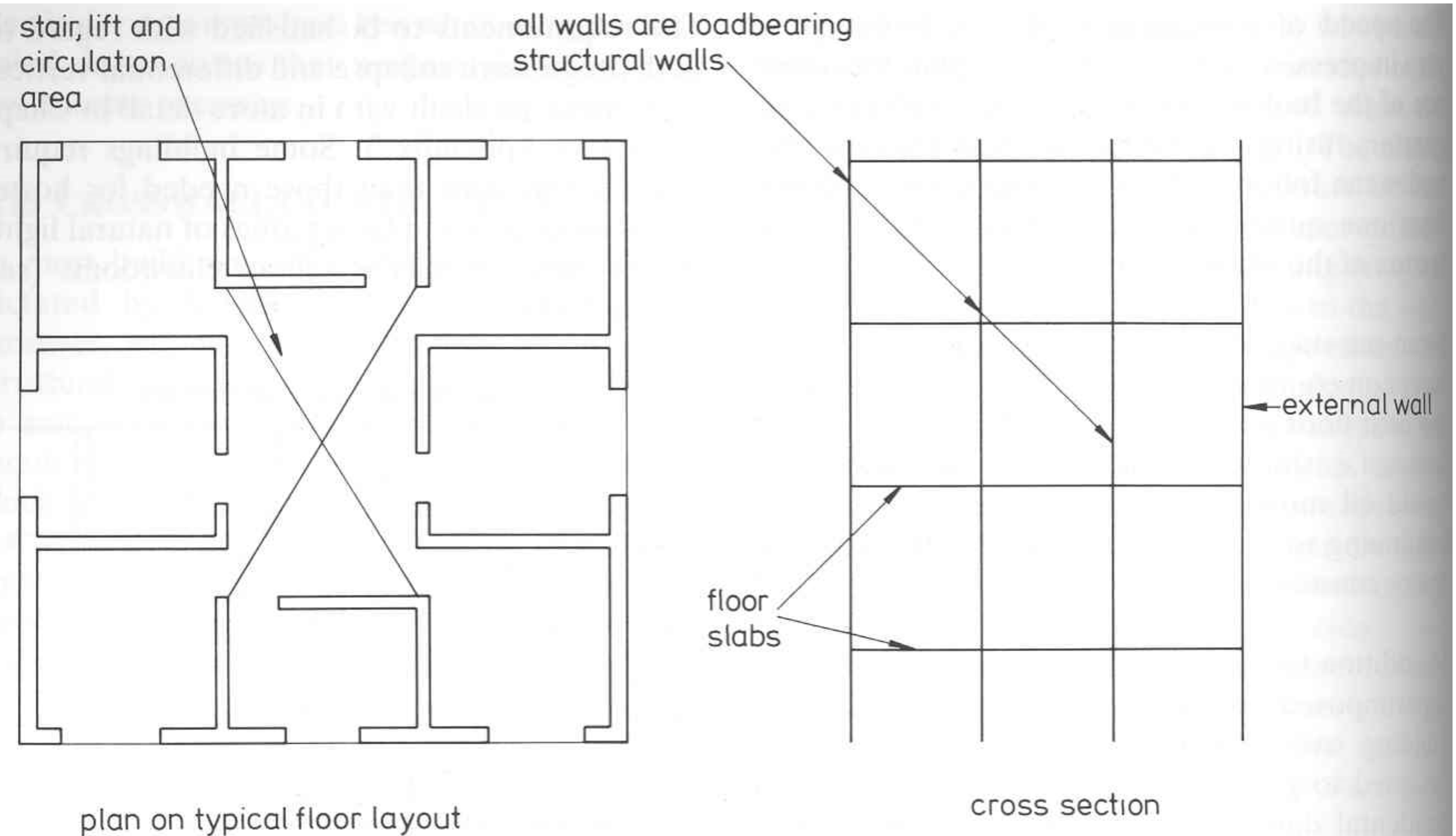
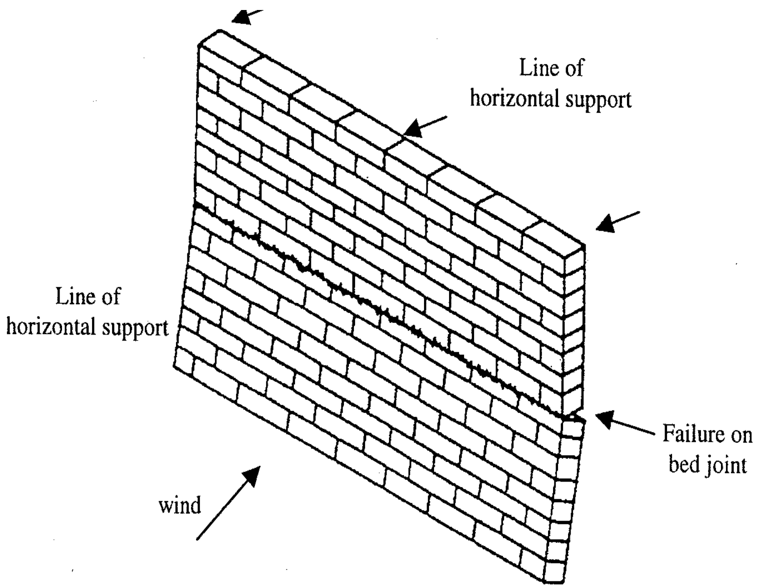


Figure 9.32 Cellular construction

Masonry subjected to lateral load normal to wall

- Free standing wall
- Curtain wall
- Partition wall
- Panel wall



Wall spanning vertically

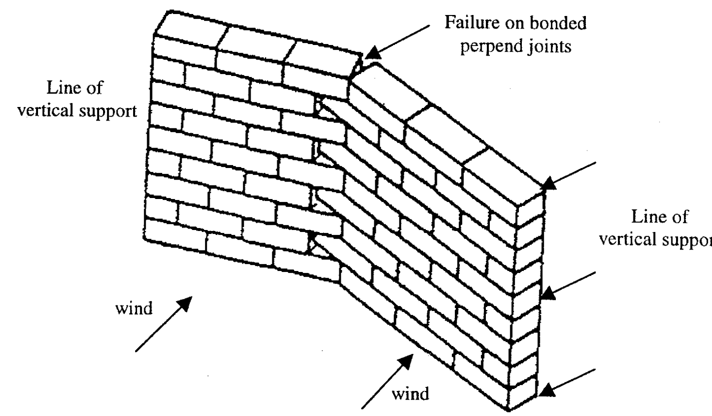
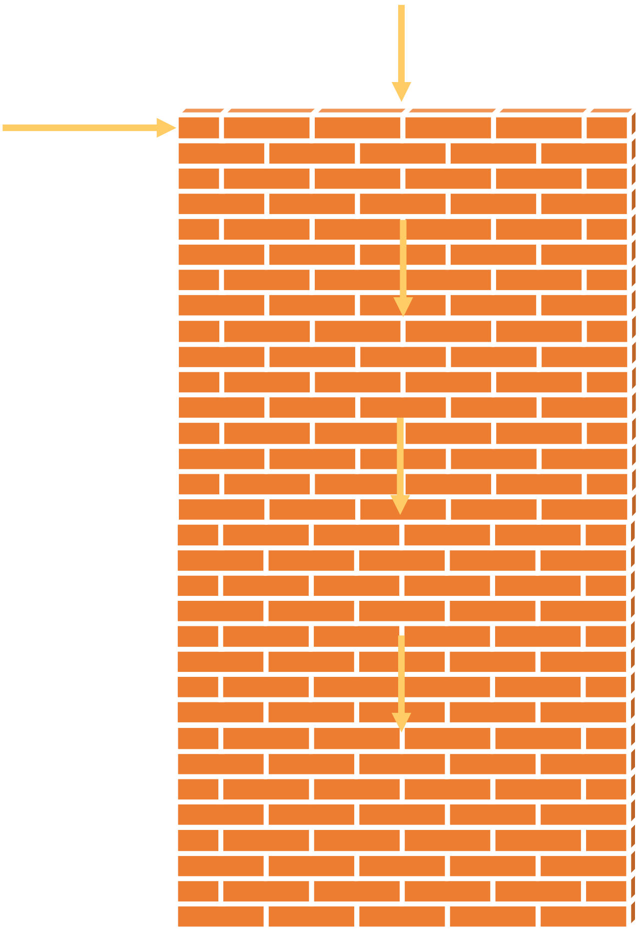


Figure 5.7 : Horizontal bending failure : toothed failure

Wall Spanning Horizontally

Shear Walls



- Essentially act as vertical beams that resist gravity and in-plane lateral loads

- Generally, shear walls must be checked for flexure and shear

- Deflections (stiffness) may also be critical difficult, consider both shear and flexural displacements

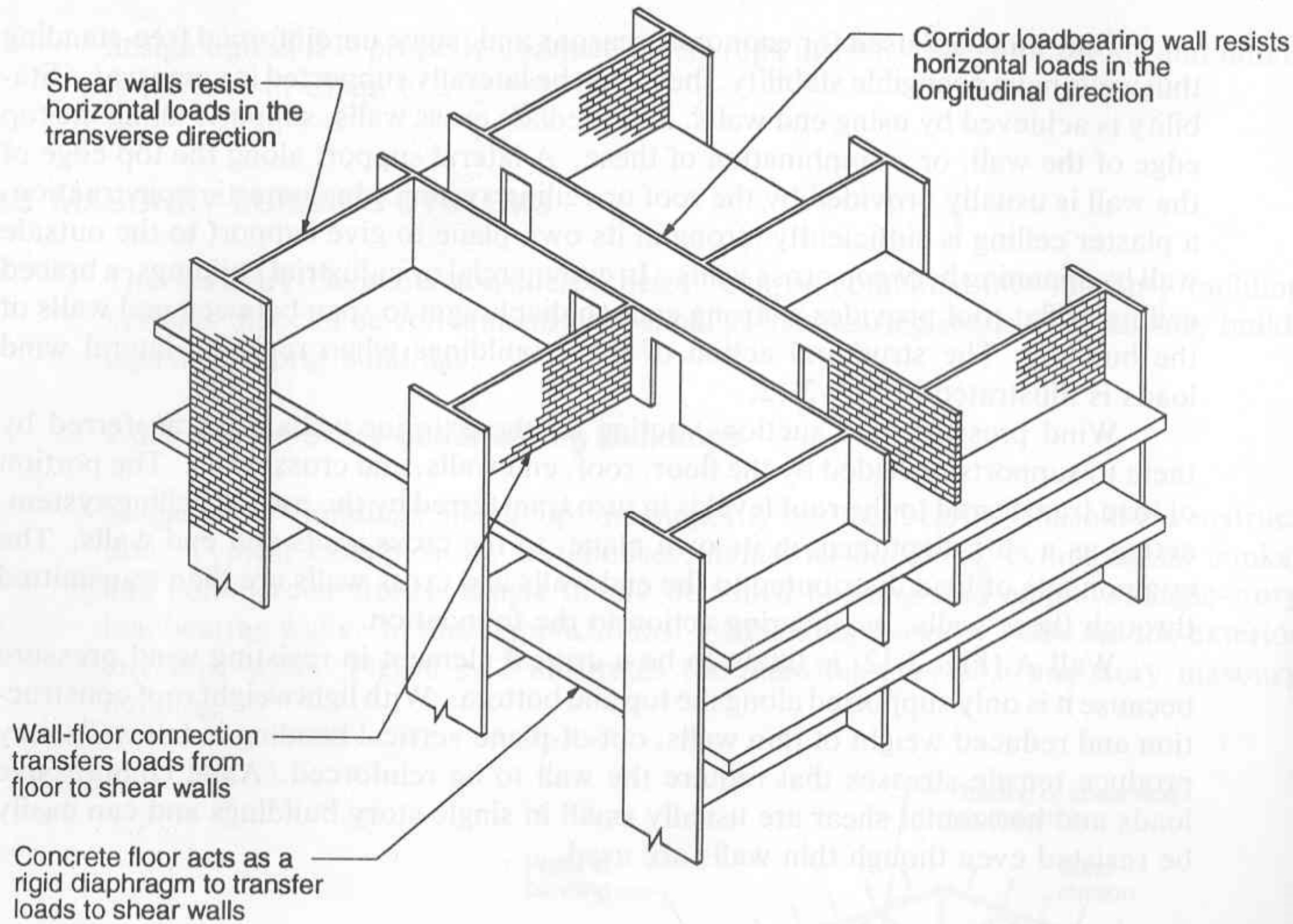
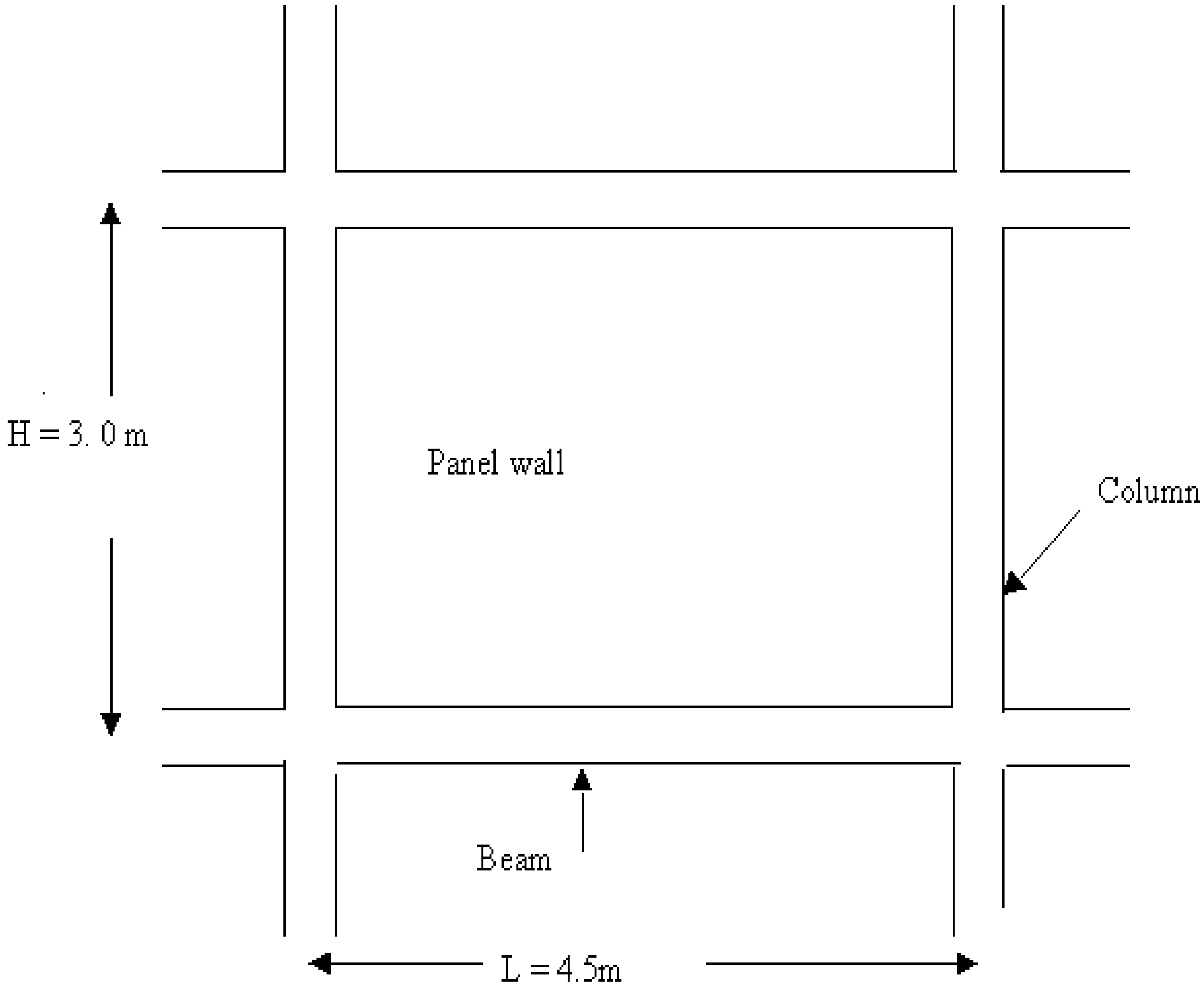


Figure 2.13 Multistory shear wall system.

Panel wall



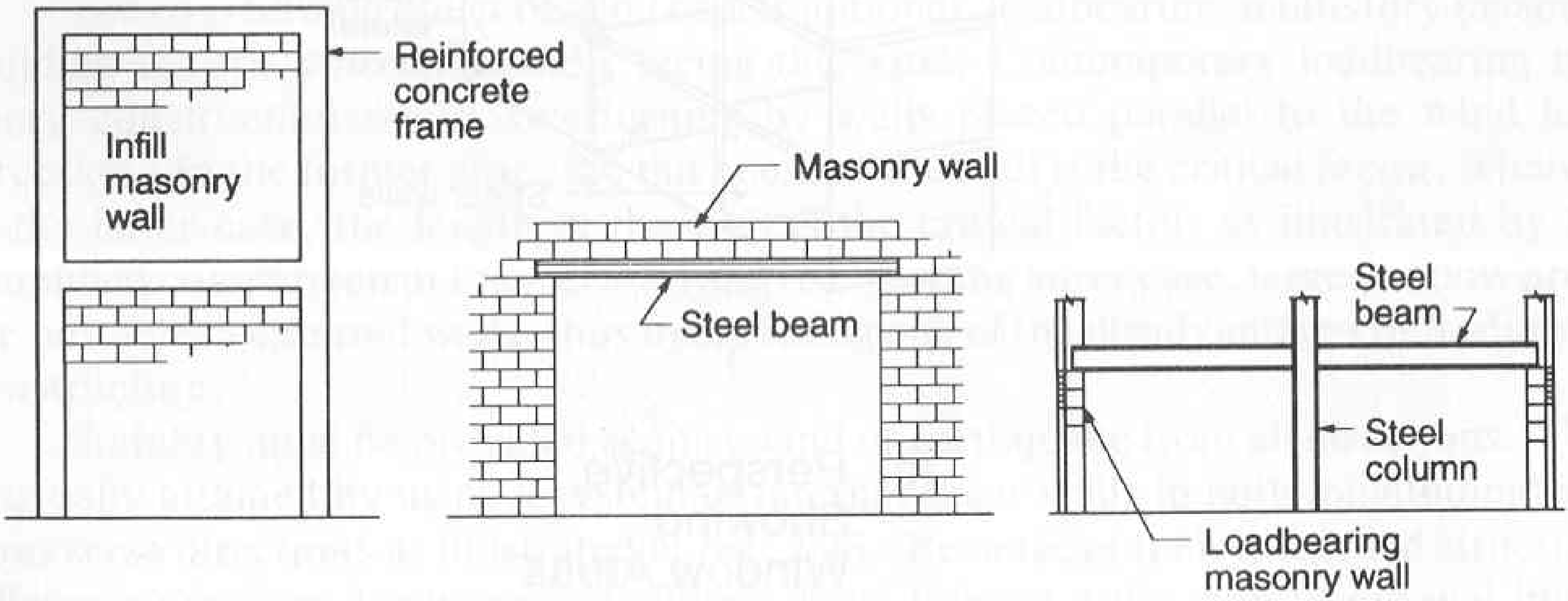


Figure 2.16 Hybrid building systems with masonry walls.

Masonry Construction: Components and Assemblages

Components of Masonry

Masonry units - actual structural components (Solid masonry units; Perforated (cored less than 25%); Hollow masonry units (cored between 25% and 50%)

- Mortar - bonds structural components together
- Reinforcement - adds strength and/or ductility
- Grout - encases the reinforcement, acts as filler in cavities
- Accessory Materials - Ties/connectors, flashing, sealants, coatings, vapor barriers, etc.

Burnt Clay Brick IS 1077

Properties of Clay Brick

- Affected by
  - composition of raw materials
  - manufacturing processes

- Physical properties
- Mechanical Properties
- Durability
- Aesthetics

Brick masonry

Course: Horizontal layer in masonry unit.

Stretcher: Side surface of bricks visible in elevation when the brick is laid flat.(19 cm x 9 cm).

