GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

STUDY REPORT
ON

COMPACTION EQUIPMENTS
AND
CONSTRUCTION MACHINERY

Report No. GE- R-76

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CONTENTS

1.0 INTRODUCTION:

In earlier days, embankment design and construction were not given adequate attention. Embankments were constructed and left for compaction by natural process. Due to loads imposed by heavier axle loads, very high degree of sub-grade support have become necessary in present scenario which requires fast and heavy compaction by suitable compacting equipments.

The densification of soil mass, commonly known as compaction, results in an alround improvement of soil properties and its performance as a pavement supporting bed. Many types of compacting equipments are available now a days for compacting different types of soils to be used in earthwork.

The construction machineries, like backhoe, dozers, graders, scrapers, JCBs and dumpers etc. began to be deployed on road / rail formation and earth dam construction works in order to complete the works in comparatively less time and expenditure.

2.0 SCOPE:

Scope of this report is to present various types of compaction equipments and construction machinery deployed to construct the railway embankment generally required.

3.0 IMPORTANCE OF ADEQUATE COMPACTION OF EARTHWORK:

Compaction is the process of increasing the density of soil by mechanical means by packing soil particles closer together with reduction of air voids and to obtain a homogeneous soil mass having improved soil properties. Compaction brings many desirable changes in soil properties as follow:

(a) Helps soil to acquire increase in shear strength
(b) Reduces compressibility thus minimizing uneven settlement during service
(c) Increase density and reduces permeability, thereby reducing susceptibility to change in moisture content
(d) Reduction in erodability
(e) Results in homogeneous uniform soil mass of known properties
(f) Reduction in frost susceptibility in cold regions
(g) Helps the pavement designer in assessing the sub-grade strength to a reasonably accurate strength and thereby produce a safe and economical design
(h) Results in little change in volume under traffic loads, thus minimizing deformation and maintaining good rideability characteristics of the pavement
(i) Reduces expenditure on maintenance of formation during service

4.0 FACTORS AFFECTING COMPACTION IN THE FIELD:

Compaction of a particular soil is affected by following given factors –

(i) COMPACTIVE EFFORT

In modern construction projects, heavy compaction machinery is deployed to provide compaction energy. Types of machinery required are decided based on type of soil to be compacted. The method of compaction is primarily of four types such as kneading, static, dynamic or impact and vibratory compaction. Different type of action is effective in different type of soils such as for cohesive soils; sheepsfoot rollers or pneumatic rollers provide the kneading action. Silty soils can be effectively compacted by sheepsfoot roller/pneumatic roller or smooth wheel roller. For compacting sandy and gravelly soil, vibratory rollers are most effective. If granular soils have some fines, both smooth wheel and pneumatic rollers can be used.

(ii) MOISTURE CONTENT

Proper control of moisture content in soil is necessary for achieving desired density. Maximum density with minimum compacting effort can be achieved by compaction of soil near its OMC (Optimum Moisture Content). If natural moisture content of the soil is less than OMC, calculated amount of water should be added to soil with sprinkler attached to water tanker and mixed with soil by motor grader for uniform moisture content. When soil is too wet, it is required to be dried by aeration to reach up to OMC.

(iii) SOIL TYPE

Type of soil has a great influence on its compaction characteristics. Normally, heavy clays, clays and silt offer higher resistance to compaction where as sandy soils and coarse grained or gravelly soils are amenable for easy compaction. The coarse-grained soils yield higher densities in comparison to clays. A well-graded soil can be compacted to higher density.

(iv) LAYER THICKNESS

The more the thickness of layer of earth subjected to field compaction, the less the energy input per unit weight of soil and hence, less is the compaction under each pass of the roller. Suitable thickness of soil of each layer is necessary to achieve uniform thickness. Layer thickness depends upon type of soil involved and type of roller, its weight and contact pressure of its drums. Normally, 200-300 mm layer thickness is optimum in the field for achieving homogeneous compaction.

(v) CONTACT PRESSURE

Contact pressure depends on the weight of the roller wheel and the contact area. In case of pneumatic roller, the tyre inflation pressure also determines the contact pressure in addition to wheel load. A higher contact pressure increases the dry density and lowers the optimum moisture content.

(vi) NUMBER OF ROLLER PASSES

Density of the soil increases with the number of passes of rollers but after optimum number of passes, further increase in density is insignificant for additional number of cases. For determination of optimum number of passes for given type of roller and optimum thickness of layer at a predetermined moisture content, a field trial for compaction is necessary as indicated in para 6.3.5 of “Guidelines for Earthwork in Railway Projects, July 2003” and para 5.0 of this report.

(vii) SPEED OF ROLLING

Speed of rolling has a very important bearing on the roller output. The greater the speed of rolling, the more the length of embankment that can be compacted in one day. Speed was found to be a significant factor for vibratory rollers because its number of vibrations per minute is not related to its forward speed. Therefore, the slower the speed of travel, the more vibrations at a given point and lesser number of pass required to attain a given density.

5.0 FIELD COMPACTION TRIALS:

With the help of field compaction trials, the appropriate type of roller for particular type of soil, optimum depth of layer of soil to be compacted and optimum moisture content of the soil to be used for compaction can be determined. For this, a ramp of following dimension is prepared. Each strip is rolled with using different moisture contents, type of roller and different thickness of lift of soil. Finally, by plotting the graph (fig-1a) between various parameters used, the desired parameters are determined.