Header: End face of the brick when it is laid flat is as header (9cm x 9cm)

Bat: Brick which is cut across its width

Closer: Brick which is cut across its length

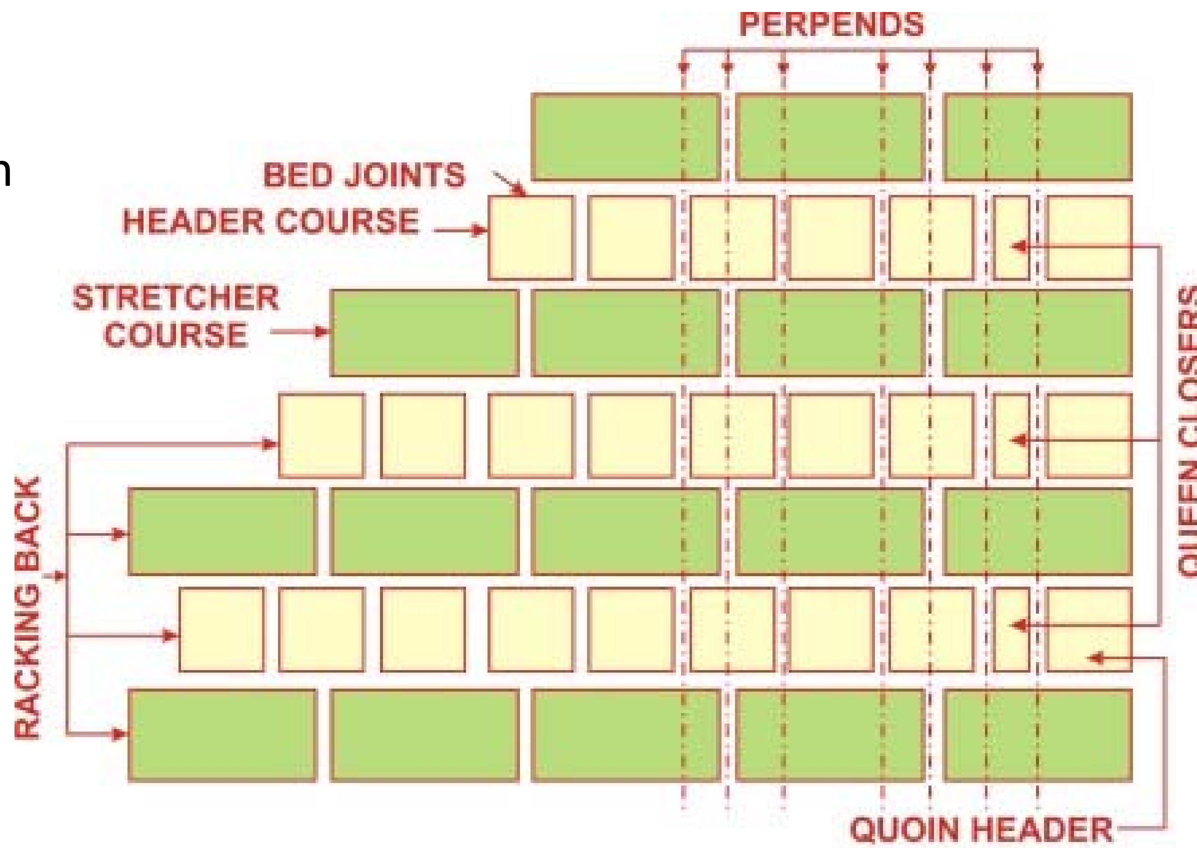
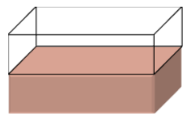


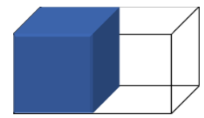
Fig. 2.1. Elevation of a wall.

CORNER

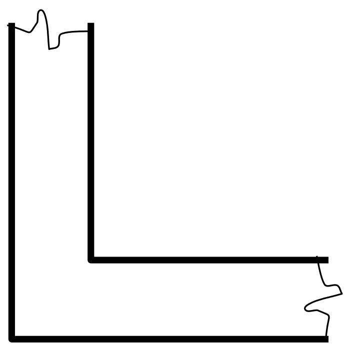


QUEEN CLOSER

¾ BRICK BAT



1/2 BRICK BAT



PLAN OF A TYPICAL CORNER

Bricks

- Handmade or machine moulded and strength of bricks varies according to the region.
- Depends upon the upon nature of available soil & technique adopted for moulding & burning.

Region	Strength(N/mm^2)
Delhi, Punjab, Haryana	7-10
Uttar Paradesh	10-20
Madhya Pradesh	3.5-5
Maharashtra	5
Gujarat	3-10
Rajasthan	3
West Bengal	10-20
Andhra Pradesh	3
Assam	3.5

- Strength of masonry depends on surface characteristics & uniformity of size & shape of units
- For same brick strength, higher masonry strength with better shaped bricks with true edges.

Size of bricks

- Bricks shall have the following dimensions:

	Length mm	*Width* mm	*Height* mm
Modular bricks	190	90	90
	190	90	40
Non-modular bricks	230	110	70
	230	110	30

- For obtaining proper bond between modular and nonmodular bricks the following size of bricks may also be used:

Length mm	*Width* mm	*Height* mm
70	110	1/3 length of brick

Classification of bricks

- Common burnt clay bricks are classified based on compressive strength

Class Designation	35	30	25	20	17.5	15	12.5	10	7.5	5	3.5
Average Compressive Strengths											
N/mm^2	35	30	25	20	17.5	15	12.5	10	7.5	5	3.5
kgf/cm^2	350	300	250	200	175	150	125	100	75	50	35

- Bricks should be free from cracks and flaws and nodules of free lime.
- Should have smooth rectangular faces with sharp corners and shall be uniform in colour.
- Tolerance on brick dimensions shall be ±3 percent for designation 100 and above ; ± 8 percent for lower designations.

Sand lime bricks

- Sand lime bricks/Calcium Silicate bricks: intimate mixture of siliceous sand or crushed siliceous rock and lime combined by action of saturated steam under pressure.
- Coloured sand lime bricks - addition of fast pigments to the raw mix before pressure casting.
- Four classes of sand lime bricks

Class	*Average Compressive Strength N/mm^2 (kgf/cm^2)*
Class 75	7.5 to 10.0 (75 to 100)
Class 100	10.0 to 15.0 (100 to 150)
Class 150	15.0 to 20.0 (150 to 200)
Class 200	20.0 and above (200 and above).

- Same size as that of burnt clay bricks(IS 1077:1992)

Compressive Strength (ASTM C 67)

- Hard capping: Sulphur, Cement mortar, Gypsum

- Soft capping: fibre board, plywood/other soft material- reduces confining effect
- Use of Teflon sheet/greased platen/brush platen

- h/t ratio of unit: Brick/block
- Brick tested flat/brick on edge

- Availability: Low strength bricks/ limited strength range
- Need to produce brick using extrusion process

Tensile & Flexural strength of masonry unit

- Masonry failure- under axial compression: Splitting
- Direct tensile strength-difficult-Split tensile strength
- Flexure: spanning horizontally/panel walls

Thermal and Moisture movements

- Brick – mortar
- Block- mortar

- Water absorption; IRA; Efflorescence

Concrete Masonry Units (CMU) IS 2185

- Raw materials (OPC, PPC, Graded aggregates, Water, Pozzolanic materials (fly ash, silica fume, etc.), Admixtures (air entrainment, water reducers, pigments, etc.)

- Mix
  - Mix to a damp consistency using only water required for hydration (Stiff mix)
  - Essentially no-slump concrete

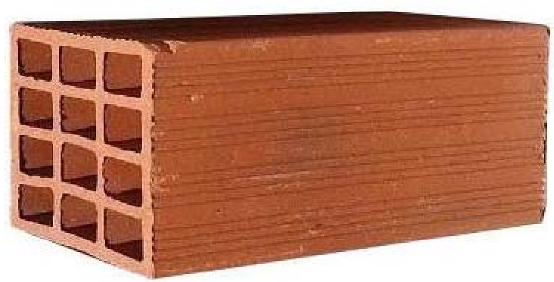
- Manufacture: Mechanized compaction/vibration
  - Mix is pressed into a mold and then consolidated by vibration
  - Units are removed from molds immediately

- Curing
  - Steam cure at atmospheric pressure(~18 h)/high pressure (4-12 hr.)
  - Moist curing for low/medium strength applications
  - Units are stored outdoors for further curing

Properties of CMU Units

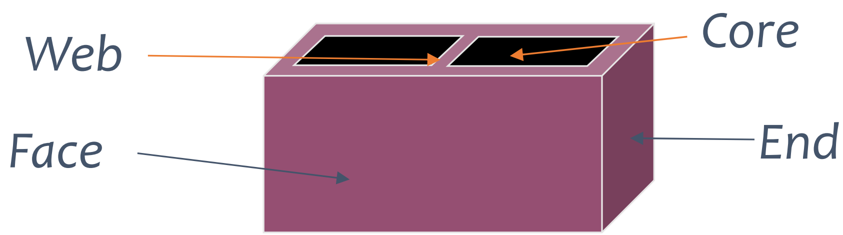
- Compressive strength on net area
  - Voids not considered, only effective area that resists loads
  - Minimum compressive strength given in ASTM standards

- Unlike brick, desired strength can be manufactured by changing the mix
- Blocks are made of soil-cement, cement mortar, concrete, aerated concrete, precast stone concrete, Fly ash concrete block



Sizes and Shapes of CMU Units

- Normally modular sizes
  - 10 mm less than nominal sizes in length to accommodate a 10mm typical mortar joint
- Common nominal face dimensions of 20x 40 cm in thicknesses of 10, 15, 20 cm
- Minimum thicknesses of webs and face shells is specified in IS 2185/ASTM C90
- Face-shell vs full mortar bedding



Mortar (IS 2250)

- Bonds individual masonry units together
- Provides compressive and shear strength
- Provides a seal against moisture penetration
- Accommodates tolerances of units /Seals irregularities of individual units (levelling)
- Provides aesthetic qualities
- weak link in masonry construction
- thin layer stronger (compression) than thick layer
- lime added
  - workability
  - adhesive properties
  - extensibility

1

Classes

- lime mortar
  - slow strength gain
  - seldom used in permanent construction
- cement/cement-lime mortar
  - most desirable
- masonry cement mortar
  - proprietary ingredients
  - workable
  - low bond strength

2

Components of Mortar

Portland cement
- durability
- high early strength
- high compressive strength
- bond strength

Sand
- filler
- Strength

Lime
- workability
- water retentivity
- elasticity
- bond strength
- extensibility

3

3

Components of Mortar

Water (flow, hydration)
- clean
- potable
- free of deleterious materials (acids, alkalis, organic materials)

Admixtures
- color
- workability
- reduced water penetration
- accelerated curing
- use with caution
  - air-entraining
  - chlorides

4

4

Specification and Types of Mortar

ASTM C270: Provides property or proportion specifications for (4+1) types of masonry mortar

M A S O N W O R K

- Type M : High compressive strength and bond strength
- Type S: Moderate compressive and bond strengths
- Type N: Low compressive and bond strengths
- Type O: Very low compressive and tensile bond strength
- Type K: Only used for pointing (not in ASTM C270)

- A higher quality mortar should only be specified where necessary, since there is a tradeoff between strength and workability.
  - The mason cares about workability, not strength

5

5

ASTM C270 Specifications for Mortar

- Proportion Specifications
  - Each mortar type must meet a predetermined mix design
  - Proportion of each component is stipulated such that specific mortar properties result
  - *No testing required!*
- Property Specifications
  - Each mortar type must meet a minimum property value for compressive strength, maximum air content, and minimum water retention
  - Properties verified only by lab prepared mortar (not a field quality control test)
  - *Testing required!*

6

Types (M~~A~~S~~O~~N~~W~~O~~R~~K)

- Type M (paving brick)
  - high strength
  - general use
  - below grade OR in contact w/ ground
- Type S (structural masonry, reinforced brick)
  - high strength
  - reinforced masonry
  - areas subject to high wind
- Type N (normal, common)
  - high strength
  - general use
  - below grade OR in contact w/ ground

7

Types (M~~A~~S~~O~~N~~W~~O~~R~~K)

- Type O (interior)
  - low strength
  - non-bearing applications
  - not subject to severe weathering
- Type K (restoration)

8

Portland Cement-Lime Mortar Proportion Specification

MORTAR TYPE	Portland Cement	Hydrated Lime	Masonry Sand
M	1	1/4	2-1/4 to 3 times total volume of cement & lime
S	1	1/4 to 1/2	
N	1	1/2 to 1-1/4	
O	1	1-1/4 to 2-1/2	

- Relationships by volume

9

Table 1: Mix Proportion And Strength Of Mortars For Masonry *(Clause 3.2.1)*

SL No	Grade of Mortar	Mix Proportions (By Loose Volume)					Minimum Compressive Strength at 28 Days In N/mm²
		Cement	Lime	Lime Pozzolana Mixture	Pozzolana	Sand	
1	H1	1	¼ C or B	0	0	3	10
2(a)	H2	1	¼ C or B	0	0	4	7.5
2(b)	H2	1	½ C or B	0	0	4½	6.0
3(a)	M1	1		0	0	5	5.0
3(b)	M1	1	1 C or B	0	0	6	3.0
3(c)	M1	0	0	1(LP-40)	0	1½	3.0
4(a)	M2	1	0	0	0	6	3.0
4(b)	M2	1	2B	0	0	9	2.0
4(c)	M2	0	1A	0	0	2	2.0
4(d)	M2	0	1B	0	1	1	2.0
4(e)	M2	0	1 C or B	0	2	0	2.0
4(f)	M2	0	0	1(LP-40)	0	1¾	2.0
5(a)	M3	1	0	0	0	7	1.5
5(b)	M3	1	3B	0	0	12	1.5
5(c)	M3	0	1A	0	0	3	1.5
5(d)	M3	0	1B	0	2	1	1.5
5(e)	M3	0	1 C or B	0	3	0	1.5
5(f)	M3	0	0	1(LP-40)	0	2	1.5
6(a)	L1	1	0	0	0	8	0.7
6(b)	L1	0	1B	0	1	2	0.7
6(c)	L1	0	1 C or B	0	2	1	0.7
6(d)	L1	0	0	1(LP-40)	0	1½	0.7
6(e)	L1	0	0	1(LP-20)	0	2½	0.7
7(a)	L2	0	1B	0	0	3	0.5
7(b)	L2	0	1 C or B	0	1	2	0.5
7(c)	L2	0	0	1(LP-7)	0	1½	0.5

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Selecting Mortar Types

- Considerations
  - structural requirements
  - exposure
  - wall type
  - workability

- No single type for all purposes

- Do not change mortar types within same structure

- NEVER use mortar stronger in compression than required
  - shrinkage, debonding
  - uneconomical

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11

Properties of Mortar

- Plastic properties
  - influence hardened properties
  - workability
  - initial flow
  - flow after suction
  - water retentivity

- Hardened properties
  - determine performance
  - bond strength
  - durability
  - extensibilty
  - compressive strength

- other properties
  - color

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Bond Strength of mortar

- most important physical property
- difficult to measure directly, simulate construction

		Bond Strength
Suction (IRA)	↑	↓
Air Content	↑	↓
Elapsed Time	↑	↓
Mortar Flow	↑	↑
Brick Texture rough		↑
Retempering		↑
Pressure	↑	↑
Movement after set		↓
Water Retentivity	↓	↑

Max Bond

- cement: lime
  1:1 to 1:1/4
- Type S mortar

	Proportion	f'_c
Cement	↑	↑
Lime	↑	↓
Water	↑	↓
Flow	↑	↓

- Compressive strength: Function of cement content, and w/c

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Grout

- Different than mortar- More like concrete
- High slump concrete poured or pumped into place
- Fills cells and cavities in masonry
- Provides bond between masonry and reinforcing steel
- Provides bond between wythes (vertical wall layers)
- Increases section properties of a wall
- Improves fire resistance of masonry walls
- Enhances capacity under concentrated loads

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Grout

- Components
  - Coarse aggregate
  - Fine aggregate (sand)
  - Portland cement
  - Water
  - Lime (sometimes)
  - Admixtures (as appropriate)

- Fluid consistency
  - HIGH Slump (200 -250 mm)– required as grout spaces are normally small-confined by mortar fins protruding out of joints-water from grout is also absorbed by absorptive masonry units- No segregation

- Compressive strength
  - Strength should be at least that of masonry units

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15

Grout Proportions by Volume (ASTM C476)

GROUT TYPE	Portland Cement	Hydrated Lime	Masonry Sand	Coarse aggregate
Fine	1	$\leq$ 1/10	2-1/4 to 3 *	-
Coarse	1	$\leq$ 1/10	2-1/4 to 3 *	1 to 2 *
* times total cement and lime volume				

Choice of fine or coarse grout generally depends on:

- minimum clear distances in grout space
- grout pour height

- Fine Grout: when grout space is less that 50 mm
- Coarse grout with 10 mm max.size of aggregate when grout space is more than 50 mm
- Coarse grout with 20 mm max. size of aggregate when the grout space is larger

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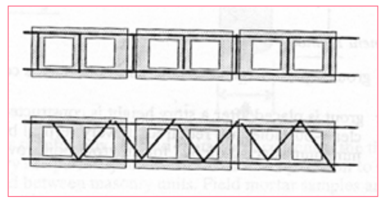
16

Reinforcement

- Provided to carry tensile and shear stresses, to tie wythes of masonry together, to increase axial load carrying capacity and to provide ductility under seismic loading
- Reinforcement is also used to control cracking due to shrinkage, temperature effects and applied loads
- Generally steel
  - FRP (fiber reinforced polymer) reinforced masonry is being researched
- Reinforcing bars
  - Generally same as for concrete construction
  - Deformed bars, circular in cross-section
- Prestressing steel
- Joint reinforcement
  - Generally plain steel wire (not deformed)
  - Commonly truss-type or ladder-type



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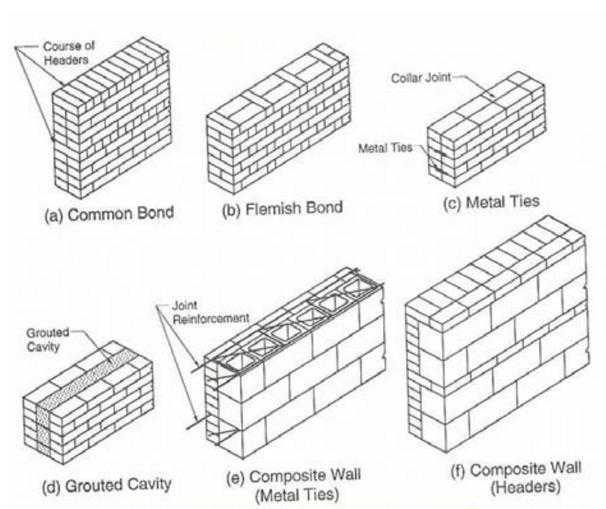
Methods of Joining Wythes to form Solid Walls



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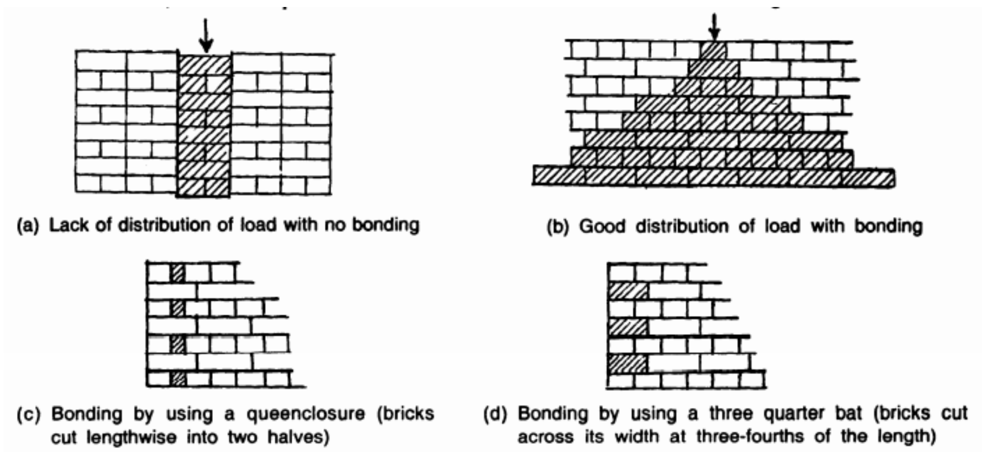
Bonding of bricks

- Bond gives strength to masonry. In brickwork, the cross joints in any course shall not be nearer than a quarter of a brick length from those in the course below it.
- Bonding helps in distribution of loads and is usually carried out with closures(in Header)or 3/4th in the stretcher course.