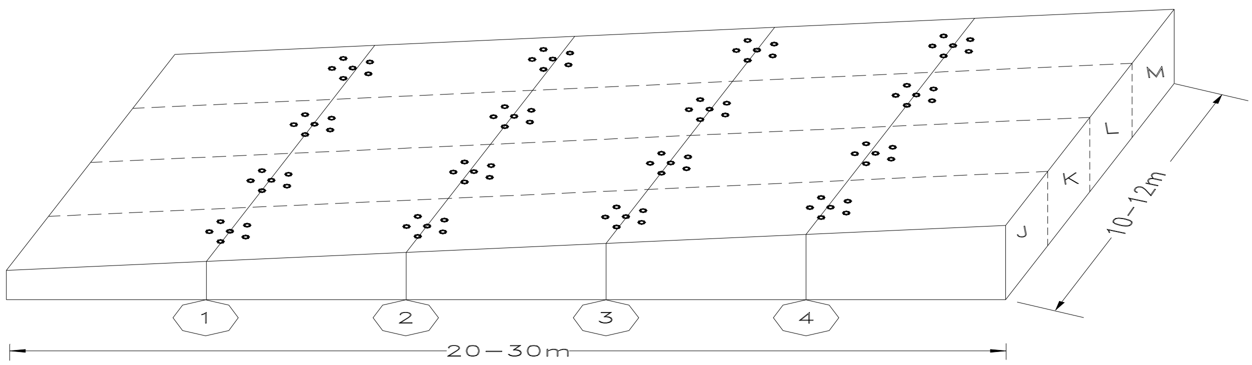


Figure 1: Sketch showing ramp for field compaction trial

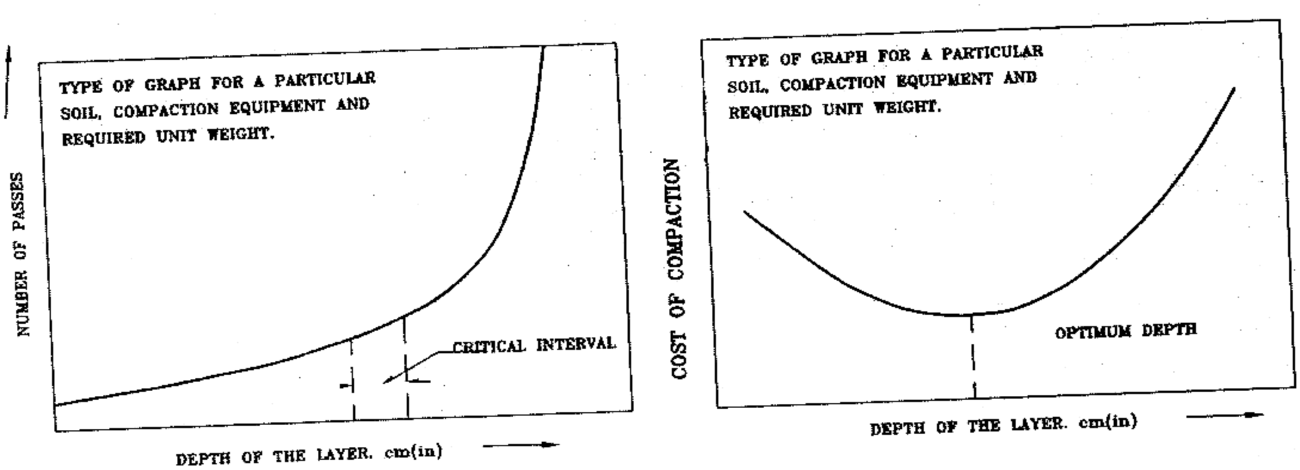


Figure-1(a) : Curves for determination of appropriate depth of layer

6.0 TYPE OF COMPACTING EQUIPMENTS

A large variety of mechanical equipments is available for compaction of soil but soil type and moisture condition will often dictate the type of equipments and method of use.

Some important compacting equipment are given below: -

1. Light compacting equipments (Rammers/Plate compactors)
2. Smooth wheel rollers
3. Sheepsfoot rollers
4. Pneumatic tyred rollers
5. Vibratory rollers
6. Grid rollers

The details about various types of rollers are given as below: -

6.1 LIGHT COMPACTING EQUIPMENTS:

6.1.1 RAMMERS:

Rammers are the light compacting equipments used for small areas, which provide impact load. These may be hand or machine operated.

The area of base is normally 15cm x 15cm or 20cm x 20cm or more. Free fall rammers can be heavier type also weighing 2 or 3 tonne lifted and dropped by cables to a height of 1 or 2m to compact large rock fragments. Automatic type operated pneumatically or using petrol engines lift to a height of 15 to 20 cm. before being dropped. Weight of such tampers can vary from 30 to 10000kg. They are suitable for compacting cohesive soils as well as other soils.

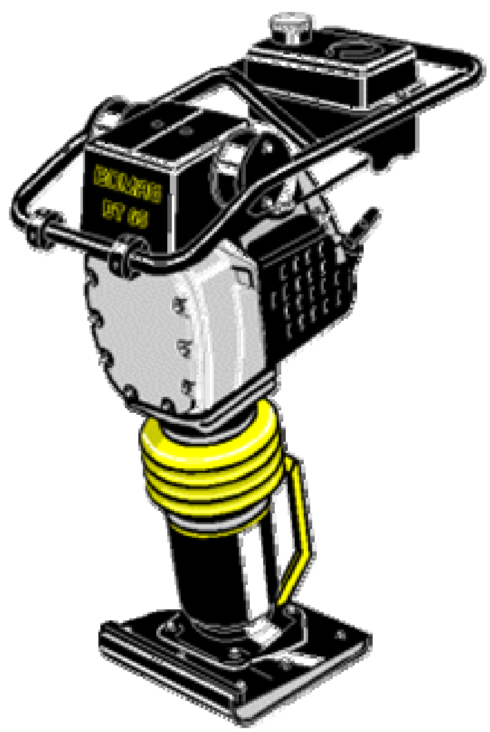


Figure 2 : Plate Rammer

6.1.2 VIBRATING PLATE COMPACTORS:

These vary in weight from 100 kg to 2 tonne with plate areas between 0.16 sqm and 1.6 sq cm. Smaller versions are manually guided and therefore suitable for compacting small or awkwardly shaped areas. They usually travel at about 0.7 km/h. They are classified in terms of mass divided by the area of the base in contact with the ground.