Types of bonding

- Stretcher bond
- Header bond
- English bond
- Flemish bond



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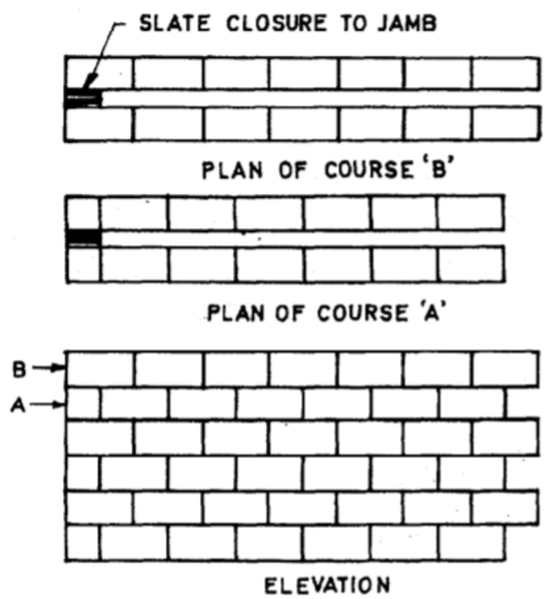
Stretcher bond

- All the bricks are laid with their length in the direction of the wall.
- Headers or 3/4th bricks are inserted wherever necessary to break up bond
- This pattern is used for walls having thickness of not more than 9 cm.



NOTE—Use of stretcher bond in cavity wall construction is illustrated here.

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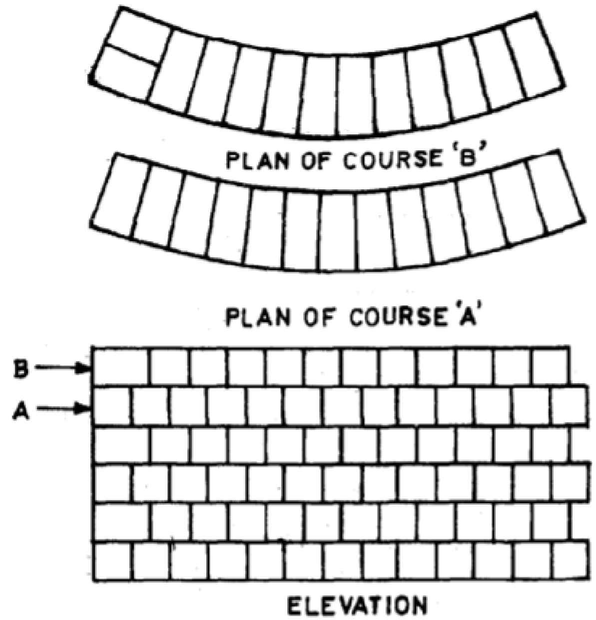
Header bond

- All bricks are laid with their ends towards the face of the wall.
- Suitable for walls, which are one brick thick.
- Also suitable for construction of curved wall and footings for better load distributions.



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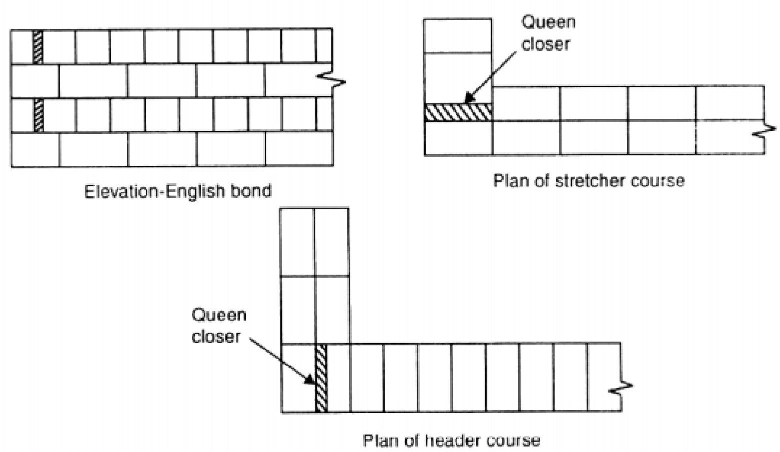
English bond

- Alternate courses of headers and stretchers are laid.
- It is necessary to place the queen closer after first header in the heading course for breaking the joints vertically.
- Great strength as fewer through joints and entails the use of max minimum number of brick bats.



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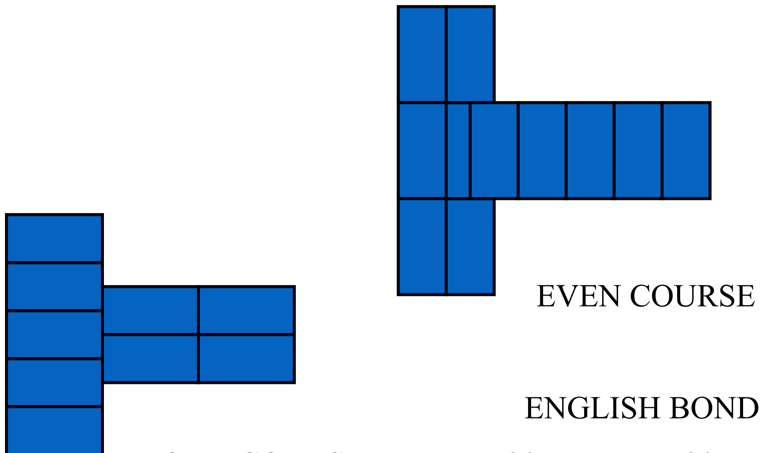
Cross walls



ENGLISH BOND

20 cm WITH 20 cm

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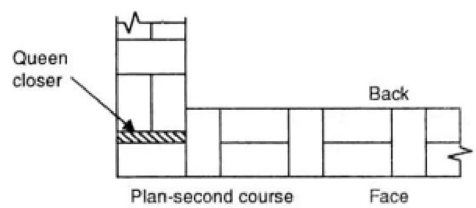
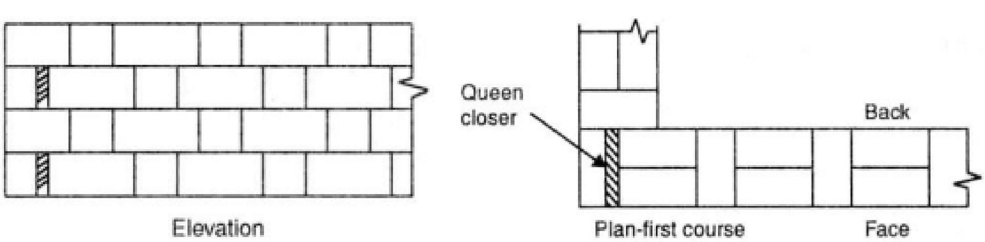
Double Flemish bond

- Alternate headers and stretchers are laid in each course. Facing and back are of the same appearance.
- Brick bats are used in case of walls having thickness equivalent to odd number of half bricks.
- Queen closer is placed next to the quoin header in alternate courses to break the joints continuity
- More economical





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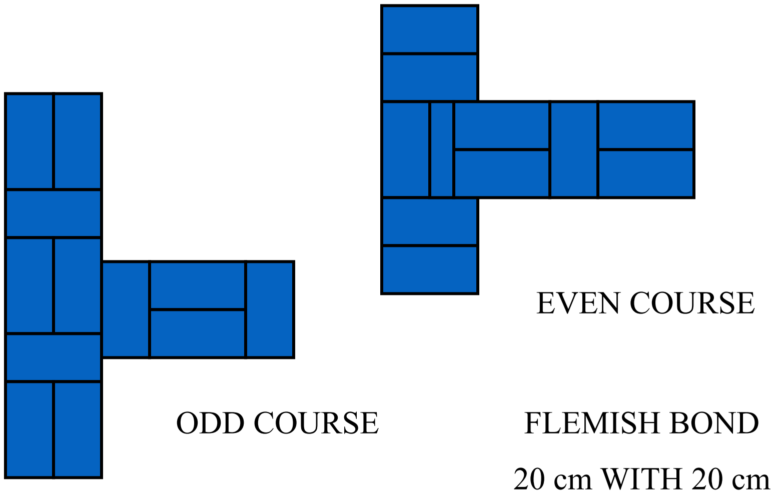
Cross walls



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English bond	Double Flemish bond
More compact and stronger for walls having thickness more than 1 ½ bricks	Less compact and stronger
No pleasing appearance of facing	Better appearance of the facing
No strict supervision and skill required for construction	Good workmanship and careful supervision is required
More costlier than double Flemish bond	Cheaper in cost because number of brick bats are used

26

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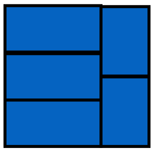
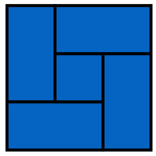
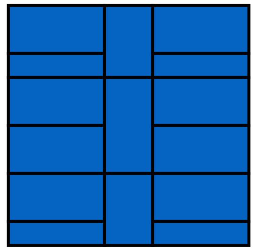
Brick Piers



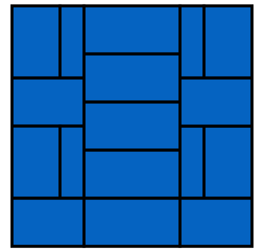
ENGLISH BOND
30 cm



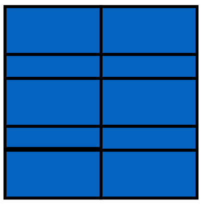
FLEMISH BOND
30 cm



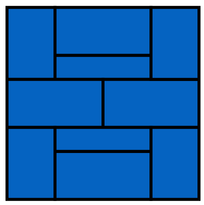
ENGLISH BOND
50 cm



FLEMISH BOND
50 cm



ENGLISH BOND
40 cm

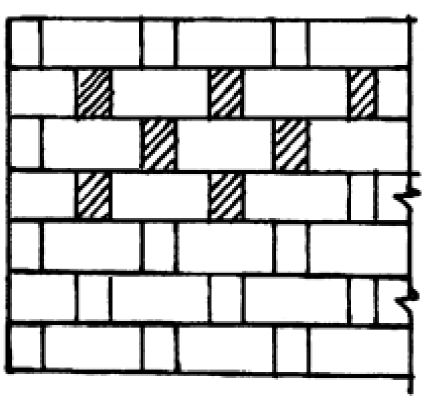


FLEMISH BOND
40 cm

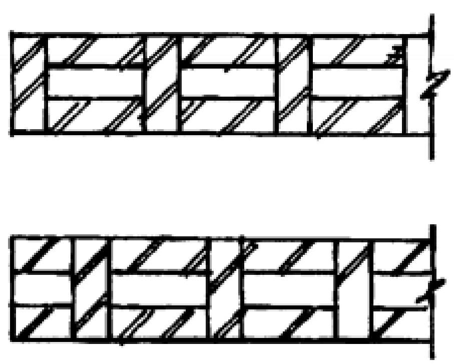
27

Rat trap bond

- Uses brick on edge courses.
- Hollow pockets or cavity reduce weight of the wall.
- Number of bricks used is less as brick are used only on edges.



(a) Elevation



(b) Plan of odd and even courses

28

Thickness of joint

a) In the case of traditional brick- Equal to four times the actual thickness of brick + 3 cm.

b) In the case of modular brick to IS 1037 : 1992 with thickness of 39 cm the maximum thickness of joint shall be 10 mm.

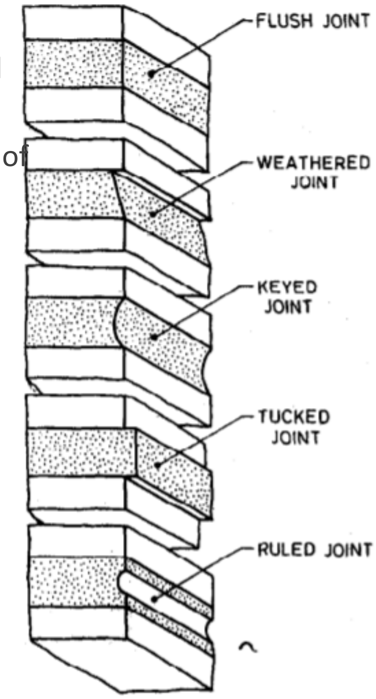
Finishing of joint

Jointing

- Either the face joints are worked out while green to give a finished surface flush or squarely raked out to a depth of 1 cm for subsequent plastering.
- Faces of the brickwork are cleaned with wire brush to remove any splashes of mortar

Pointing

- Joints are squarely be raked out to a depth of 15 mm while the mortar is green
- Joints are then tilled with mortar to give the required finish. Some finishes are 'flush', 'weathered', 'tucked', 'ruled', etc.



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Methods of laying of bricks

- **Soaking of bricks**
- Bricks are soaked in water before laying except in case with mud mortar or fat lime mortar.
- This removes any dirt along with reducing suction of water from mortar.
- They are removed from water so that at time of laying they are skin dry.
- **Brick laying operation**
- Layer of mortar spread to cover full width of wall for suitable length
- Each brick is laid with frogs down if 2cm deep or either up or down if 1cm deep.
- Inside face of brick are buttered with mortar before next brick is laid
- On completion of course, vertical joints are filled with mortar.
- Bricks at corners and perpends shall be properly keyed into position using cut bricks.

30

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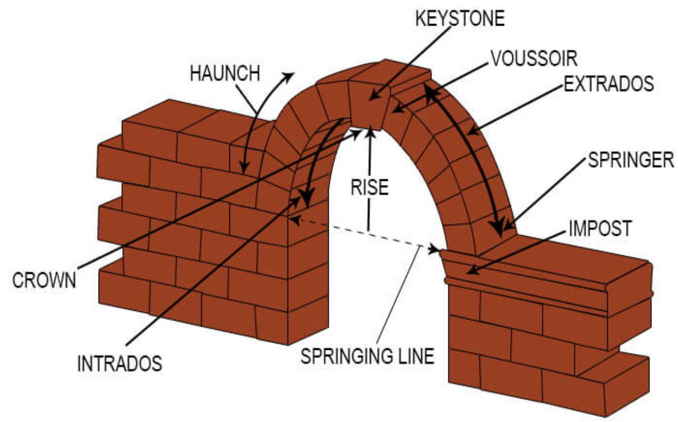
Brick Arches construction practices

- Construction is similar to wall
- In plain arches, uncut bricks are used. In gauged arches moulded bricks are used.
- Bricks forming skewbacks are dressed or cut to give proper radial bearing to the end voussoirs.
- Defects in dressing up bricks not to be covered by extra use of mortar, nor use of chips be permitted.
- Bricks of the spandrel wall at their junctions with extrados of arch cut to fit the curvature of the arch.



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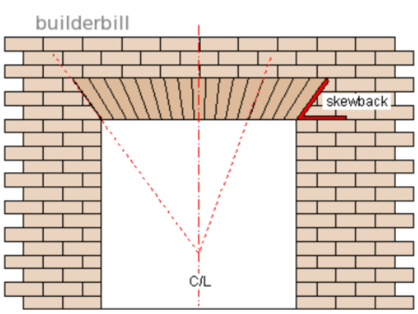
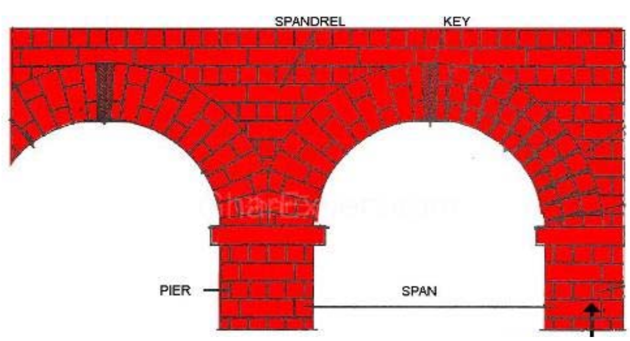
Flat Arch and Circular Arch





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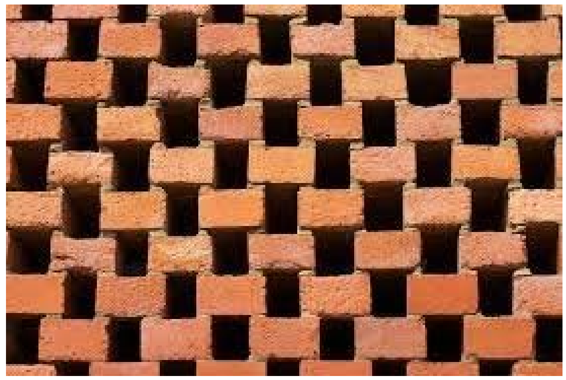
Honey Comb Brickwork

- Done with specified class of brick, laid in specified mortar with half brick thickness.
- All joints and edges are struck flush to give an even surface.
- Equal openings and alternate with half-brick laid with a bearing of 2 cm on either side.



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Brickwork in openings

- Size and spaced in walls as to reduce the cutting of bricks to minimum.
- Width of openings a multiple of width of brick.
- In the external walls, it is desirable to rebate the sills, jambs and heads of openings to restrict rainwater.
- Sill may be sloped slightly to allow the rain water to drain off.

34

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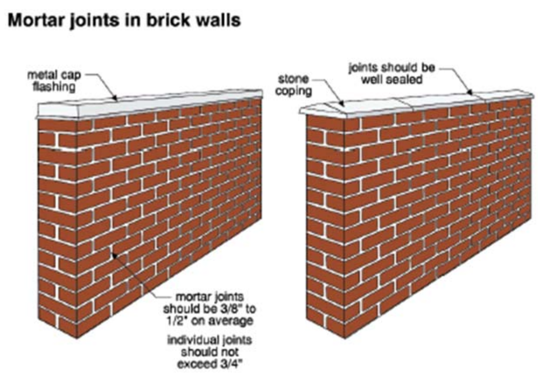
Parapets and copings

- Base thickness should cover the junction of roof slab and effectively treated against possible leakage of rainwater.
- Coping may be of stone, concrete, brick or terracotta; it is throated underside of the projection.
- The top of the coping shall be slightly sloped to allow water to drain off.



https://www.homeinspector.org/Newsroom/Articles/Brick-Veneer-vs-Solid-Masonry/15034/Article

35

35

Influence of workmanship

- Incorrect Proportioning & Mixing of mortar
- Incorrect adjustment of suction rate of bricks
- Incorrect jointing procedure
- Disturbance of units after laying
- Failure to build walls "plumb and true to line and level"
- Unfavourable curing conditions

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Incorrect Proportioning & Mixing of mortar

- Relatively weaker mortar used for functional considerations
- But use of Stronger brick & very weak mortar influences strength

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Incorrect adjustment of suction rate of bricks

- Water absorbed by bricks leaves cavities in mortar
- Results in air voids and leads to reduction in strength
- Saturated bricks lead to poor adhesion (susceptible for frost damage)
- Increase in suction rate from 2 kg/sq.m/min. to 4 kg/sq.m/min reduces strength of Loaded wall by 50%
- Important in slender walls
- Bricks of high IRA - to adjust this by wetting before laying.
- Use of high water retentivity mortar (cement lime) controls water extraction.

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Incorrect jointing procedure

Perpend or vertical joints:

- Does not affect compressive strength
- But lead to poor sound insulation and rain penetration

Bed Joints

- Influences greatly on comp strength
- Reduction in strength up to 33%

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Incorrect jointing procedure

Thickness of Joint:

- Influences greatly
- Increase from 10 mm to 16-19mm reduces comp. strength by 30%
- Same reduction in caused by deep furrowing

Spreading of mortar

- Only sufficient mortar should be spread
- Spreading too longer bed mortar will make it to become plastic before next layer of brick is placed.
- Affects strength

40

Disturbance of units after laying

- Bond between brick & mortar bricks
- Adversely affect this strength and resistance to moisture penetration
- It occurs at corners when brick layer attempts to correct plumbing by hammering

Failure to build “plumb and true to line and level”

- Reduces the capacity of wall

Test results:

2-Story wall with 20 mm off plumb 15% reduction in strength

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Unfavourable curing conditions

b. Failure to protect from weather

- Wall constructed in 78^0 F – 100^0 F and cured under sun showed reduction of 10% in strength compared to that cured under shade.
- Wall constructed and cured at (15^0 C) compared with that cured at room temperature (25^0C) is reported to result is same strength
- But undesirable deformations may occur which leads to reduction in strength

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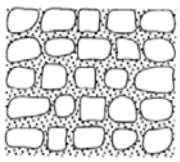
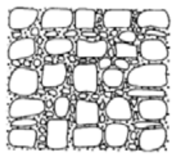
Materials for stone masonry

Materials are used for stone masonry

- Mortar
- stones

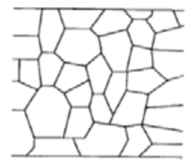


(a) Stones Placed with Soil



(b) Stones Wedged and Bedded in Clay

(c) "Squared" Units Laid Dry



(d) Polygonal Units Laid Dry

Types of stones

- The following Indian Standards on different types of stones used for stone masonry:

i. IS 1127 : 1970 for Natural building stones.
ii. IS 1128 : 1974 for Lime stone (slab and tiles).
iii. IS 33 16 : I974 for Structural granite.
iv. IS I 130 : 1969 for-Marble (blocks, slabs, tiles).
v. IS 3622 : 1977 for Sandstone (slabs and tiles).
vi. IS 12440 : 1988 for Precast concrete stone masonry blocks.
vii. IS 3620 : 1979 for Laterite stone brick.