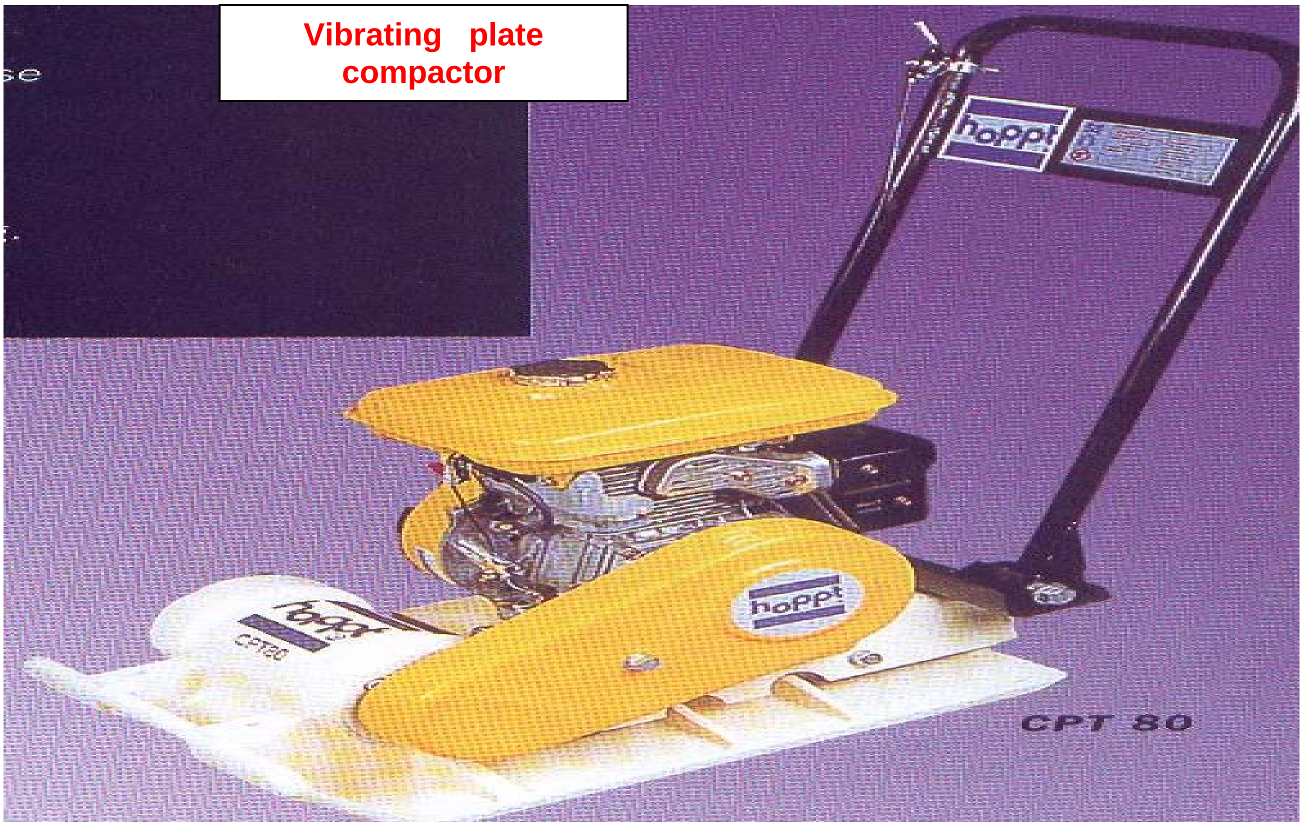


Figure 3: Vibrating Plate Compactor

6.1.3 VIBRO TAMPERS:

Vibro tampers compaction is induced by vibrations set up in a base plate through a spring activated by an engine driven reciprocating mechanism. They are usually manually guided and weigh between 50 and 100 kg. They are best suited for compaction in confined spaces. They are classified in terms of the static mass of the machine.

Table 1: Characteristics of different type of light compactors

Make	Model	Type	Operating Weight	Compaction Plate Size (mm x mm)	Drum Size (mm x mm)	Vibrating Frequency(Hz)	Area capacity Per Hour	Gradeability	Recommended	Remarks
HOPPT L&T	CPT 80	Vibra-tory Plate Compactor	80	585x 400	-	6000	-	-	-	For long hours compacting
	CPT 0B		80	490x 440	-	6000	-	-	-	-do-
	CPT 90B		90	490x 490	-	6000	-	-	-	Powerful vibration and effective in compacting
	CPT 140		140	600x 500	-	5100		-	-	-do-
	ROL 650 K	Vibratory Roller	665	-	352x 585	3300	-	-	-	For compaction of gravel, sand and soil
	ROL 650 C		665	-	352x 585	3300	-	-	-	-do-
INGER SOLL RAND	RX 654 X	Upright Rammer	71	330x 270	-	-	235sq m	-	530 mm	Effective for compaction of wide range of soils types
	BX 8W H	Vibratory Plate Compactor	90	585x 480	-	100	725sq m	-	300 mm	Effective for granular soils and coarse grained aggregates
	SX 17	Single drum walk behind roller	240	-	450x 560	74.3	-	27°	230 mm	-do-
	DX 500 E	Vibratory walk behind roller	590	-	356x 575	55	-	47°	305 mm	For better rolling width
	DX 500 E	Vibratory walk behind roller	590	-	356x 575	55	-	47°	305 mm	For better rolling width

Figure 4: Smooth Wheel Roller

6.2. SMOOTH WHEEL ROLLERS:

These rollers have one large steel drum in front and two steel drums on the rear. The gross weight of these rollers is in the range of 8-10 tonne. The other type of smooth wheel roller is called Tandem Roller, which weighs between 6-8 tonne. The weight of the roller can be increased up to 20 tonne by ballasting the inside space of the roller drums with either water ar wet sand. Steel sections are also loaded sometimes on double drum rollers mounted on a steel frame to which axles are attached. Non-reversibility of these tractor drawn rollers is a major drawback and hence is not very popular.

The performance of a smooth wheel roller depends upon its load per cm width and diameter of the roll. The load per cm width is derived from the gross weight of the drum. Smooth wheel rollers are useful for compaction when the material does not require great pressure. These are also used to finish the upper layers.

The desirable speed and number of passes appropriate for a specific soil should be established in each project site to get the best production. About 8 passes are adequate for compacting 20 cm layer.

Smooth wheel rollers are most suitable for compacting gravels, sand and crushed rock where some crushing action is required.

A speed of 3-6 kmph is considered appropriate for smooth wheel rollers.

Table 2: The general characteristics of 8-tonne and 2.75 tonne smooth wheel rollers

PARAMETERS	8-TONNE ROLLER	2.75 TONNE ROLLER
Gross Weight	8682kg	2800kg
Weight on front rolls	3555kg	865kg
Weight on rear rollls	5086kg	1935kg
Diameter of front rolls	105cm	85kg
Width of front rolls	53cmx2	30cm
Width of rear rolls	135cm	90cm
Diameter of rear rolls	45cm	38cm
Rolling width	175cm	128cm
Wheel base	285cm	180cm
Load per inch. Width		
Front roll	85kg	36.4kg
Rear roll	141kg	64.5kg
Load(kg)/Width(cm)x Diameter(cm)		
Front roll	0.31kg/cum	0.27kg/cum
Rear roll	0.48kg/cum	0.16kg/cum

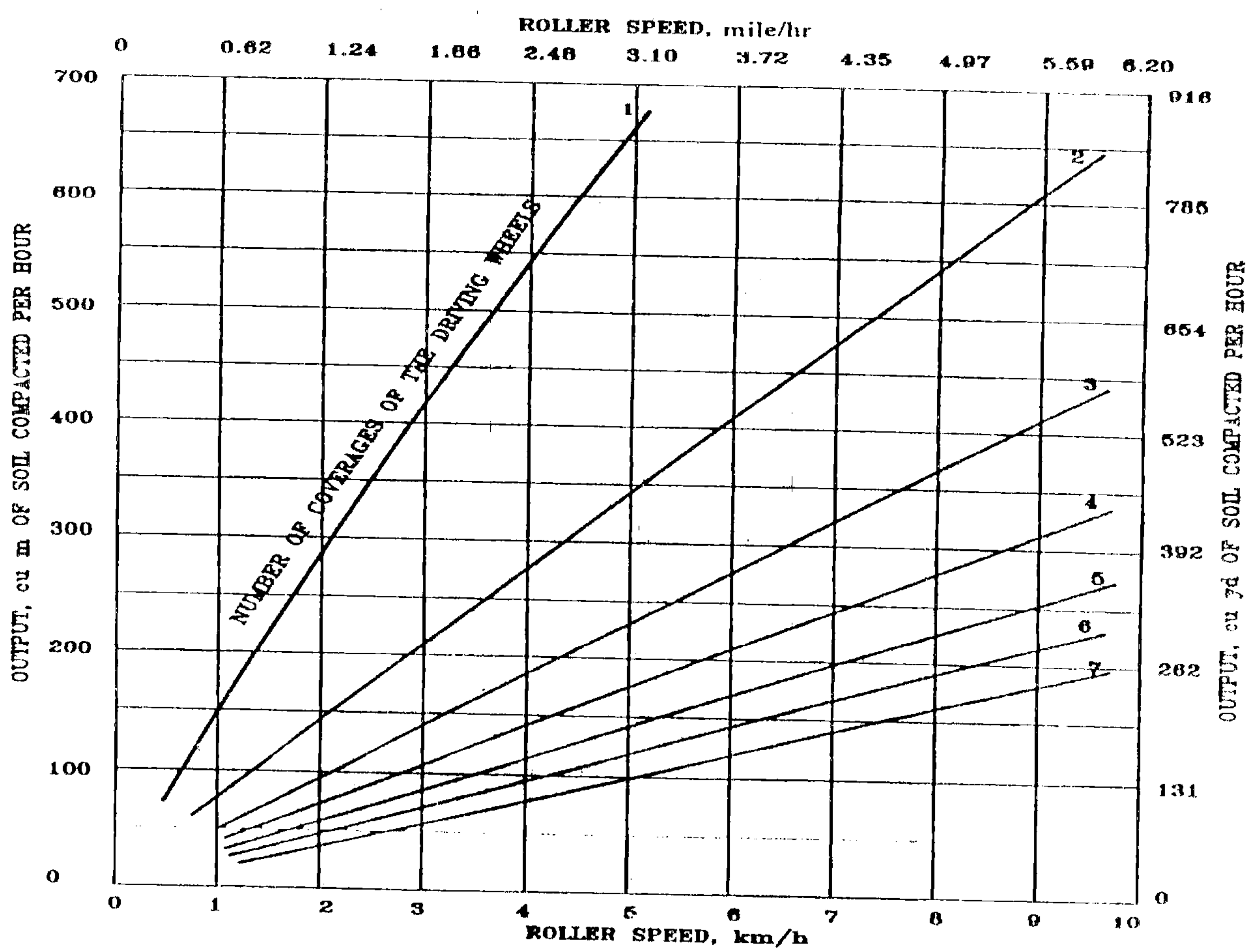


Figure 5: Relation between roller speed, number of pass and output:

The above graphical representation of speed vs. production and no. of passes vs. production is linear. It shows that the output of the roller is maximum for the first pass at minimum speed. After subsequent passes even with higher speeds of the roller does not produce more output.

Table 3: Comparison of maximum dry densities and optimum moisture content obtained with compaction plant and laboratory tests:

Soil type	Heavy clay		Silty clay		Sandy clay		Sand		Gravel sand clay	
Description	**MDD (g/cc)**	**OMC (%)**	**MDD (g/cc)**	**OMC (%)**	**MDD (g/cc)**	**OMC (%)**	**MDD (g/cc)**	**OMC (%)**	**MDD (g/cc)**	**OMC (%)**
B.S. compaction test	1.552	26	1.664	21	1.840	14	1.936	11	2.064	9
Modified AASHTO compaction test	1.808	17	1.920	14	2.048	11	2.080	9	2.208	7
2.75 tonne smooth wheel roller	1.520	21	1.760	17	1.824	16	2.032	10	2.144	8
8 tonne smooth wheel roller	1.664	20	1.776	16	1.856	14	2.112	8	2.208	7
Pneumatic tyred roller	1.568	25	1.664	20	1.728	19	2.032	11	2.016	7
Sheepsfoot roller (Clubfoot type)	1.712	16	1.856	14	1.904	12	-	-	2.064	6
Sheepsfoot roller (Taperfoot type)	1.712	15	1.840	14	1.920	12	-	-	2.048	5
0.5 tonne frog rammer	1.712	17	1.760	15	1.856	13	2.048	10	2.176	7

The above study was carried out for finding out the efficacy of various compacting equipments on 5 types of soils, viz., heavy clay, silty clay, sandy clay and gravel-sand-clay. The rollers employed were smooth wheel roller, pneumatic tyred roller and sheepsfoot roller. The density results of B.S. Compaction test and modified compaction test have been reported in the table for the sake of comparison. Effect of 8 tonne smooth wheel roller on compaction of 5 soils was studied. Gravel-sand-clay is found to respond very well to the compaction effort of smooth wheel roller; where as heavy clay is found to have got the least density.

Figure 6: Sheepsfoot Roller

6.3 SHEEPSFOOT ROLLER:

For compacting heavy clays and silty clays, sheepsfoot rollers are found to be very effective. These rollers are employed in road and rail projects. They consist of steel drum/s on which projecting legs are fixed which may apply pressure up to 14kg/sqcm or more. Different types of lugs are namely spindle shaped with widened base, prismatic and clubfoot type.

A single drum required to be towed with a tractor or these can be mobile sheepsfoot rollers with tandem drums. Ballasting with water, wet sand or steel sections can increase the weight of these drums.

Efficient compaction can take place when these lugs are gradual walkout of the roller lugs with successive coverage. The important factors are the pressure on the foot and coverage of ground obtained per pass. The parameters that really matter are gross weight of the roller, the area of each foot, the number of lugs in contact with the ground at any time and total number of feet per drum.

As the roller moves on the soil, its foot penetrates into the soil and exerts pressure. The pressure is maximum when a foot is vertical. When the roller moves, the foot which is vertical starts receding and the pressure reduces. The compaction takes place from the bottom.

In some cases not only the foot, the drum also presses the soil. It is stated that for best result, the thickness of the lose layer should not exceed by more than 50 mm the length of the feet of sheeps foot roller.

The nature of compaction applied by a sheep foot roller is known as kneading.

Table 4: The general characteristics of Sheepsfoot rollers are given as below:

PARAMETERS	SPECIFICATIONS
Width of drum	1..22 to 1.98m
Diameter of drum	1.02 to 1.83m
Number of feet of shafts	64 to 144
Area of straight section of feet	33 to 135 sq cm
Length of feet	18 to 46 cm
Weight of empty roller	1.6 to 7.0 tonne
Weight of roller filled with water	2.5 to 11.5 tonne
Contact Pressure, Empty	5.2 to 30 kg/sq cm
Contact Pressure filled with water	8.0 to 55.00 kg/sq cm