Table 4.7 Recommended Use of Common Types of Stones
(*Clause* 4.1)

Type of Stone	Use
1. Dense stone like granite, gneiss	a) Masonry work submerged in water b) Masonry below plinth level or in contact with soil
2. Granite, quartzite	Masonry work exposed to smoke or chemical fumes
3. Sandstone	Fire resistant masonry
4. Soft stone like marble, sandstone	For carved ornamental work, arches, veneers, etc

Properties of stone

Strength

- Adequate to carry imposed loads.

Table 4.6 Crushing Strength of Stones

(*Clause* 2.1)

Type of Stone	Minimum Crushing Strength N/mm^2 (kgf/cm^2)
Granite	100 (1 000)
Basalt	40 (400)
Limestone (except very soft stone)	20 (200)
Sandstone	30 (300)
Marble	50 (500)
Laterite	3 (30)

Durability

- Free from Defects like cavities,cracks,flaws,sandholes,veins,patches of soft or loose materials etc.
- should not contain crypt0 crystalline silica or chert, mica or any other deleterious materials, like iron oxide, organic impurities, etc.

3

Size

- Size of stones used in masonry work shall be as following:

	Length mm	*Breadth* mm	*Height* mm
a) Ashlar masonry based on 3 mm joint thickness	597	297	297
	697	347	347
	797	397	397
b) Block in course based on 6 mm joint thickness	394	194	194
	494	244	244
c) Squared rubble, based on 10 mm joint thickness	Length — 90, 140 mm in increments of 50 mm Breadth — 90, 140, 290 mm in increments of 50 mm		
d) Random rubble	May be any shape and size but not less than 150 mm in any direction		

4

Preparatory work

- **Dressing of stone**
- **Scaffolding**

Single scaffolding having one set of vertical supports used and the other end of the horizontal scaffolding member rest in a hole.

Double scaffolding having two vertical supports provided for pillars less than 1 m wide or for two storey building

- **Handling**

The use of grips in the tops of stones is preferable to any method of holding the stone at the end.

Enables the stone to be set in final position before the tackle is released.

- **Wetting**

Stones sufficiently wetted before laying to prevent absorption of water from mortar.

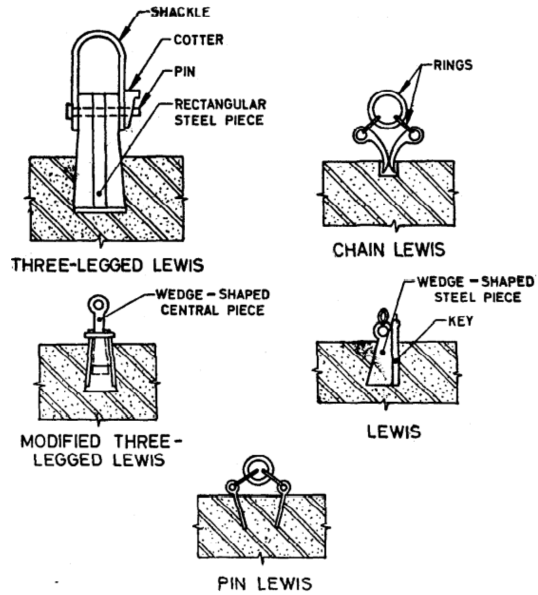


Fig: Typical details of lifting appliances of stones

5

Classification of stone masonry

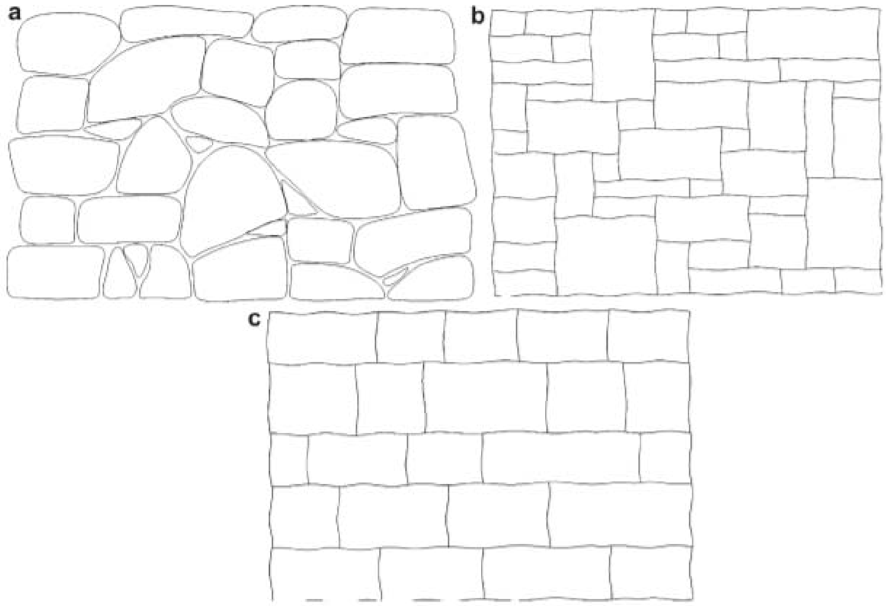


Fig: Different kinds of stone masonry a)Rubble masonry, b)Ashlar masonry, c)coursed ashlar masonry

RUBBLE MASONRY

- Stones of irregular sizes and shapes are used.
- The stones, as obtained from quarry, are taken for use in the same form or they are broken and shaped in suitable sizes by means of hammer as the work proceeds.

Random rubble masonry

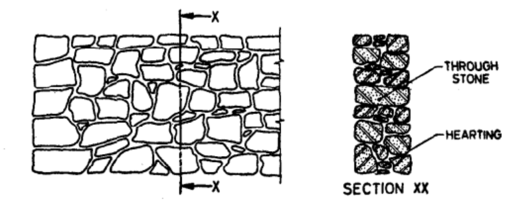


Fig: Random rubble uncoursed masonry

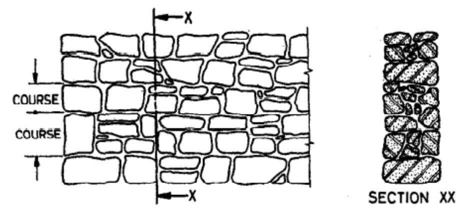


Fig:Random rubble masonry brought to courses

In **Uncoarsed random rubble masonry**, courses are not maintained regularly.
The larger stones are laid first and the spaces between them are then filled up by means of spells
Minimal cutting pf stone only to remove inconvenient corners

In **Coarsed random rubble masonry**, the masonry work is carried out in courses such that the stones in a particular course are of equal heights.

Square rubble masonry

- In this type of masonry stones having straight bed and sides are used. The stones are usually squared and brought to a hammer dressed or straight cut finish.

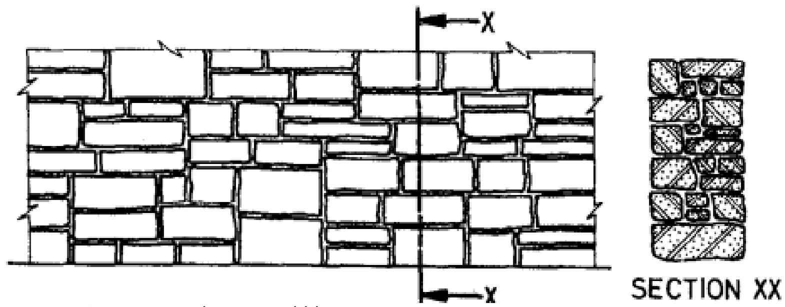


Fig: Uncoursed square rubble

Uncoursed squared rubble masonry, the different sizes of stones having straight edges and sides are arranged on face in several irregular patterns.
Stones are roughly squared as risers or jumpers and stretches with varying heights, and are laid uncoursed.

8

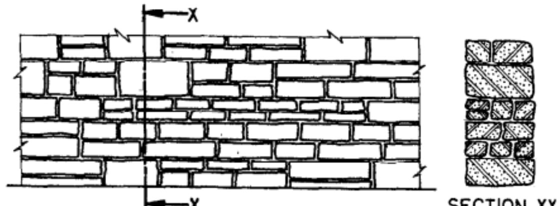


Fig: Square rubble: built to course

- In **coursed squared rubble masonry** the work is carried out in courses of varying depth(300-900 mm)

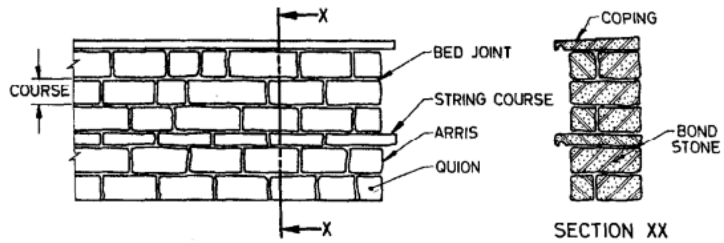


Fig: Square rubble:regular coursed

In **regular course-coursed rubble masonry** the height of stones in one particular course is same.
Coursed masonry is built in courses which may vary in height from 100 mm to 300 mm.
The faces of the stones may be pitched to give a rockface appearance or may be dressed smooth.

- **Polygonal rubble masonry**
  - ➢ Stones are hammer finished on face to an irregular polygonal shape.
  - ➢ Two types: Rough picked and close picked
- **Flint rubble masonry**
  - ➢ stones used are flints or cobbles. These are irregularly shaped modules of silica
  - ➢ The stones are extremely hard. But they are brittle and therefore they break easily.
  - ➢ The face arrangement may be either coarse or uncoarsed.
- **Dry rubble masonry**
  - ➢ Mortar is not used in the joints.
  - ➢ This type of construction is the cheapest and requires more skill in construction.
  - ➢ This may be used for non-load bearing walls such as compound wall etc.

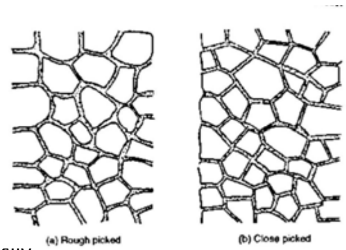


Fig: a) Polygon rubble masonry

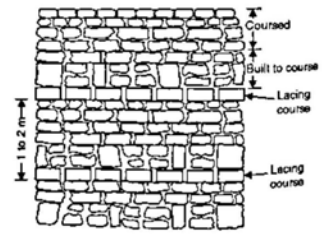


Fig: a) Flint rubble masonry

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Ashlar masonry

- Stones used in this masonry are rectangular blocks and are all dressed finely with chisel.
- No irregular stones are used. Courses are not necessarily of same height. It may vary from 25 to 30 cm.

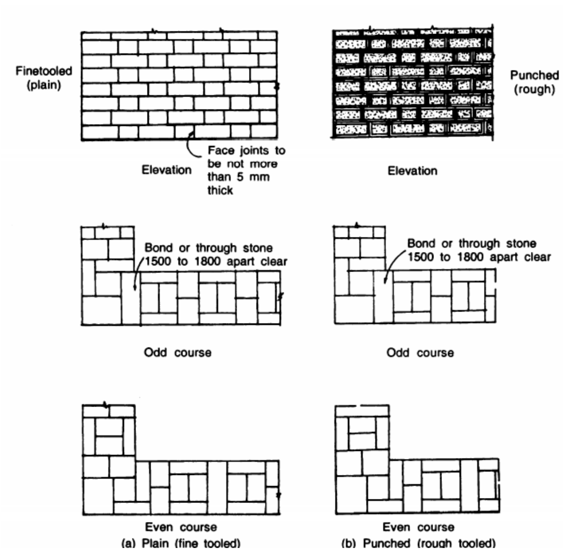


Fig: Ashlar masonry

Ashlar rough tooled masonry

The beds and sides are finely chisel-dressed. But the face is made rough by means of tools. A strip, about 25 mm wide and made by means of a chisel is provided around the perimeter of the rough dressed face of each stone.

Ashlar rock or quarry faced masonry

A strip about 25 mm wide and made by means of chisel is provided around the perimeter of every stones as in case of rough-tooled ashlar masonry. But the remaining portion of the face is left in the same form as received from quarry.

Ashlar chamfered masonry

- A strip is provided as ashlar rock masonry. But it is chamfered or beveled at an angle of 45 degrees by means of a chisel for a depth of about 25 mm.

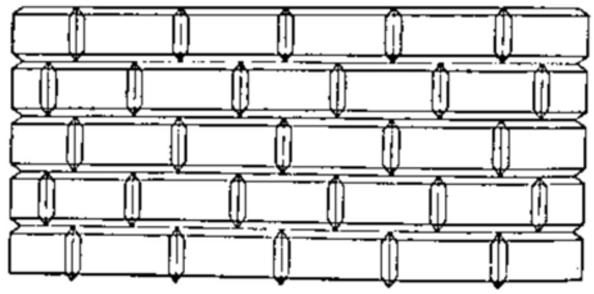


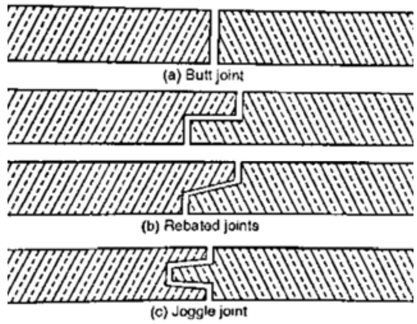
Fig: Ashlar chamfered

Ashlar block-in-coarse masonry

- This is combination of rubble masonry and Ashlar masonry.
- In this type of masonry, the face work is provided with rough tooled or hammer dressed stones and backing of the wall may made in rubble masonry.

Joints in stone masonry

- Butt joint or square joint
- Rebated joint or lapped joint
- Tongued and grooved joint or joggle joint
- Bed joint or tabl
- Cramp joint
- Plugged joint
- Dowel joint
- Rusticated joint



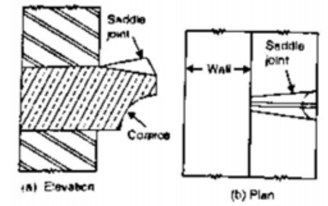


FIG. 5.42. SADDLED JOINT.

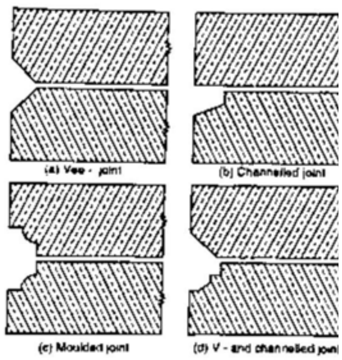


FIG. 5.41. RUSTICATED JOINTS

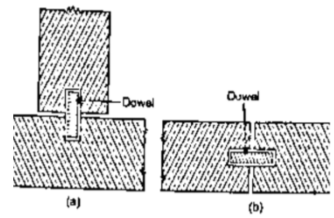


FIG. 5.40. DOWELLED JOINT.

Fig:Types of joint

Laterite stone masonry

- ➢Blocks obtained from a good laterite which hardens on exposure after it is quarried.
- ➢Stones are dressed immediately after quarrying.
- ➢Can be cut into size manually or by machine.
- ➢Exposed to nature for 3 months before using to improve compressive strength.
- ➢Blocks laid in regular horizontal courses with no continuous vertical joints
- ➢Joint thickness not more than 10mm.
- ➢Joints should be raked to a depth of 15mm for pointing while mortar is green.

https://www.article-25.org/stories/laterite

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Stone veneering

- **Lime stone & sand stone-top**

➢Bottom and sides chisel dressed so that variation at no point exceeds 5 mm.

➢Back dressing not done for better grip

- **Marble slabs**

➢Cut into required size and shape and chisel dressed to remove waviness

➢Slabs anchored to backing using cramps.

➢Facings: provide with a continuous support in the form of projection or recess in floor slab.

➢Backing: carry out simultaneously with face work in concrete backing

➢Joints should be of mortar specified and thickness not more than 3mm.

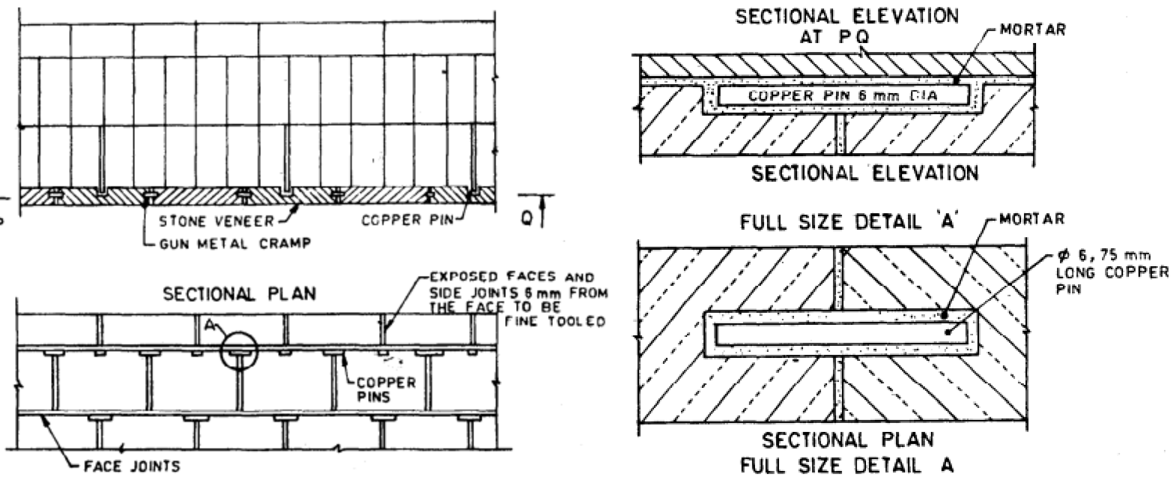


Fig: Typical details of fixing stone veneer work facing using gun metal cramps and copper pins

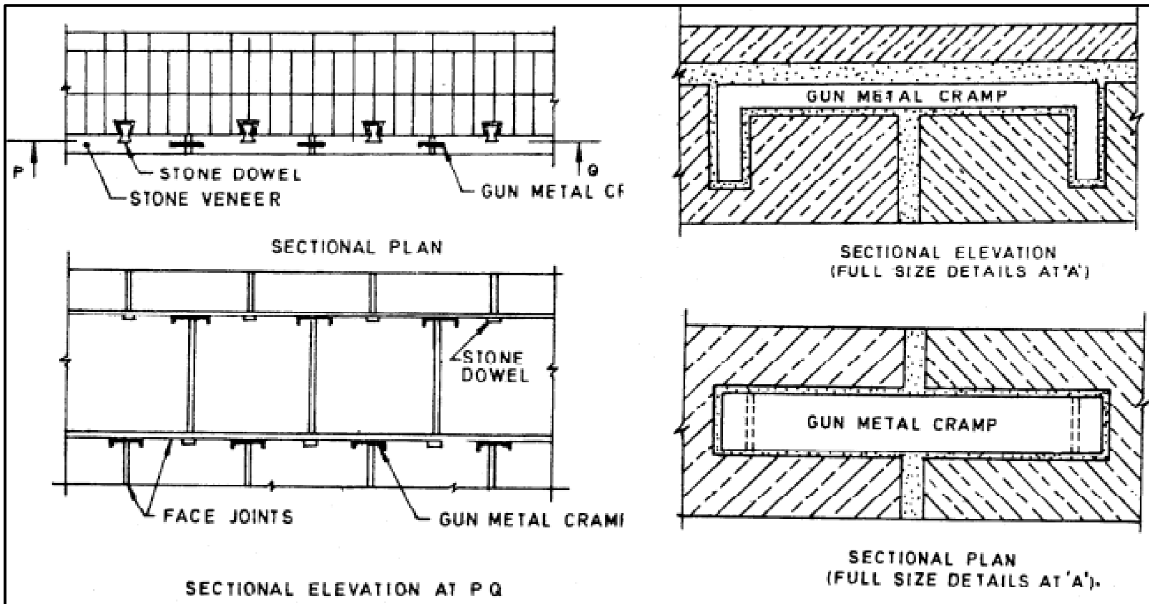


Fig: Typical details of fixing stone veneer work using stone dowels and gun metal cramps