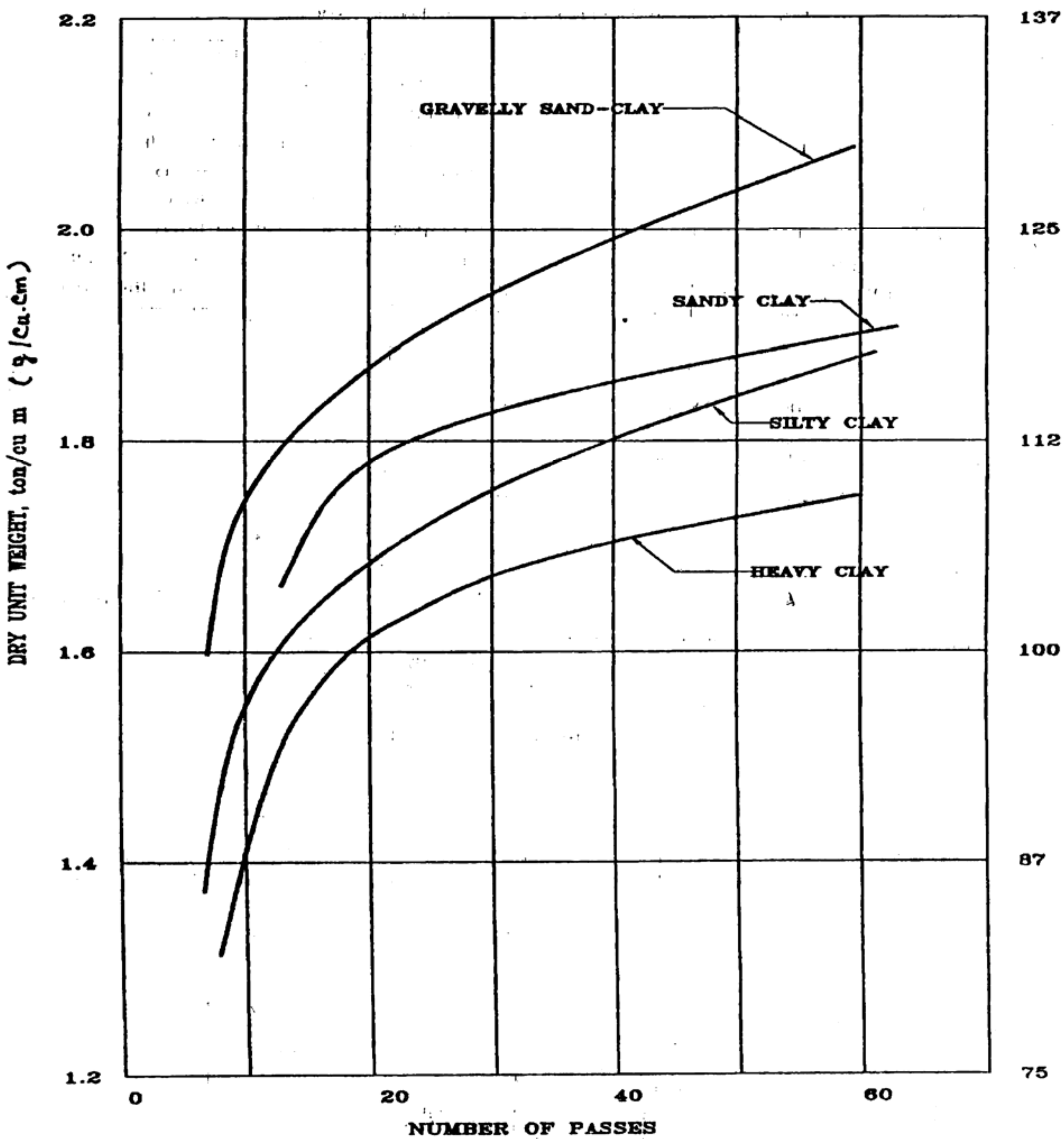
Table 5: Sheepsfoot Roller- Effect of contact pressure on the maximum dry density

Type of soil	**Contact pressure** (kg/cm^2)	**Contact area** (cm^2)	**Number of passes**	**Compaction** (%)
Clayey sand	17.5 31.5	43.75 43.75	9 9	99 99
Silty clay-I	17.5 35.0 52.5	43.75 43.75 43.75	8 8 8	102 101 101
Heavy clay	8.0 17.5	75.25 31.50	64 64	108 108
Silty clay II	8.0 17.5	113.68 248.67	64 64	112 111
Sandy clay	8.0 17.5	75.25 31.50	64 64	104 104
Mixture of gravel, sand and clay	8.0 17.5	75.25 31.50	64 64	100 99

The above table shows that the contact pressure of foot has no bearing on the density achieved at the end of the day. For instance, in the case of silty clay I, the pressures of 17.5 kg/cm^2 and 52.5 kg/cm^2 have been able to give density of 102 and 101 % after 8 passes. It also suggests that rolling beyond 8 to 10 passes does not increase the density proportionately.

Therefore, it is prudent to stop rolling after 8-10 passes. This, however should be decided after field trials.

Figure 7: Compaction with sheepsfoot roller- Effect of number of passes on the degree of compaction of various soils



6.3.1 PAD FOOT/ TAMPING ROLLERS:

These rollers are similar to sheepsfoot rollers with lugs of larger area than sheepsfoot rollers. The static pad foot rollers also called tamping rollers have static weights in the range of 15 to

40 tonne and their static linear drum loads are between 30 and 80 kg/cm. On account of their larger production capacity, they are replacing sheepsfoot rollers.

The degree of compaction achieved is more and there is more uniformity of density. They operate at high speeds and are capable of even breaking large lumps. The rollers with leveling blades have the capability of spreading the material.

There are also self-propelled pad foot rollers weighing around 11.0 tonne or more and having a linear load of 30 kg/cm to 50 kg/cm. They can compact clay materials from 30 cm to 40 cm thickness. Lately tandem pad foot rollers have been introduced to obtain better speed and volume. These rollers are best suitable for compacting cohesive soils.

The optimum speed varies between 4 and 10 kmph.

Figure 8: Tamping Roller

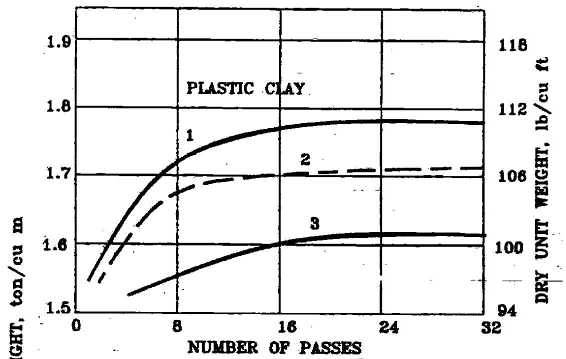
6.4 PNEUMATIC TYRED ROLLERS:

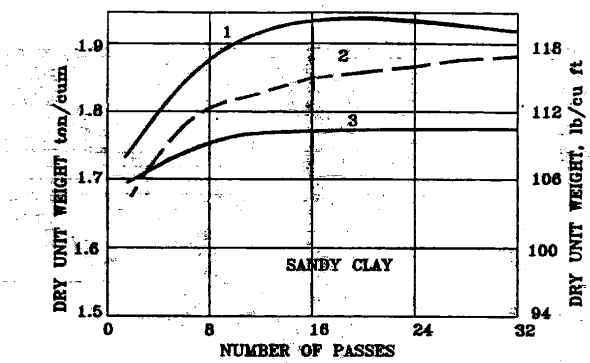
Pneumatic tyred rollers are used in both earthwork and bituminous work. These rollers have wheels on both the axles but they are staggered so that they can compact the layers with uniform pressure throughout the width. The front axle may have four pneumatic smooth wheels where as there can be five wheels on the rear axles. The two important parameters governing compaction are the tyre inflation pressure and the area of the contact. The latest rollers have an arrangement to inflate the tyre to the desired pressure automatically. The total weight of the roller can be increased from 11.0 tonne to 25.0 tonne or more by ballasting with steel sections or other means.