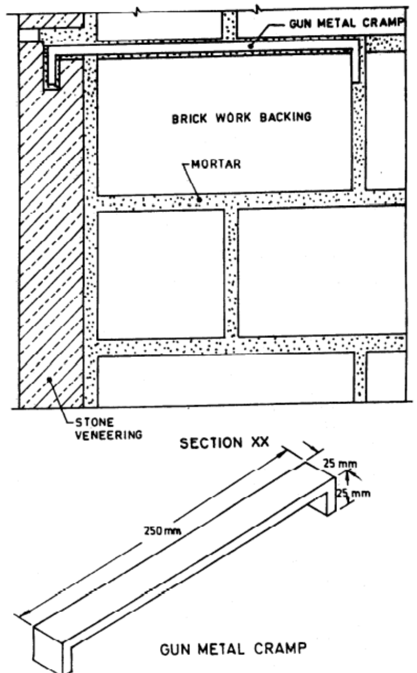


Fig: Typical details of fixing stone facing showing use of gun metal cramps

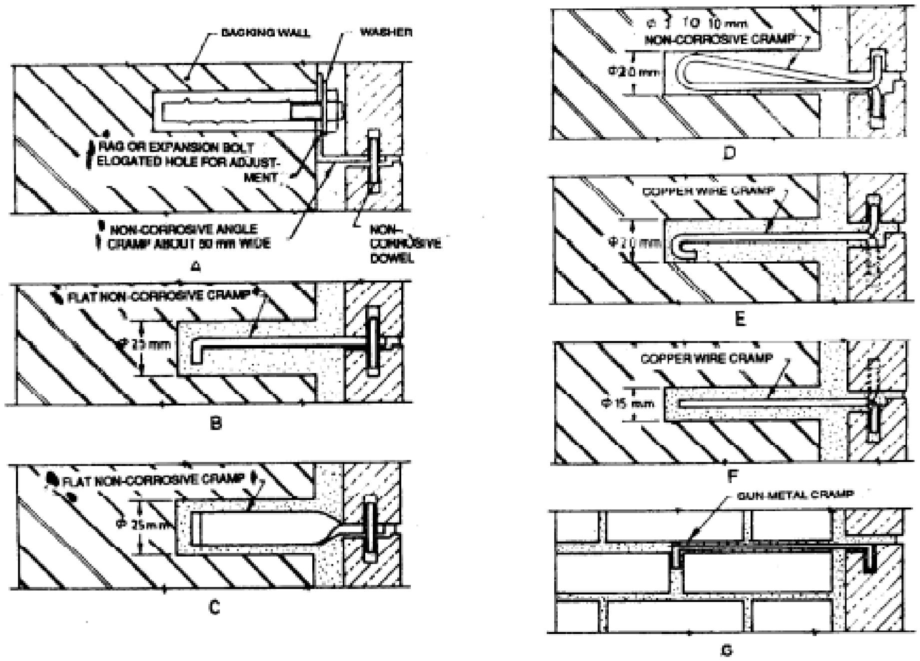


Fig: Types of cramps for stone facings

Construction of Vertical elements
Concrete column and walls

1

Vertical elements in buildings

WALLS

- Structural/non-structural element - a surface defining an area
- Transmits load through compression if it is a structural element
- Provides privacy and partition
- Walls forms the enclosure of a structure

COLUMNS

- Structural element that transmits the weight of building to other structural elements below through compression
- Compression member

2

Concrete Mixes

- Prescribed mixes
- Designed concrete mixes
- In-Situ concrete
- Ready mix concrete
- Different types of concrete(Ex: High strength, High Performance, Self compacting)

3

Based on Density

1. Heavy concrete (over 2500 kg/m^3)
2. Normal concrete (1800-2500 kg/m^3)
3. Light weight concrete (500–1800 kg/m^3)
4. Extra light weight concrete (below 500 kg/m^3)

4

4

Based on place of casting

- In-situ concrete - When concrete is made and placed in position at the site it is known as in-situ concrete
- Precast concrete - When used as a material for making prefabricated units in a factory is known as precast concrete.


Cast in-situ concrete retaining wall


Precast concrete retaining wall

5

5

Types of concrete walls

Walls below ground

- Foundations or Basement walls

Walls above ground

- Plain concrete walls
- Reinforced concrete walls
- Partition walls

6

BASEMENT WALLS (OR) RETAINING WALLS

- Supports vertical load from the walls above + lateral pressure of earth
- Only lateral earth pressure – columns may rest on the footing directly

7

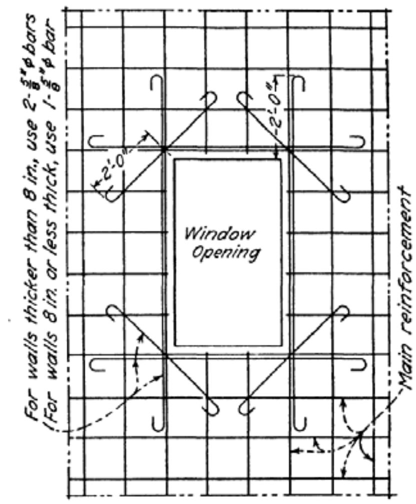
Plain and reinforced concrete wall above ground

- Steel reinforcement
  - to avoid cracks due to settlement and
  - temperature changes (at corners and around openings)
- Vertical and Horizontal reinforcement
- Provide a band of one or two horizontal bars above openings
- Hollow walls can be constructed

8

RCC wall above ground

- Widely used for panel walls, bearing and non-bearing walls
- Steel rebars shall be placed at 200 to 300 mm apart
- Additional rebars at corners and around openings should be provided
- Piers bet. openings to be provided with ties perpendicular to face of wall
- Used for high-rise building construction



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Partition walls

- Concrete is not extensively used in constructing partitions
- When used, the minimum thickness should be of at least 75 mm
- Walls should be reinforced with light steel rods or wire fabric
- Reinforcement shall be provided both horizontally and vertically

10

Formwork for vertical elements: walls and columns

11

11

Wall formwork

Hand-set forms

Ganged forms

Large panel forms

Large custom-made forms

12

Handset forms

- Small panel modular forms
- Sheathing connected to permanent frames
- Connected through holes, screws, and wedges
- Provision for mounting working platforms & insertion of wall ties

Image source: KITSEN Formwork

13

Ganged forms

- Modular (or) hand set forms ganged together to form one rigid larger size panel
- Used as crane lifted industrial forms
- Panels are connected using screws, clamps, or other means
- Common ganged forms use high quality, coated plywood sheathing, which ensures great number of reuses

Modular elements lifted as larger ganged units

Formwork ready for concrete placement

Image source: Peurifoy et al. (2018)

14

Large panel forms

- All-steel forms, prefabricated as large units, whose parts are welded together
- Crane lifted forms integrated with work platforms, guardrails, ladders, and screw ties
- One large element is one floor (3 to 3.5 m) high and up to 6 m long
- Built to withstand any pressure

Image source: Peurifoy et al. (2018)

15

Large custom-made forms

Image source: Peurifoy et al. (2018)

- Large forms composed of standard elements tailored to fit the specific needs
- Built on-site
- Sheathing made of plywood
- Edges not protected by frames
- Aluminium joists and wales, or timber studs with steel wales and strong backs

16

Specialised core wall form

- Walls of elevator shafts, stairwells, etc.
- Special difficulties in the inner form while removal
- Inner form should shrink to allow the formwork for removal - in core wall it is somehow difficult
- Types of core forms can be restricted by the presence of mast (crane or boom mast)

Image source: Horizon formwork Co., Ltd.

17

Specialised wall forms

SINGLE-SIDED WALLS

- Walls concreted against excavation slopes, pier walls, or existing permanent structure
- Only one side of the concrete wall is formed
- Regular wall ties cannot be used
- Use diagonal braces anchored to the ground
- Use wall ties in case of thickening of existing walls

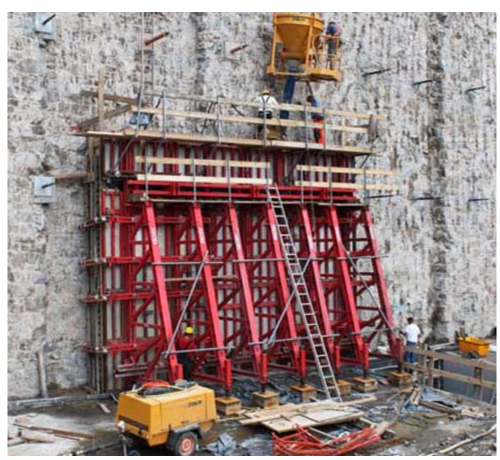


Image source: Novatec Formwork Systems

18

Specialised Wall forms

SELF CLIMBING FORMS

- Automatically raise from one floor to another without the help of cranes
- Savings in crane time & fast progressing rate
- Functions in high winds
- Retracts from the hardened concrete wall of current level and climbs to the next level
- Virtually a *'vertical plant'*

Image source: Peninsula Salsette 27 Project, L&T - Mumbai

19

Specialised wall forms

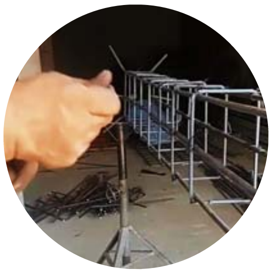
VERTICAL SLIPFORM

- Silos, chimneys, bridge piers, and core of high rise buildings
- Monolithic concreting – water-sealed concrete
- Forms raised continuously without retracting the forms
- Uses hydraulic jacks and yokes for lifting
- 6 to 10 in. layers for each slipping
- Slipping rate: 6-12 in./hr

Image source: Ferrovial

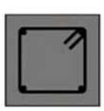
20

Sequence of Construction of Columns

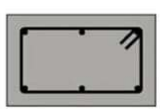
STEP 1	STEP 2	STEP 3	STEP 4
			
REINFORCEMENT →	SHUTTERING →	CONCRETING →	CURING

21

Colum sections – reinforcement

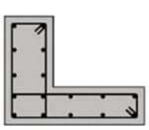


Square- Section

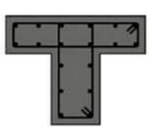


Rectangular- Section

Circular- Section



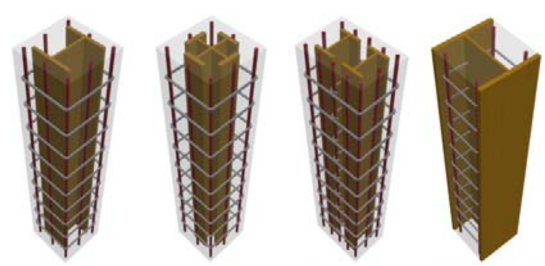
L- Section



T- Section

+ Section

COMPOSITE COLUMNS



H-shape | Cruciform | Twin-section | Partially-encased

22

Column forms

- Difficult to industrialize -wide variations in column geometry
- Slabs & walls - large flat surface area - use of modular forms is viable
- Mostly conventional forms - industrialized forms initial costs more- Life cycle cost - lower
- Important driving factor for industrialization - repetitiveness (in high-rise buildings)
- High contact area to volume ratio than slabs and walls
- Mostly fabricated (site-made configurations) than industrialized (standard) forms are used

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Column forms

Image source: https://tmsformwork.com

Image source: https://ulmaconstruction.com

24

Standard column forms

- Derivatives of wall forming systems
- Offer provisions for various size options, clamps, external ties, couplers, ladders, safety cages, concreting platforms
- Two configurations:
  - Four panels overlapped to achieve required size; Panels are bolted, no clamps are used; Maximum pressure of 80 – 120 kN/m^2
  - Sheathing and stud panels with adjustable steel or aluminium clamping wales; Sheathing is plywood & studs are steel, aluminium, or timber; Maximum pressure of 100 kN/m^2
- Standard circular columns are made of steel, or aluminium with quick latching mechanism; Maximum pressure of 150 kN/m^2

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Standard Column forms

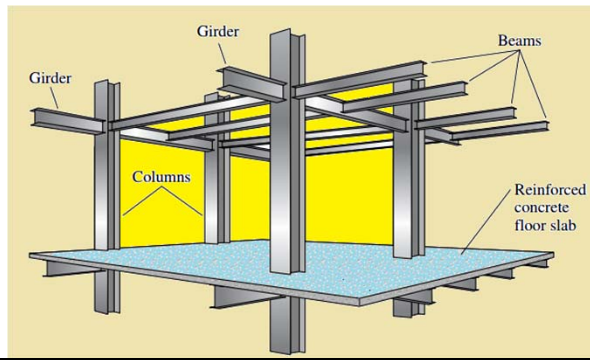
Image source: ForPro, Shanghai

Image source: Indian scaffold and formwork

26

Steel Columns/frames

- Main vertical element – Steel column
- Columns connected to the foundation with base plate
- Columns are welded directly or bolted using cleat angle
- Common column section: ISMB and ISMC section
- Less frequently: ISA section and Built-up section



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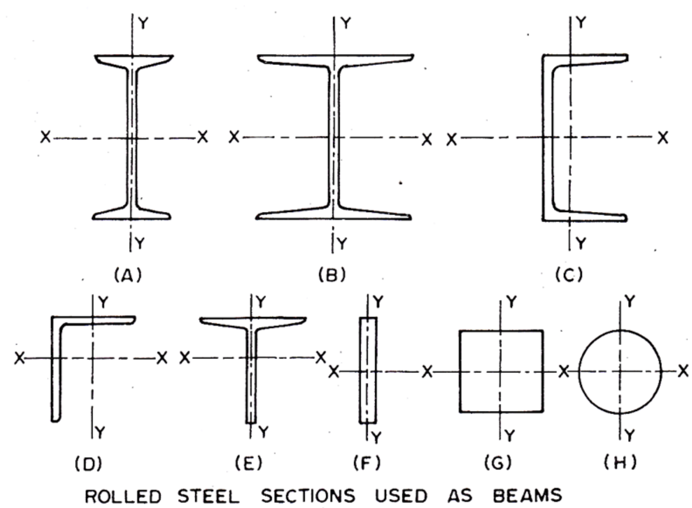
Common Rolled steel sections



(A)- Standard beam section
(B)- Wide flange beam section
(C)- Standard channel section
(D)- Standard angle section
(E)- Tee section
(F)- Steel flats
(G)- Square bars
(H)- Circular bars

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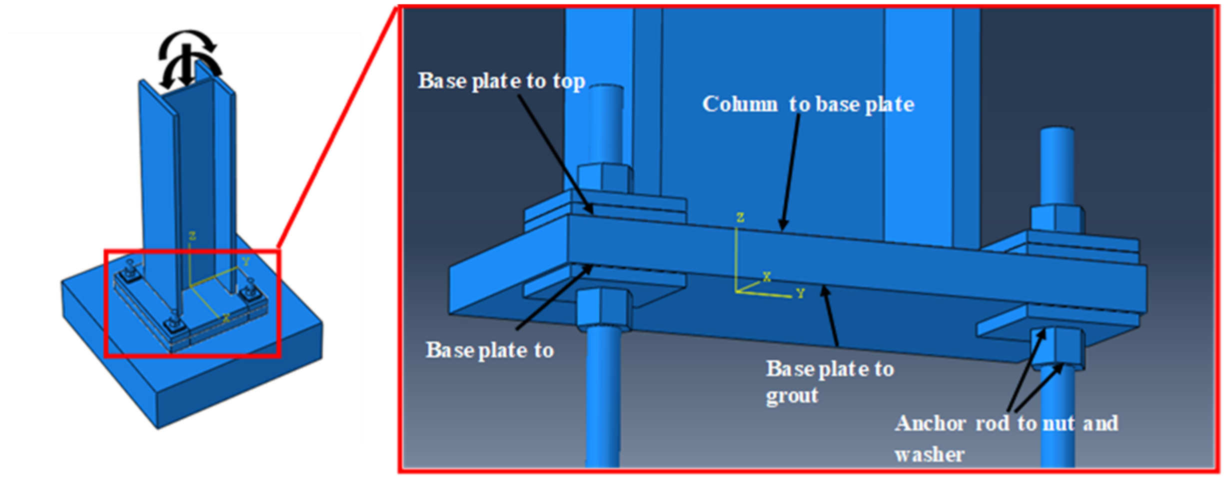
Column Base connection



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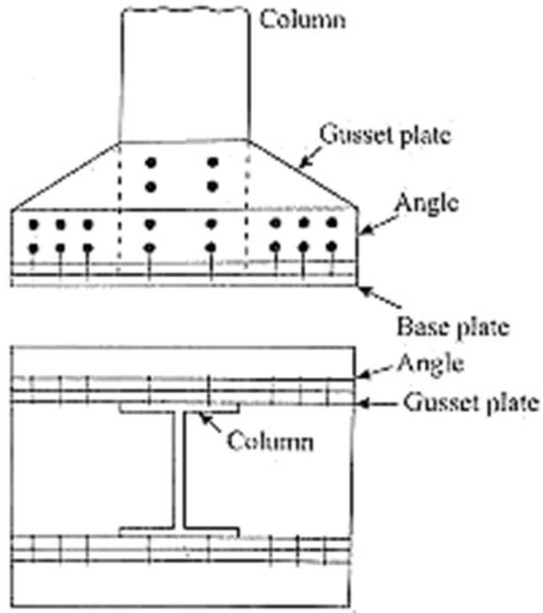
Column base connection

COLUMN WELDED DIRECTLY

COLUMN WITH CLEAT ANGLE

30

Column with gusted base



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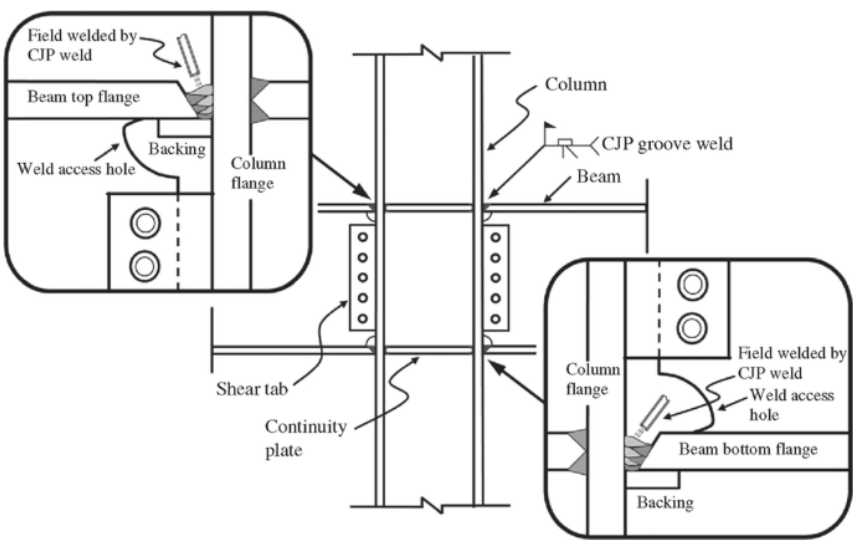
Beam-column Connection/Junction



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Scaffolding for construction of vertical elements

33

Scaffolding

- Supporting platform for people (labor, supervisor, mason, fitter, painter, carpenter)
- A fixed/movable platform which can be used for working at heights.
- Used for activities such as plastering, painting, brick work at heights etc.

34

Scaffolding

- Temporary structure- gaining access to higher levels of construction of permanent structures
- Required at all stages of construction as it is convenient, versatile, and economical
- Without scaffolding platform- work cannot be done conveniently and easily carried out either from the ground level or any other floor of the building or using a ladder.
- Scaffoldings are also used for
  - centering for the formwork, and
  - for supporting heavy loads at great heights.