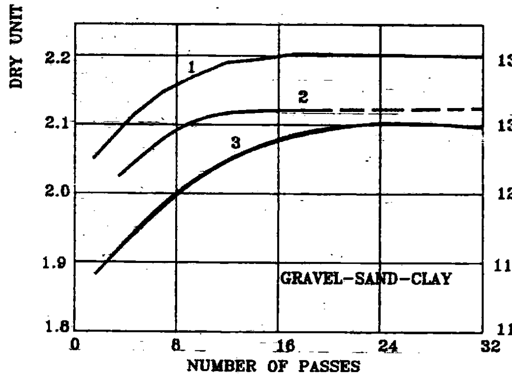
Generally, 8 passes of pneumatic tyred roller yield almost maximum density. The optimum speeds are between 1.6 and 24 kmph.

Figure 9: Pneumatic tyred roller

Figure 10: Compaction with Pneumatic tyred roller: effect of no. of passes and tyre pressure on the dry density of various soils:







CURVE	LOAD/WHEEL ton	(kips)	TIRE PRESSURE kg/sq cm	(lb/sq in)	DEPTH OF LOOSE LAYERS cm	(inches)
1	10.15	22.3	10.0	142	30.5	12
2	5.00	11.0	6.3	90	30.5	12
3	1.35	3.0	2.5	36	23.0	9

The effect of number of passes and the tyre pressure on dry density of three types of soils viz. plastic clay, sandy clay and gravel-sand-clay has been given in above table. The results show that with the increase in tyre pressure, dry density increases. Beyond 16 passes dry density has not much effect on compaction.

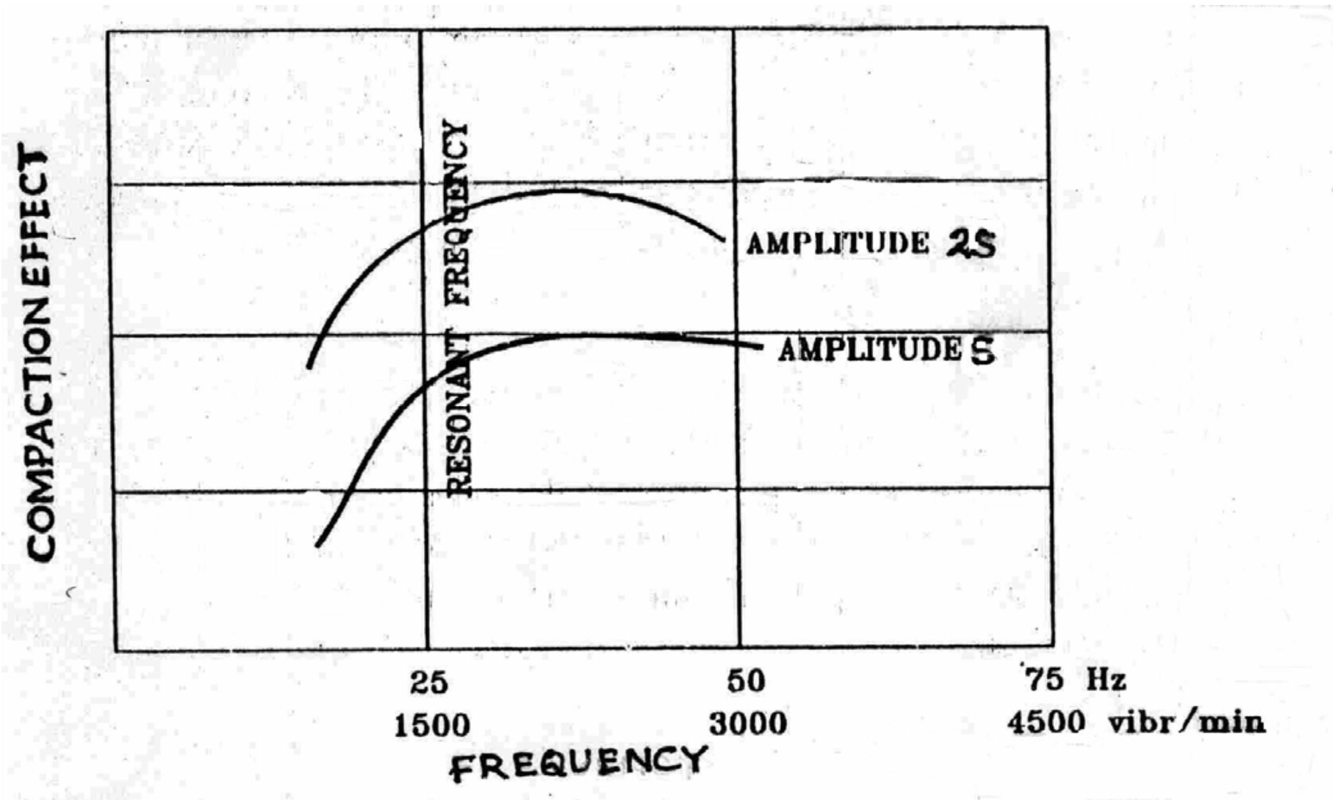
6.5 GENERAL DEFINITIONS:

Important parameters having influence on compaction by vibratory rollers are given as below:

- Frequency - No. of resolutions per minute
- Amplitude - Vertical displacement of roller drum
- Dead load - Gross weight of the roller
- Dynamic force - Force developed during each oscillation
- Area of contact - Contact area of the roller on soil
- Influence of vibration and amplitude on compaction of soil is profound.
- All soils have their natural frequency
- Frequency of roller should be between 1 to 1.5 times the frequencies of soil for best compaction results

Influence of vibration and amplitude on compaction of soil is profound. All soils have their natural frequency and it is found that the frequency of roller should be between 0.5 and 1.5 times the natural frequency of soil for obtaining best compaction results. The suggested range is 1500 to 2000 cycles per minute.

Figure 11: Relation between compaction effect, frequency and amplitude



The above curves show that the effect of frequency on compaction is almost flat between 25 and 50 Hz. where as the amplitude has pronounced effect on compaction in the same range.

6.5.1 VIBRATORY ROLLERS:

Latest specifications of earthwork invariably recommend vibratory rollers. These rollers are helpful from several considerations like:-

(i) Higher compaction level can be achieved with maximum work
(ii) Compaction can be done up to greater depths
(iii) Output is many times more than conventional rollers

Although these rollers are expensive but in the long term the cost becomes economical due to their higher outputs and improved performance.

Vibratory rollers are similar to smooth wheel rollers with the modification that the drum or drums are made to vibrate by employing rotating or reciprocating mass. Considerable research has gone into the development of vibratory rollers, the capacity of the roller increase, thereby bringing about economy in construction cost of embankment.

Figure 12: Vibratory Roller

Vibratory rollers are similar to smooth wheel rollers with the modification that the drum or drums are made to vibrate by employing rotating or reciprocating mass. Considerable research has gone into the development of vibratory rollers, the capacity of the roller increase, thereby bringing about economy in construction cost of embankment.

The general characteristics of Vibratory rollers manufactured in India are given as below:

Table 6: Salient features of vibratory rollers manufactured in India

Make	Model	Operating Weight (kg)	Drum details			Normal Amplitude	Vibrating frequency (Hz)	Remarks
			Drum width	Axle load (t)				
				Front	Rear			
	SD110	11050	2135	6510	4540	1.92	0-31	For better gradeability
	SD110D	11090	2135	6550	4550	1.92	0-31	For better gradeability

INGER SOLL RAND	SD110F	11640	2135	7100	4540	1.59	0-31	For variable frequencies
	SD150F	15000	2135	9380	5620	1.87	0-31	Useful for granular and cohesive soils
	SD150D	15025	2135	9405	5620	1.77	0-30	For variable frequencies
ESCORTS	5250 STD	9350	2130	5050	4300	1.72	30	For better gradeability
	EC5250 D	9550	2130	5250	4300	1.72	30	For better gradeability
	EC5250 PD	10500	2130	6650	4300	1.53	30	For better radeability and breaking clods
	HD85	9300	1680	4650	4650	1.27/ 0.75	0- 30/42	Double drum vibration
L&T	1107 STD	11300	2330	6450	4850	1.8/ 0.8	30/33	For better gradeability
	1107D	11300	2330	6450	4850	1.8/ 0.8	30/33	For better gradeability
	1107PD	11400	2330	6550	4850	1.8/ 0.8	30/30	For better gradeability and breaking clods
GREAVES BOMAG	BW21D -2 (2A)	10424	2100	6463	3961	1.67	40/31	For better gradeability and breaking clods
	BW212-PD-2	10879	2100	6201	4678	1.5	30	For better gradeability and breaking clods

6.5.2 TYPES OF VIBRATORY ROLLERS:

(a) TOWED VIBRATORY ROLLERS
(b) SELF PROPELLED ROLLWERS
(c) VIBRATORY TANDEM ROLLERS
(d) COMBINATION ROLLERS
(e) DOUBLE DRUM ROLLERS (DUPLEX ROLLERS)

(a) Towed Vibratory Rollers:

The weight of these rollers varies from 4-6 tonne but there are heavy-duty rollers weighing even 15.0 tonne, which are towed, with help of tractors or shoves. With heavy rollers, the layer depth can be increased and also daily production. As these rollers cannot be reversed, great inconvenience and loss of time are caused.

(b) Self Propelled Rollers:

A standard self-propelled roller has steel vibrating drum and two pneumatic wheels at the rear. Its dead weight varies from 8.0 to 12 tonne. Half weight isof the drum. These rollers can be ballasted to increase the weight.

Drum Diameter and width:

Static linear load of the drum, which is an important parameter influencing soil compaction, is basically dependent on the diameter of the drum. Larger the linear load better is the compactive pressure imparted by the roller. For better performance at high static linear load, the drum diameter must be large.

(c) Vibratory Tandem Rollers:

This was first developed in 1950. Small rollers are popular for road works of small scale and for repairs. The roller weighing from 7 to 17 tonne are being manufactured mostly for bituminous works. Modern vibratory tandem rollers have vibration and drive on both drums.

(d) Combination Rollers:

Combination rollers have a vibrating drum on one axle and on the other; there are three to five pneumatic tyres. These are primarily used in bituminous work where the beneficial effect of both vibratory roller and pneumatic wheels are usefully employed.

(e) Double Drum Rollers (Duplex Rollers):

Bomag developed walk behind double drum rollers similar to tandem rollers in 1950. These are useful for compacting soil in restricted areas, trenches etc. Two factors contributing to the improved compaction of soil, sand and sandy soil by vibration are-
(a) Elimination of internal friction between particles because of state of motion of the soil particles.
(b) Pressure and shear stresses generated by vibratory compactor in the soil. It is to be noted that pressure imparted by a vibratory roller is partly static and partly dynamic.

The effect of vibration on the reduction of internal friction in sand and cohesion by capillary in cohesive soils has been evaluated quantatively by Liamazanes. He has proved that internal friction can get reduced by vibration to 1/15 for sands and 1/40 in gravels. This effects when complemented by pressure from roller enhances the compaction process.

The general characteristics of single drum vibratory rollers are given as below:

Table 7: Characteristic features of Single drum vibratory rollers

Type of Compactor	Suitable for	Operating mass (kg)	Drum width (mm)	Static linear load (kg/cm)	Amplitude (mm)	Frequency (Hz)
A small vibratory soil compactor	Compaction of sand & silty soils, sub bases and base courses	4200	1365	12.5	1.4	30
		4350	1365	-	1.2	30
A small vibratory soil compactor	Compaction of sand, gravel, silt & silty soils, sub base and base courses	9550	2130	23.8	0.9/1.8	33/30
		9750	2130	24.7	0.9/1.8	33/30
		11150	2130	-	0.8/1.6	33/30
A small vibratory soil compactor	Compaction of sand, gravel, silt & silty soils, sub base and base courses	11350	2130	31.5	0.8/1.7	33/30
		12050	2130	31.5	0.8/1.7	33/30
		11900	2130	-	0.8/1.6	33/30

6.6 GRID ROLLERS:

These rollers have a cylindrical heavy steel surface consisting of a network of steel bars forming a grid with squire holes and may be ballasted with concrete blocks. They are generally towed units and can operate at speeds between 5 and 24 kmph. Typical weights vary between 5.5 tonnes net and 15 tonnes ballasted. Grid rollers provide high contact pressure but little kneading action and are suitable for compacting most coarse grained soils.