35

Classification of Scaffolds

- Timber scaffolds
  - Single pole
  - Double pole
- Metal Scaffolds
  - Heavy duty
  - Medium duty
  - Light duty

36

Timber Scaffold

- Timber is used for a long time- Common type: Bamboo scaffold.
- Used in residential & tall multi-story building, dams & barrages of considerable heights,
- Safety: to be neatly erected properly braced and well tied to the buildings-
- if not done carefully- safety for workers is questionable - will be in a constant fear for safety.
- Bamboo scaffolds are constructed by tying them with coir rope.
- Long exposure to weather- bamboo gets distorted- coir ropes also get deteriorated- joints no longer remain firm- scaffold goes out of plumb.
- Such scaffolds are still used with scant regard to safety of working platforms, guard rails

37

Bamboo Scaffold

38

Types of Timber Scaffold

- Single pole type: single row of the upright poles is fixed close to the building or wall and connected horizontally by ledgers along with the length connected to the buildings or walls by means of cross timbers known as 'Putlogs'.
- Bamboo Scaffolds: coir ropes used

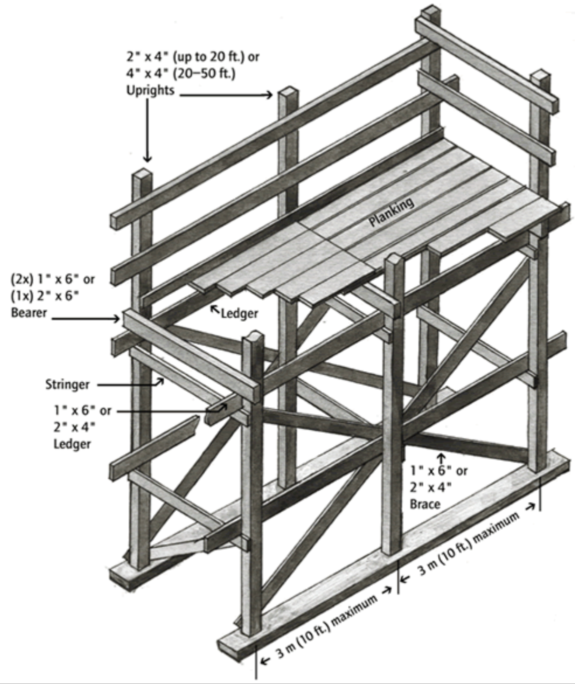
39

Types of Timber Scaffold

- Double pole scaffolds: 'Independent scaffolds'- 2 rows of uprights kept about 1 to 1.5 m apart across the building and at suitable intervals along the length.
- Two rows of uprights are connected by cross timbers viz. putlogs or transoms and longitudinally by ledgers.
- Suitable diagonal bracings are provided
- Scaffolds built with sawn timber sections: Joints use bolted/ nailed connections.

40

Double pole scaffolds



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Metal Scaffolds

Need:

- Increase in building construction activity, tall structures
- To enhance safety- use of more dependable and durable scaffolds

Classification based on Usage:

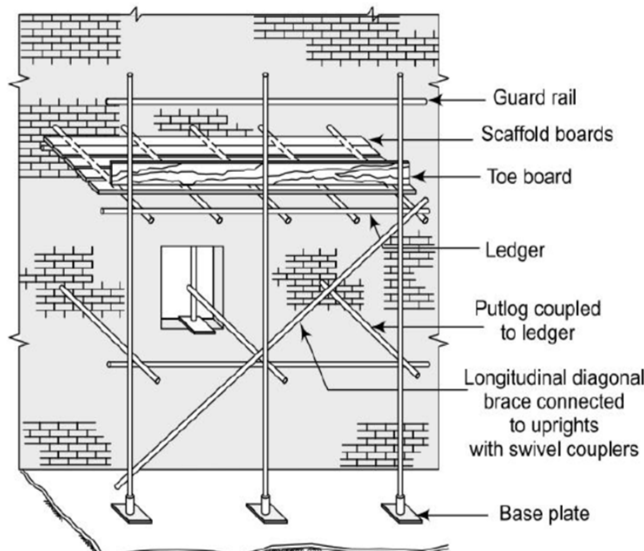
Type of scaffolding	Usage/Application
Heavy Duty Scaffolding	Used by brick layers and masons and in concreting operations and for facade cladding work and demolition work
Medium Duty Scaffolding	Used by carpenters, plasters, glaziers, sign board erectors, clearers, welders and electricians, etc.
Light Duty Scaffolding	used by electricians, painters, window cleaners, etc.

42

Metal Scaffolds: Classification based on Type of Construction

Putlog scaffolds or single pole scaffolds:

- Consist of single row of uprights connected by ledgers.
- Putlogs are fixed to the ledgers &built into the wall of the building as construction progresses.
- Consists of a base plate, ledger, uprights, double coupler for coupling the ledger to the uprights, putlog, putlog coupler, horizontal tie member, longitudinal diagonal brace, toe board & guard rail

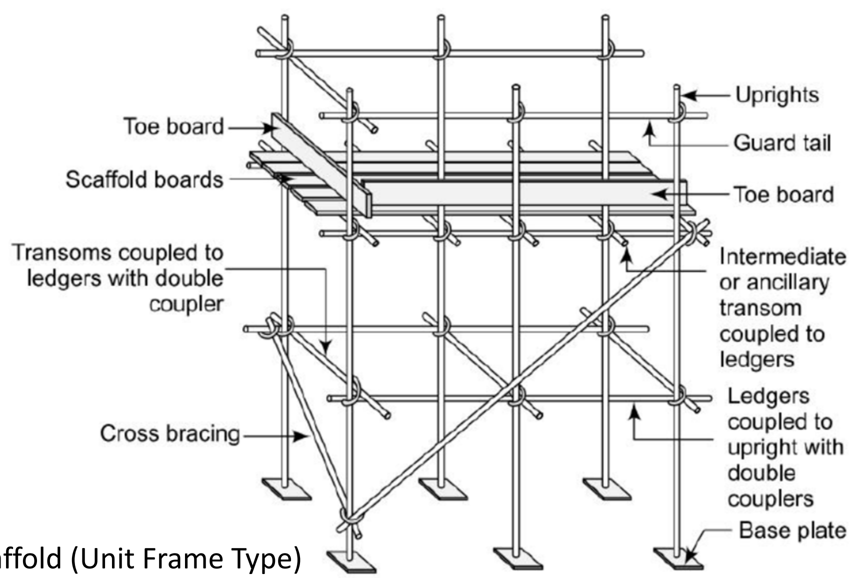


Putlog Scaffold (Unit Frame Type)

43

Independent scaffolds or double pole scaffolds

- Consists of two rows of uprights connected longitudinally by ledgers and transversely putlogs or transoms.

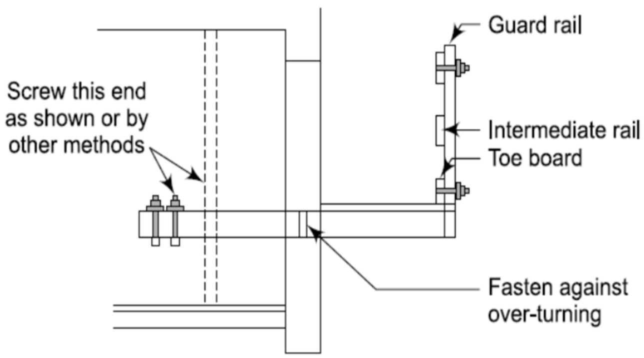


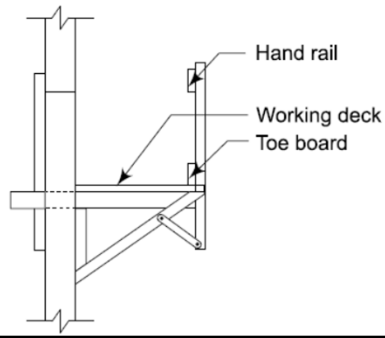
Independent scaffold (Unit Frame Type)

44

Outrigger (Cantilever) scaffolding

- Independent type of scaffolding which does not rest on the ground but is cantilevered from the face of the buildings or structures





45

Types of scaffolds

Platform scaffolds: usually a working platform is placed on top of the scaffold.
Used for supporting heavy loads at the top level & for providing an access platform at one level

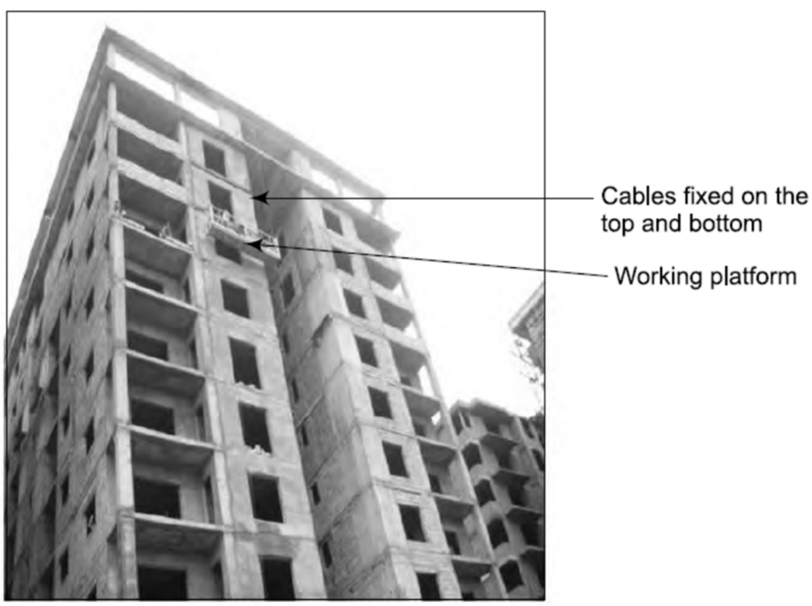
Tower scaffolding: Consists of uprights connected by ledgers and transoms. Can be made mobile also

46

Suspended Scaffold or cradles

- Independent scaffold which is hung from a building or structure and not supported on the ground.
- Used for cleaning glass at malls usually

47



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Proprietary Scaffolds: L&T light Duty Scaffolds

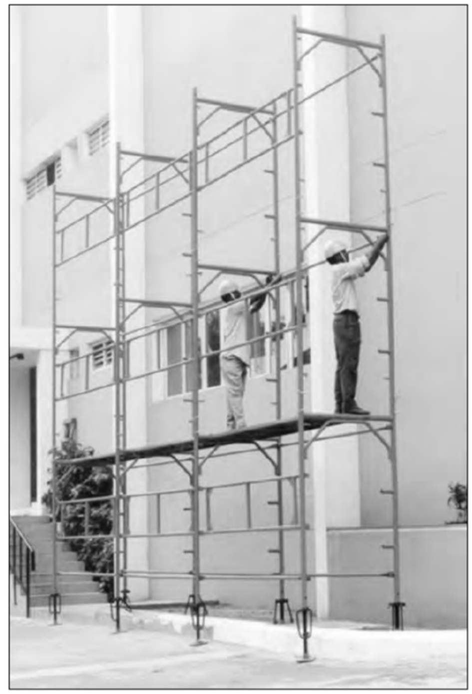
Consists of 1.8 m high welded frames braced with horizontal bracings.

Bracings also serve as handrails.

Safe erection height up to 40 m.

Couplers & pins are used to connect two frames which are kept one over the other to attain the desired height.

Minor adjustments in heights is by tower spindles which are provided in the bottom most frames



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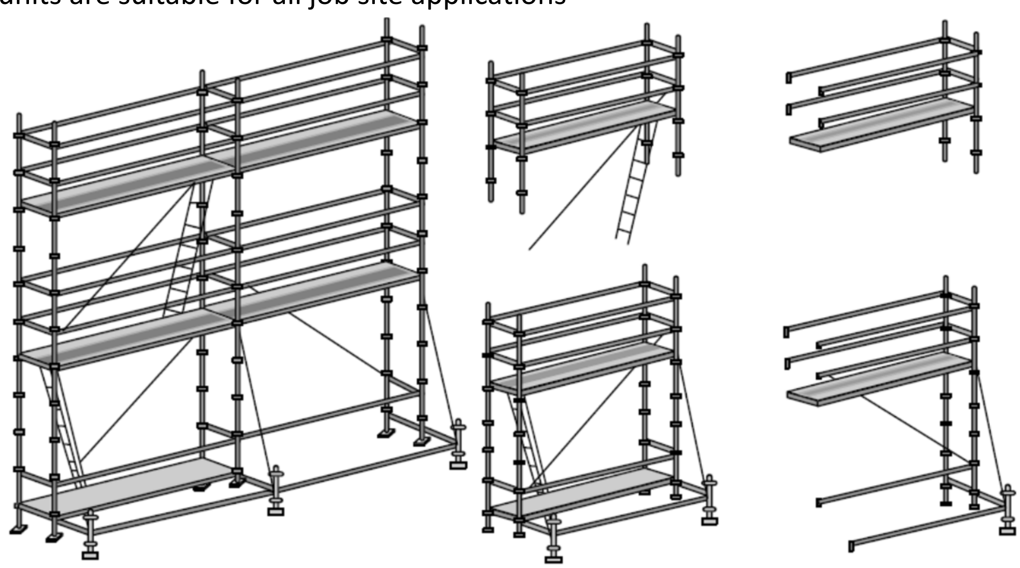
Proprietary Scaffolds: PERI Scaffold

Used for reinforcement work, closing the formwork, setting the form ties, concreting works, etc. Scaffold units are suitable for all job site applications



50

Horizontal Floor/Roof and sloping Roof

Floor/roof/ceiling

1

Floors: Burnt clay brick flooring: IS 5766

- Usefulness: wearing quality and facility for quick installation
- Common burnt clay bricks: (IS 1077) Low-cost temporary sheds, courtyards, footpaths, etc.
- Heavy duty bricks (IS2180 & IS3583) for locations of floors subject to heavy wear and tear (stores, godowns and platforms.
- Bricks laid on edge give better performance than when laid flat.

2

Burnt clay brick flooring: Preparatory work: Base concrete

- Base concrete : Heavy duty floors- essential
  : Light duty floors- Optional
- Recommended: Lime concrete with brick or stone aggregates
  : Lean cement concrete mix 1:5:10 also be used.
- Thickness : Heavy duty floors-150 mm
  Light duty floors - 75 mm
- Sand layer: 75 mm thick- under base concrete to prevent subsidence
- Lime concrete sub-grade: allowed to set for 7 days
- Lean cement concrete: Commence flooring within 48 h; if not – roughen surface with steel wire brush- sprinkle water- smear with a coat of cement slurry to get good bond between sub-grade and flooring

3

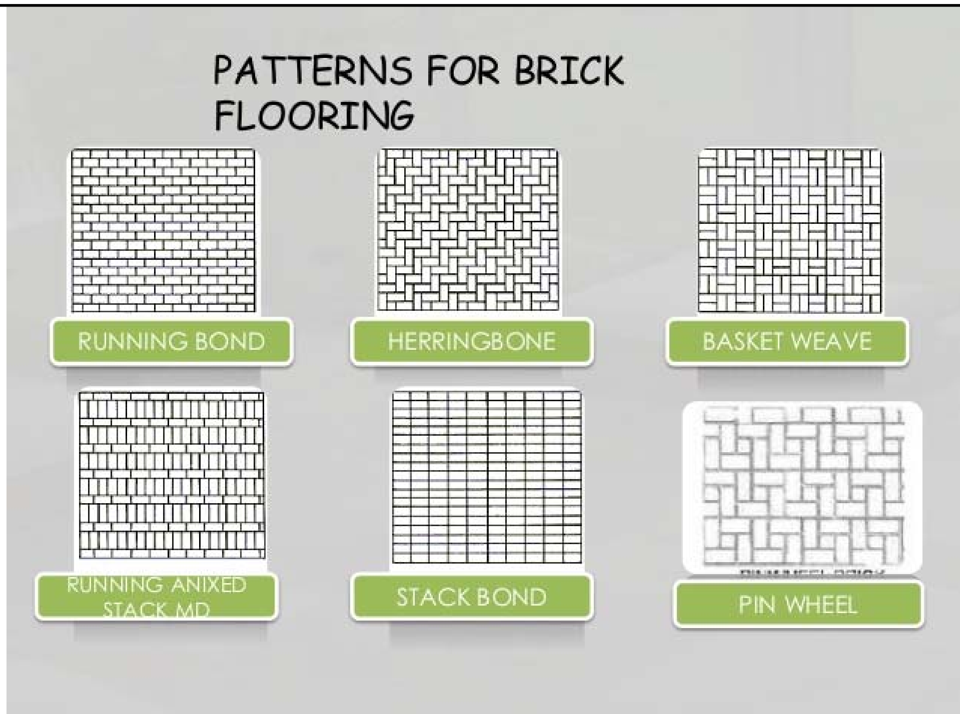
Burnt clay brick flooring: Preparatory work: bedding

- Proper drainage: Provide slope for sub-grade –for proper drainage of floor

  If no sub-grade: Give slope to earth below-water, ram & compact-moisten before laying the floor
- Bedding mortar: Before final set of concrete subgrade- spread ~10 mm mortar layer
- Mortar mix: Heavy duty floors- 1:4 (C:S) or 1: 1:6 (C:L:S)
  Light duty floors - 1:6 (C:S)) or 1:2:9 (C:L:S)

Laying of Bricks
- Bricks to be soaked before laying to reduce suction- Use in SSD condition
- Methods of laying: Plain, diagonal, herring bone, or other suitable pattern
- Laid flat or on edge- laying on edge is preferred
- Bricks shall be laid on the mortar bed by gentle tapping.

4



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Pale bricks laid in a two-brick basket weave pattern

Herringbone flooring pattern creates an illusion of space

6

Dry Brick Paving

- Lay Bricks
  - dry without soaking in water
  - Flat or on edge on 12 mm thick mud mortar
  - To required slope on the sub-grade.
- Mud Mortar- made of soil free from vegetable roots, gravel, and coarse sand; Plasticity index - 9 to 12 %
- Fill joints with fine sand after laying

7

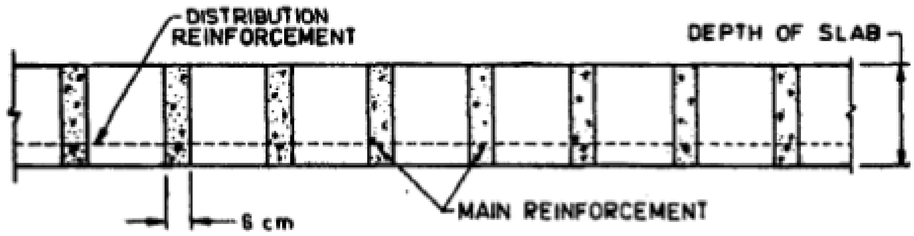
REINFORCED BRICK AND BRICK CONCRETE FLOORS

- Adopted in some parts of India.
- Laying high strength bricks over the formwork with reinforcements between joints & filling joints with concrete.
- Advantage: Construction is strong, durable - facilitates quick construction.
- Limitation: Protection reinforcement deteriorates due to corrosion, unless otherwise protected.

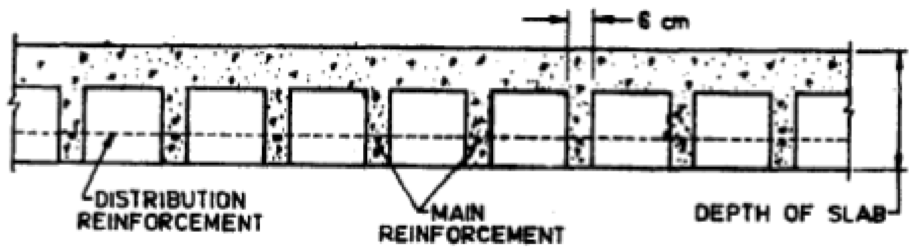
Preparatory Work: Brick

- Immerse bricks in water for 4 to 6 h
- Remove 15-20 min before they are used
- Ensures SSD condition when concrete is poured.

8



•9.1A Cross Section of RB Slab



9.1B Cross Section of RBC Slab

9

RB and BC floors: Preparatory work: Reinforcement

- Reinforcement should not touch bricks- Min cover: 25 mm all-round the reinforcement.

Details of corrosion protection:

a) Quality of concrete mix > M 15

b) Cover to reinforcement: (IS 456-1978-to severe exposure condition)

c) Protective coatings:

i. *Cement-sand-asphalt coal-tar pitch mixture coating*- Dry mixture of cement, molten asphalt or coal-tar pitch and dry sand in the ratio of 1: I:3 by mass should be applied on the steel surface to a thickness of 6 mm and surface should be finished by flaming.

ii. *Cement-sand-mortar with neat cement finish* - 1:3 cement mortar to a thickness of 6 mm shall be applied. The surface should be finished with a neat cement slurry finish with a 2: 1 w/c ratio.

iii. Empty resin/ mortar rendering may also be applied in existing structures.

iv. Steel reinforcement may be coated with cement slurry to inhibit corrosion.

d) Reinforcement- free from rust; remove heavy rust by brushing or by de-rusting jellies.

10

Construction of RB and RBC Roof or Floor

a) Centering

- Erect to support RB floor or roof from below- Smooth, clean and to correct alignment
- Top of formwork- allow for initial settlement- provide 1: 150 camber (max 30mm)
- Check formwork and supports to prevent undue sag and to ensure overall safety and stability.

b) Reinforcement

- Place main & distribution bars (Fig) - fully embedded in concrete.
- Secure against any displacement
- In either direction shall not be less than 0.20 % of c/s slab for MS & 0.16 % for deformed bars
- Ensure proper cover to reinforcement.
- pitch of the distribution bars- not more than 5 times the effective depth or 450 mm whichever is smaller.

11

12

Construction of RB and RBC Roof or Floor

c) Lay bricks with cement mortar 1:3

d) Maintain a min. spacing of 60 mm in between bricks for preventing corrosion.

i) Single brick thick floor/roof:

- Lay bricks on the formwork directly without bedding
- After laying 1 or 2 bricks - next row is similarly laid providing gap for concrete joint.
- Pour concrete into the joints after placement of reinforcement.
- Concrete to be fluid enough to run freely around reinforcing bars and fill joints completely

ii) Slab of 2 courses brick:

- Place a fresh layer of concrete over 1st layer to make the middle horizontal joints
- Lay top course in the same manner as 1st layer

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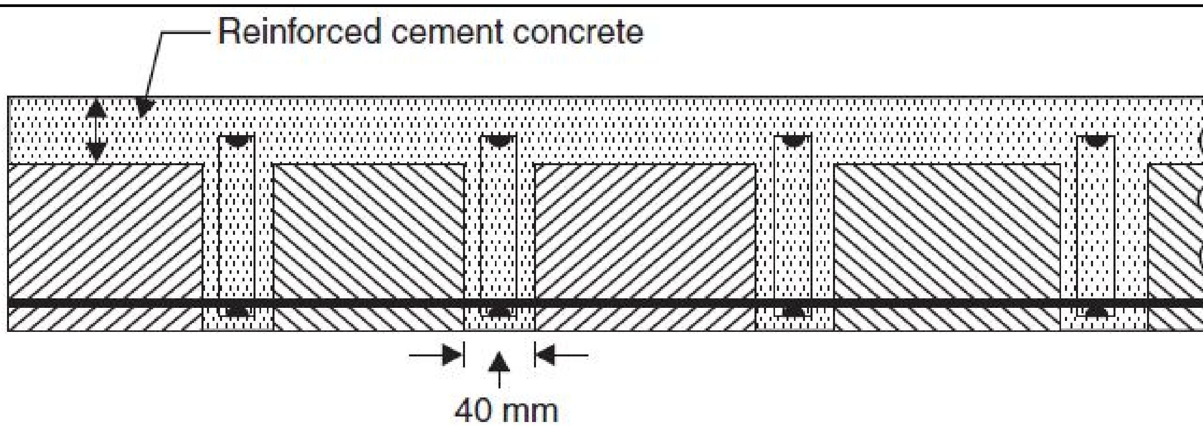


Fig. 8.10. Reinforced brick slab

14

Construction of RB and RBC Roof or Floor

e) Curing

- Keep brickwork wet for about 24 h after finishing:
    - Wet straw or
    - Wet sand or
    - Sprinkling water gently over the surface
- Continuous watering to be done for min. 10 days for Slab

f) Removal of Formwork: min. 14 days

g) Finishing

- Floor or roof: Waterproofing with Lime concrete finish required
- Floor/roof - cure with water for > 3 weeks
- Ceiling: rendered/plastered; C:S mortar (1:3) or L:Smortar (1:2) – Thickness-12 mm

15

Slab on grade: Slab cast on the surface of the earth-Ground slab.

Slab on ground

- Simplest type - composite of stiffening beams constructed around perimeter of the slab
- Thickness-100 mm
- Suitable for stable ground which is mostly composed of sand and rock and not influenced by moisture, and soils that undergo slight movement due to moisture.

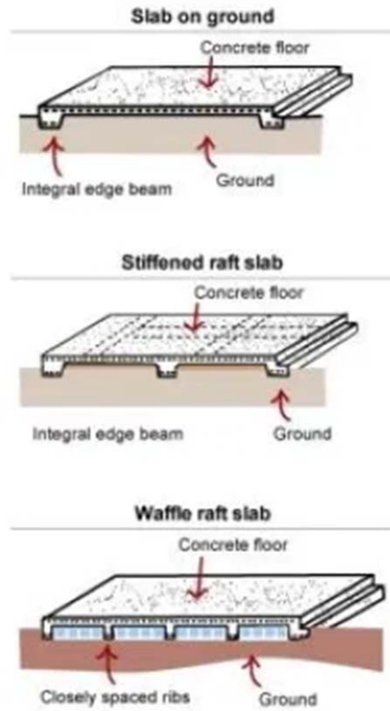
Stiffened raft slab

- Like on ground - apart from stiffening beams which are set in channels through the middle of the slab.
- Creates supporting grid of concrete on the base of the slab.
- Suitable: Soil with moderate, high amount, and severe movement due to moisture.

Waffle raft slab

- Constructed above ground by pouring concrete over a grid of polystyrene blocks 'void forms'.
- Suitable for sites with less reactive soil, 30% less concrete -20% less steel- cheaper and easier to install than other types. Suitable only for very flat ground.

16



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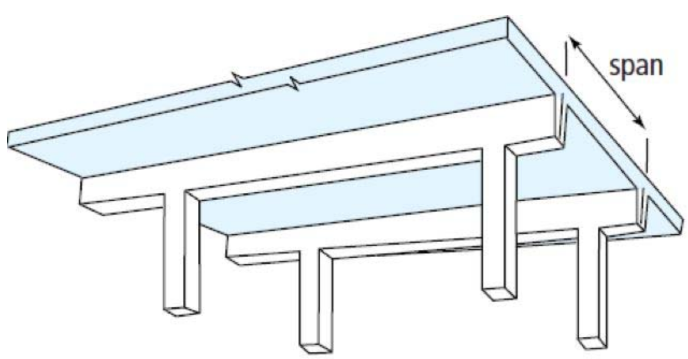
Concrete Flooring

One-Way Slabs on Beams

- Cast in situ method is used to construct one-way slabs on beams
- Fixing of forms followed -installation of reinforcements- pouring of fresh concrete.
- Suitable: for spans of 3-6m- Larger spans - relatively higher cost and higher slab deflection.



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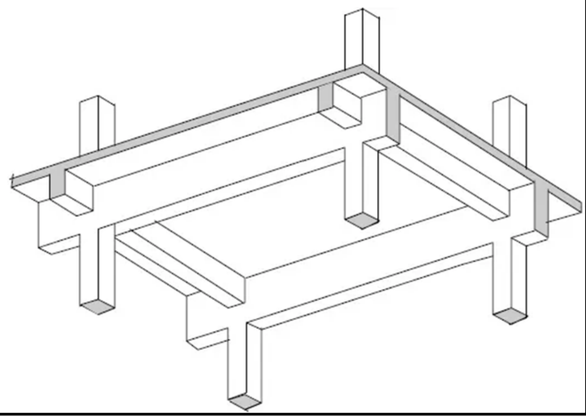
Two-way Slabs on Beams

- Similar to 1-way slab on beams
- Needs more formwork as 2-way slabs are supported on all sides.
- Span: 6 and 9m.
- Beam increase stiffness of the slabs, producing relatively low deflection.



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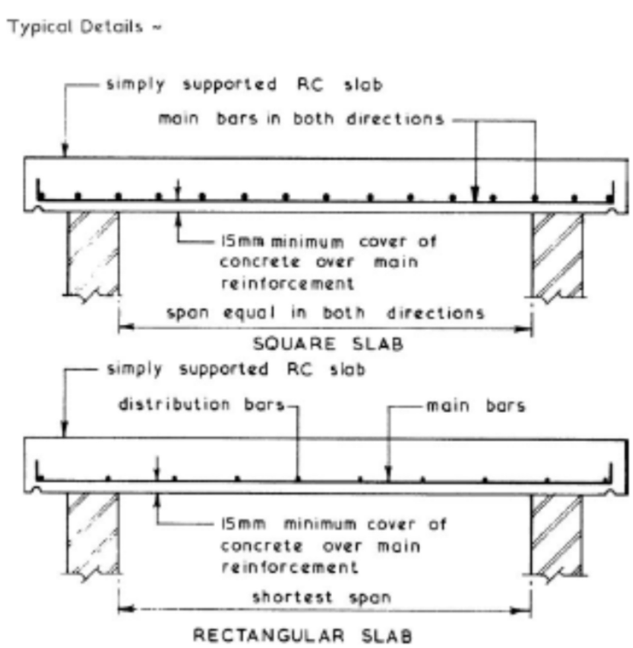

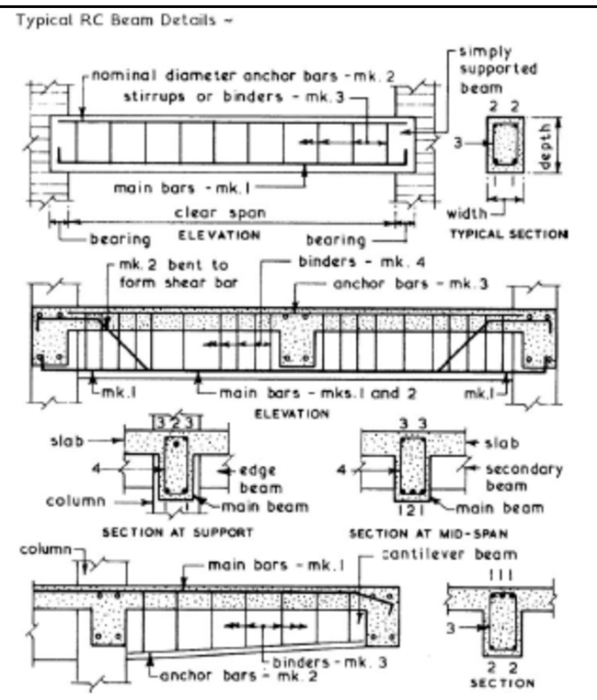

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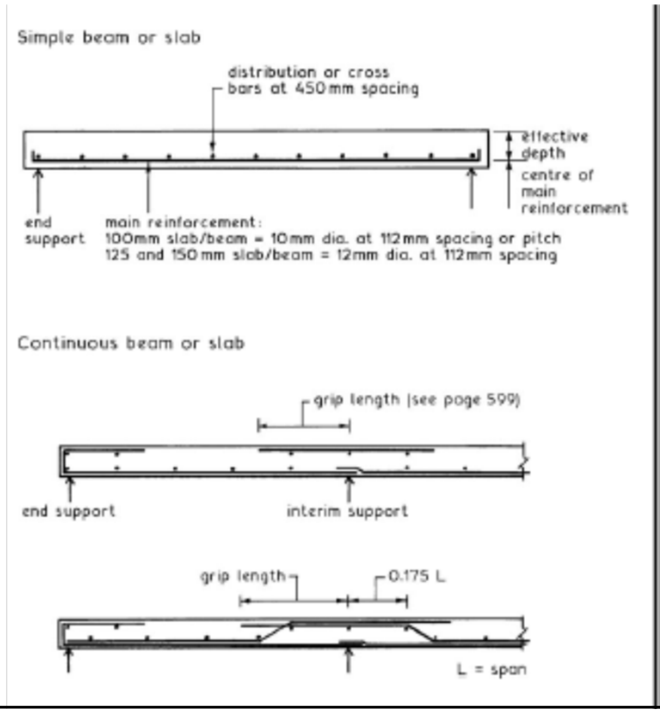

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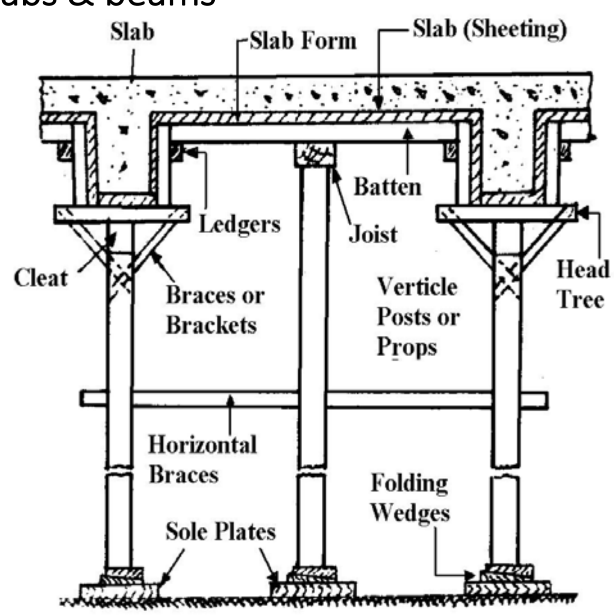
Formwork for Slabs & beams

Consists of
- Sole plates
- Wedges
- Props
- Head tree
- Planks
- Batten
- Ledgers

- Beam formwork rests on head tree
- Slab form work rests on battens and joists



Form Work for concrete Beams & Slabs

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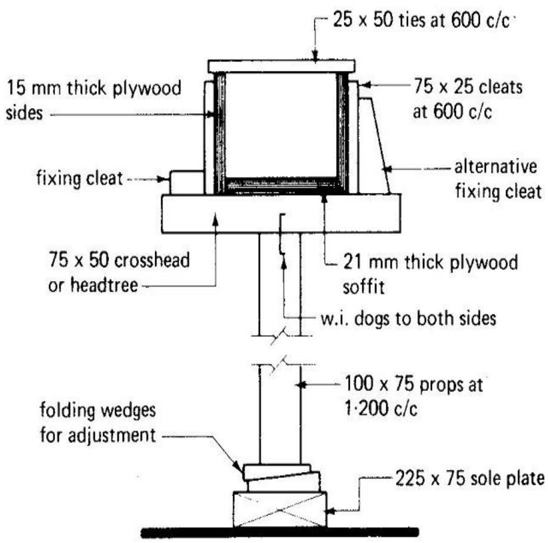
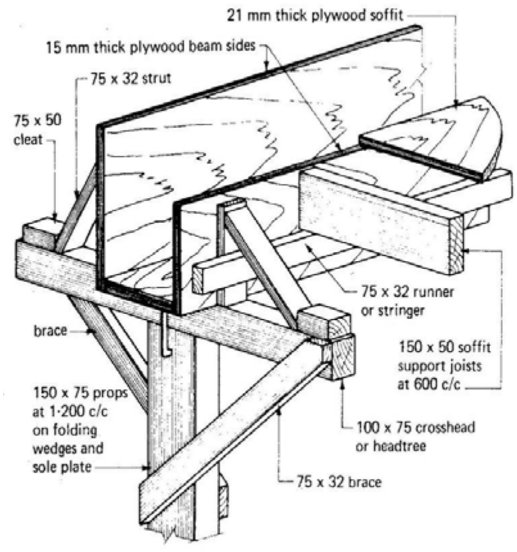
Lintel or Beam Formwork



Simple beam or lintel formwork



Edge beam and slab formwork

Typical beam formwork

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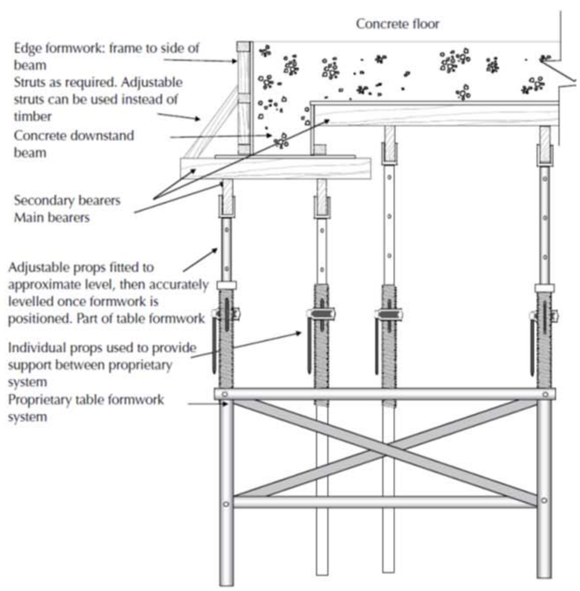

Figure 7.20 Beam and slab formwork.

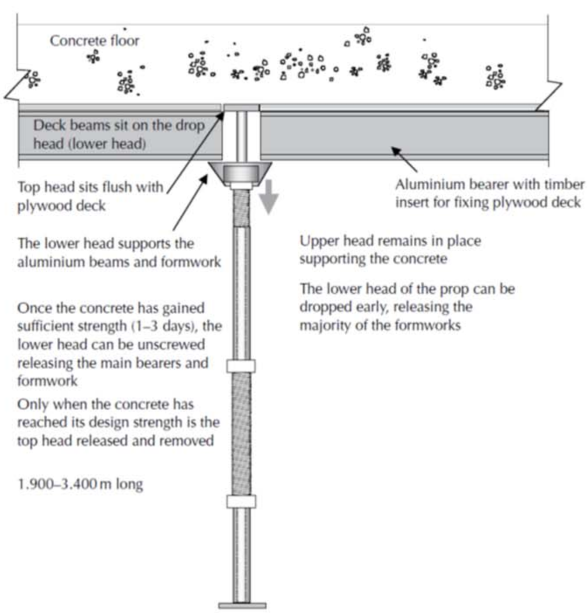

Figure 7.25 Double headed/drop head props.

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11.3.1 - While the above criteria of strength shall be the guiding factor for removal of formwork, in normal circumstances where ambient temperature does not fall below 15°C and where ordinary Portland cement is used and adequate curing is done, following striking period may deem to satisfy the guideline given in 11.3:

Type of Framework	*Minimum Period Before Striking Formwork*
a) Vertical formwork to columns	16-24h
b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
c) Soffit formwork to beams (Props to be refixed immediately after removal of form work)	7 days
d) Props to slabs: 1) Spanning up to 4.5 m 2) Spanning over 4.5 m	 7 days 14 days
e) Props to beams and arches: 1) Spanning up to 6 m 2) Spanning over 6 m	 14 days 21 days

For other cements and lower temperature, the stripping time recommended above may be suitably modified.

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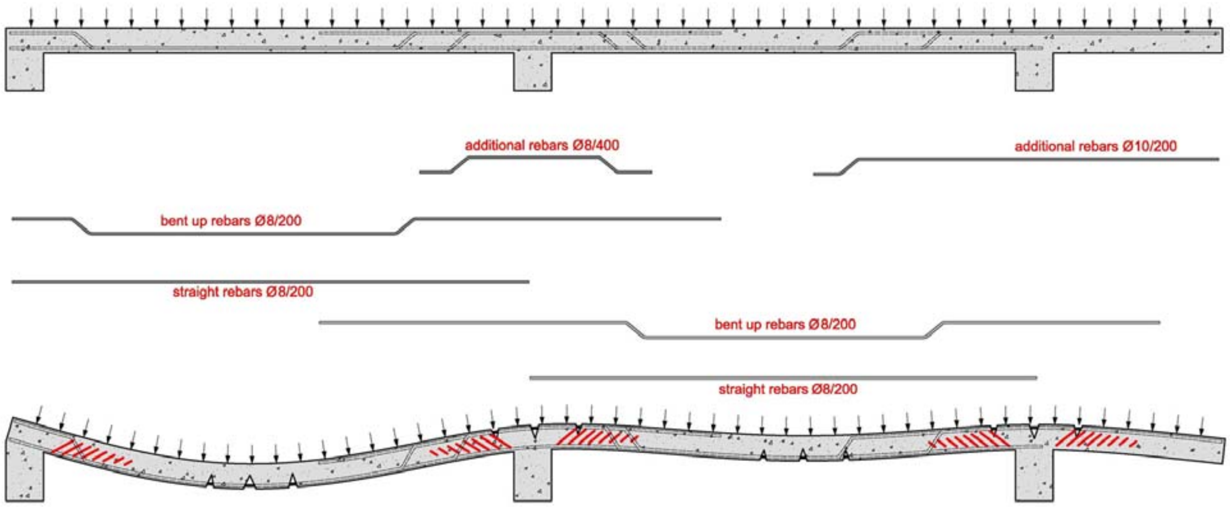
RCC beam/Slab reinforcement detailing/Sequence of De-shuttering



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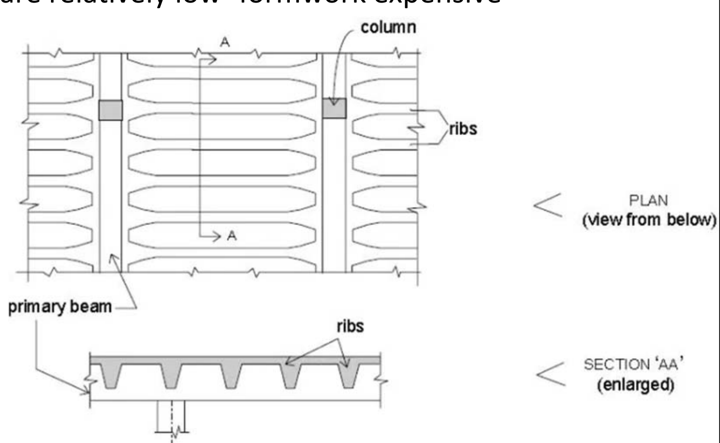
One-way joist slab (Ribbed slab)

- Consists of floor slab- 50 to 100mm thick, supported by RC ribs (or joists)
- Ribs are tapered - uniformly spaced @ < 750mm.
- Ribs are supported on girders that rest on columns.
- Suitable for spans of 6-9m
- Deep ribs- concrete and steel quantities are relatively low- formwork expensive



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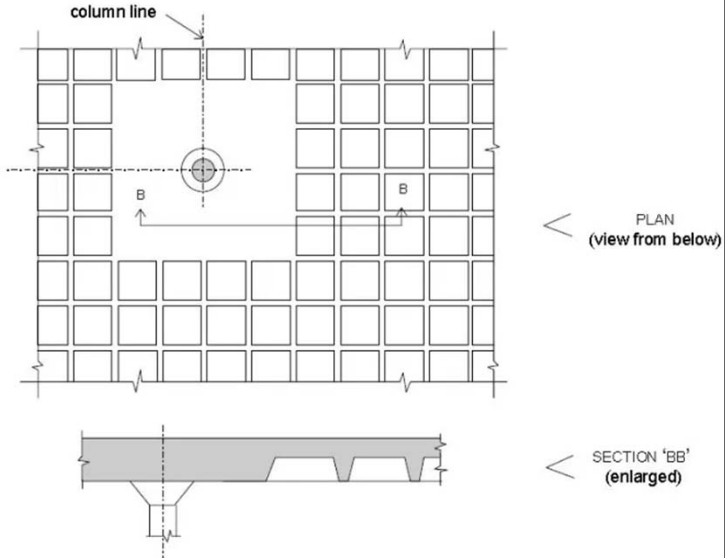
Waffle Slab (Grid slab)

- Contains square grids with deep sides.
- Process: Fixing forms- placing of pods on shuttering- installation of reinforcement between pods- installation of steel mesh on top of pods,- pouring of concrete.
- Suitable for spans of 9-15m.
- Formwork, including the use of pans, is quite expensive.



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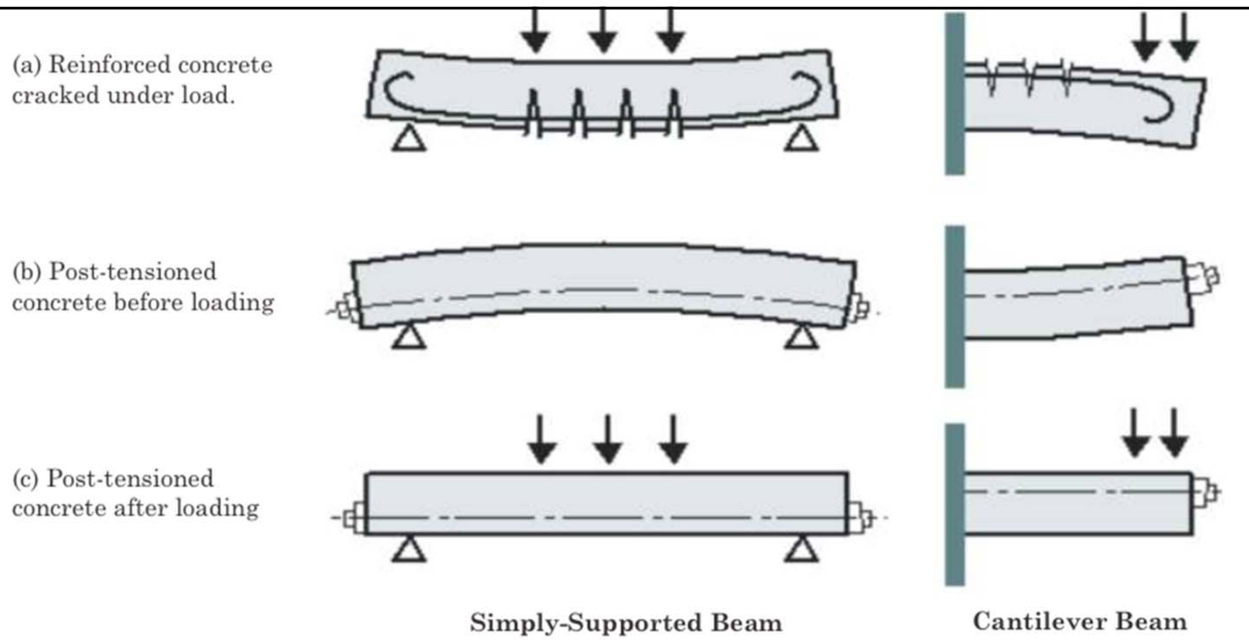

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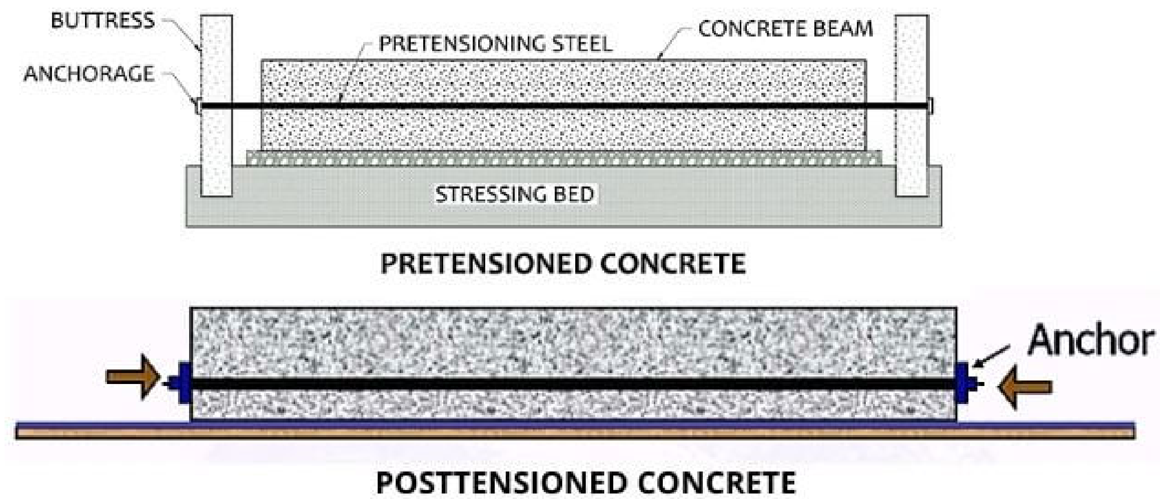

Difference Between Pre-Tensioning and Post-Tensioning

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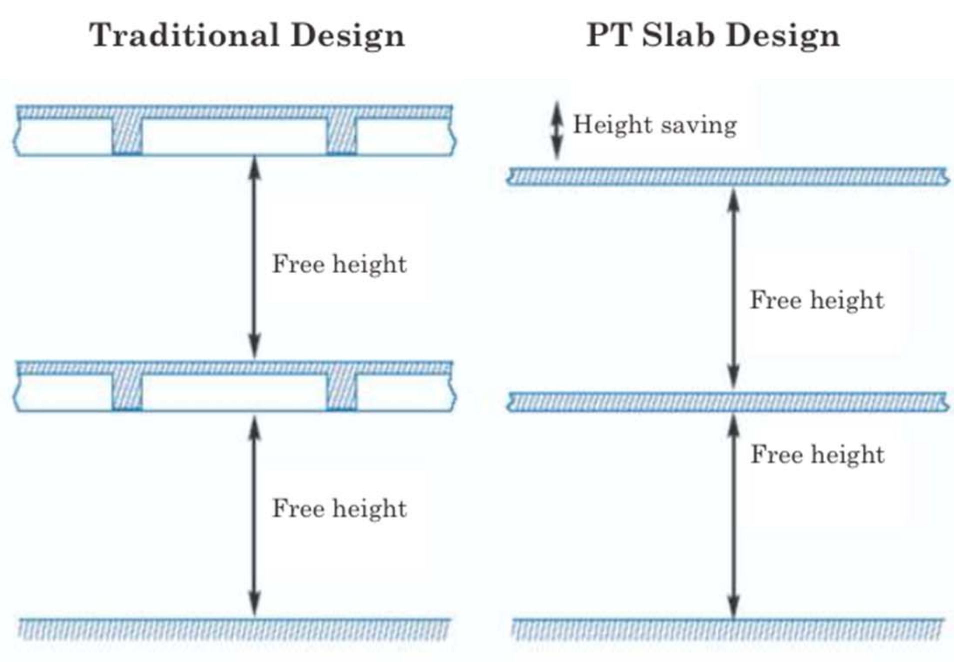

The PT slab method allows designers to reduce building heights or to increase free heights between floors.

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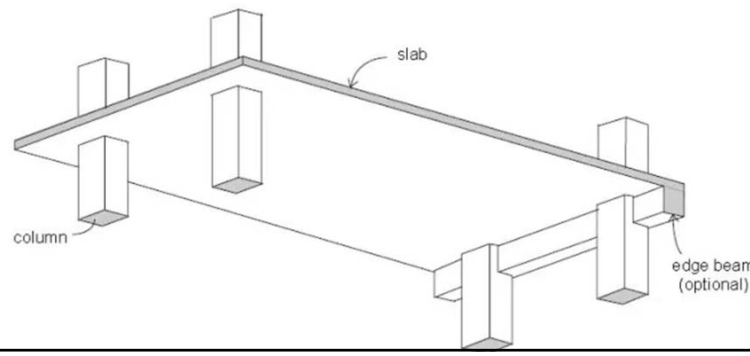
Flat Plates

- Constructed as 1-way/2-way slabs- directly supported by columns or walls.
- Easy to construct- requires simple formworks.
- Span: RCC -Suitable for spans of 6 to 8m
- PSC flat plates Span: 8-12m – Pre-tensioned or post-tensioned slabs
- Advantages: low-cost formwork, exposed flat ceilings, & faster construction.
- Posses low shear capacity &relatively low stiffness- may cause noticeable deflection.



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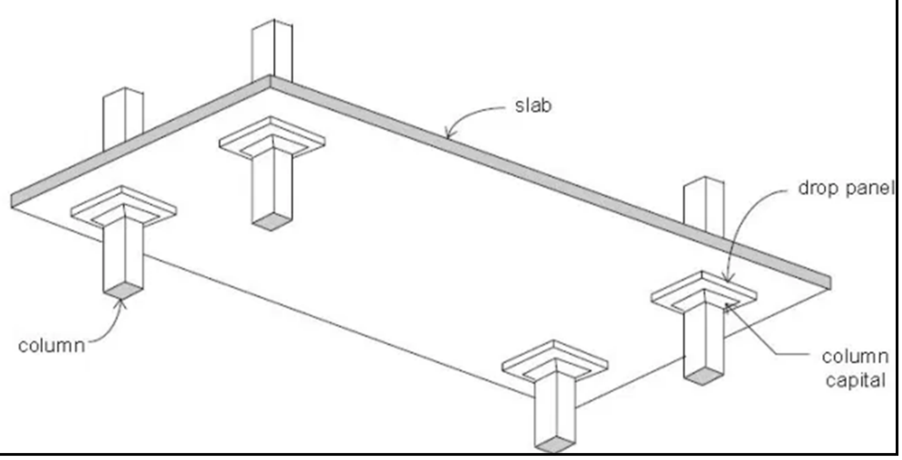
Flat Slabs

- RC slab/Post-tensioned supported directly by columns or caps- without use of beams.
- Easy to construct - requires little formwork - more formwork than flat plates- especially for column capitals
- Loads- directly transferred to columns- Drop panels without column capitals are also used
- Span: 6 to 9m.



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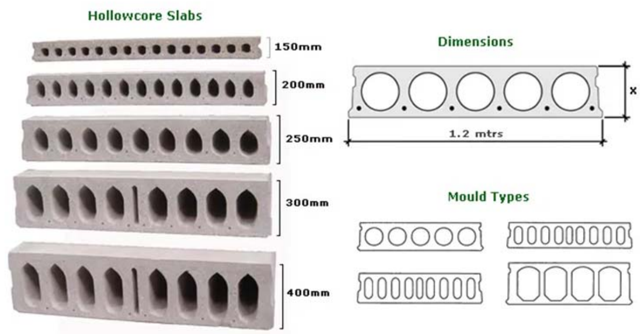
Hollow core slab

- Precast slab through which cores are run.
- Cores- Reduces slab self-weight - increase structural efficiency – enables service ducts.
- Suited for fast constructions are desired.
- Span- no restriction - Width =120mm; Depth - 110 to 400mm.
- Installed between beams using cranes - gap between units filled with screeds.
- Suitable for offices, retail or car park developments



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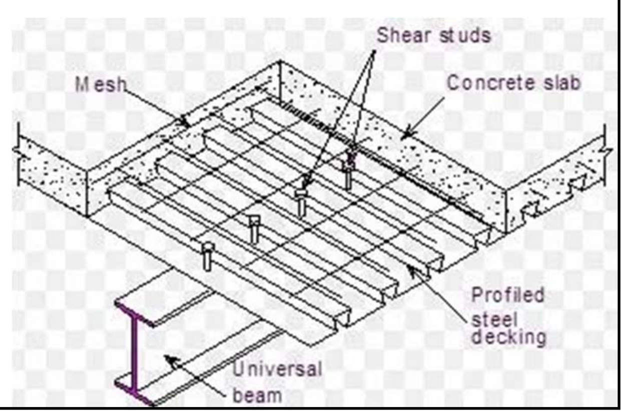
Composite Slab

- RCC cast on top of profiled steel decking.
- Decking acts as formwork & working area during the construction
- It also acts as external reinforcement during service life of the slab.
- Steel decking of thickness 50-60mm- Span up to 3 m
- Steel decking thickness is 80mm- Span up to 4.5m can be constructed.



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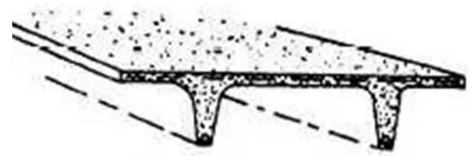
Precast Slab

- Cast & cured in manufacturing plants- delivered to site
- Advantage: Increase in efficiency and higher quality control which is difficult at site
- Types: Channel and double-T types.
- Spans up to 15m.
- Tongue of one panel is placed inside the groove of adjacent panel.
- Cost: casting cost cheaper- quality control- transportation cost


A. CHANNEL


B. DOUBLE-T


C. TONGUE AND GROOVE

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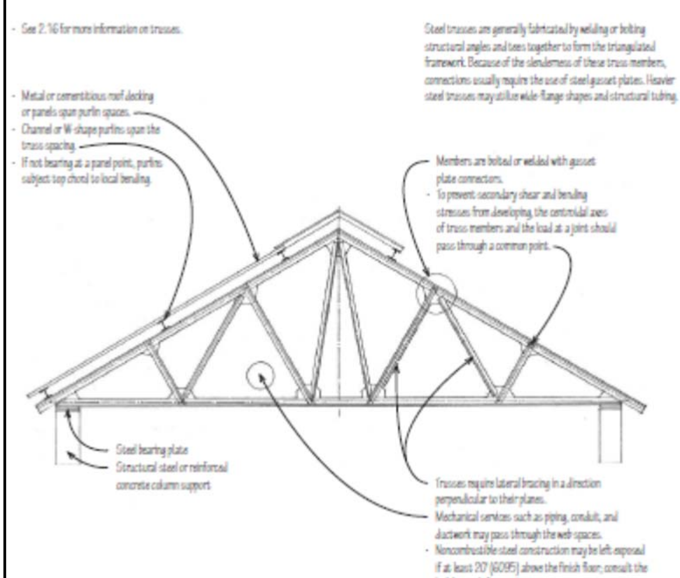
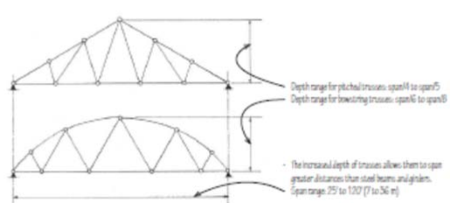
Sloped roof





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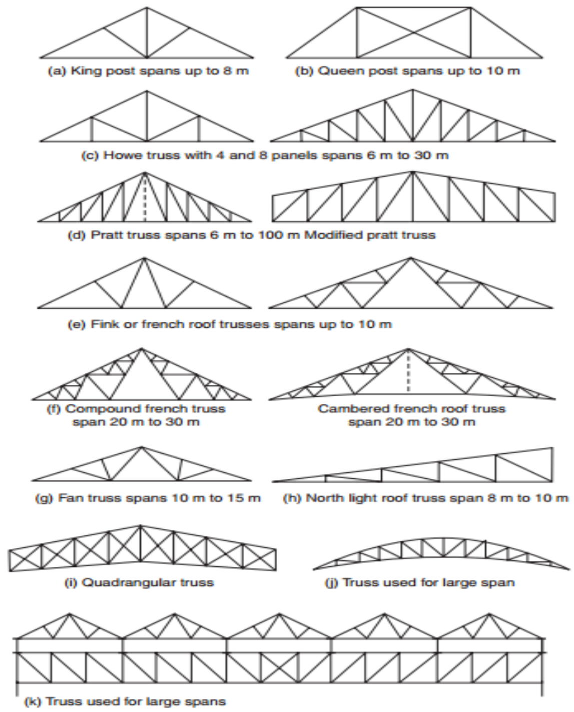
Types of Roof trusses for pitches roof



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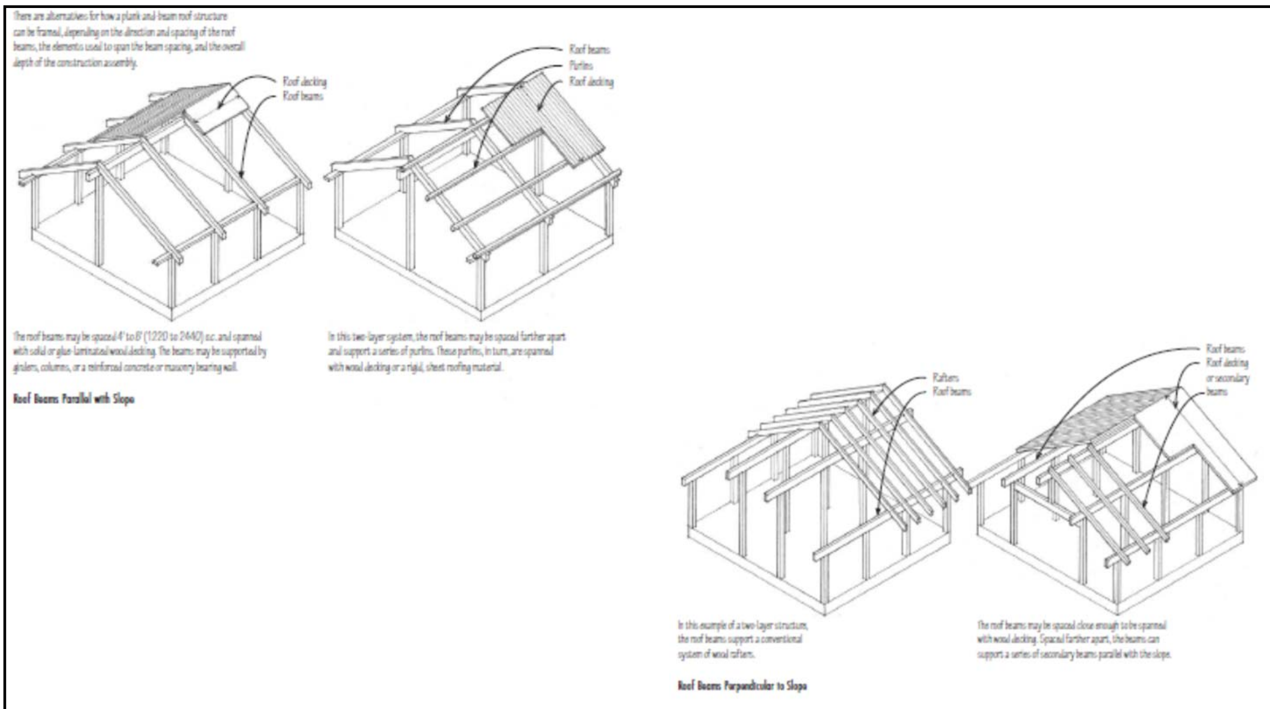

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