GRID ROLLER

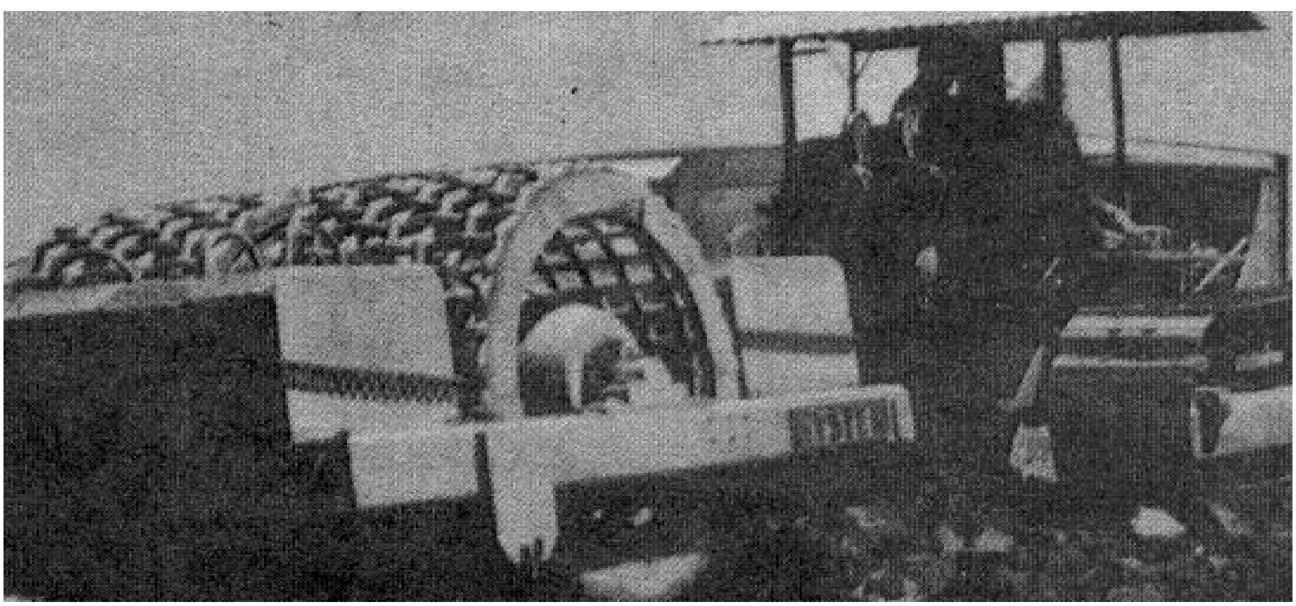


Figure 13: Grid Roller

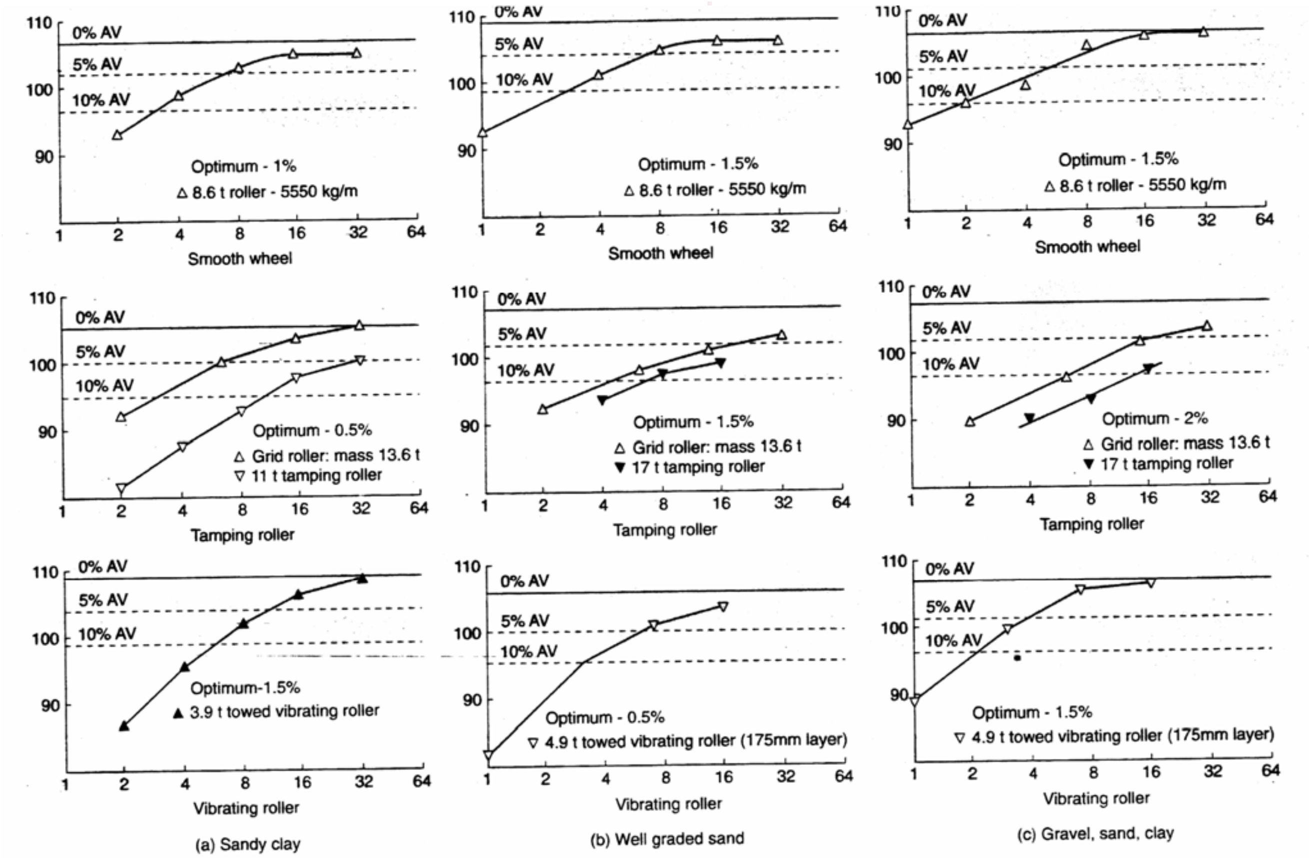


Figure 14: Performance of compaction plants on different type of soils

The above figure gives the information on the characteristics of several soils compacted by various compaction equipments. The performance is illustrated for three type of soils viz. sandy clay, well graded sand, and gravel-sand-clay. Direct comparison is difficult because of the difference between layer thickness, and water content and because different sizes of plants were frequently used. Nevertheless, good performance of the vibrating equipment is evident, even though it was substantially lighter than the other plants used for study. However, satisfactory performance is also observed for the smooth wheel roller.

7.0 CONSTRUCTION MACHINERIES:

Following are the other construction machinery used for handling earthwork:-

7.1 BACKHOE:

Backhoe comprises a bucket on the end of an articulated boom, set on a pneumatic tyred or crawler tractor unit. The boom, bucket arm and bucket are usually controlled by hydraulic rams. Back-acters operate by digging towards the machine in an arc from a small distance above the surface on which the machine stands to a position vertically below the outer edge of the machine. The maximum depth of excavation is related to the length of the boom and machines with depth capacities between 2.6 and 6m are in common use. Long reach machines with nominal reach and depth capacities up to 18 and 14m respectively are also available. Buckets are available for back-acters in different sizes up to 3 cum. depending on the power of the machine and the use. Loading is generally carried out by lifting the bucket and swinging the boom away from the working face to the awaiting haulage vehicle. Alternatively, material can be dumped adjacent to the machine.

Figure 15: Backhoe

7.2 FACE, FRONT OR LOADING SHOVEL:

Face, front or loading shovel is constructed in a similar manner to a back-acter except the boom; bucket arm and bucket operate in the opposite direction, i.e. up and away from the machine.

Generally used for excavating faces upto about 8m high and stockpiles, buckets are available in different sizes upto 4cum (heaped) depending on the power of the machine. Loading is carried out in a similar manner to the back-acter, although some machines have bottom dump buckets to increase the speed of loading. It is useful in excavating soils, weak rocks and blasted rocks from faces in cuttings etc. Some larger excavators can be converted from back-acters to face shovels

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Figure 16: Shovel

7.3 FORWARD LOADER:

Forward loader consists of a pneumatic tyred or crawler tractor at the front of which is mounted a wide bucket that can be moved in a vertical plane. Excavation is carried out by driving the machine towards and the bucket into the material; the bucket is then turned and lifted upwards, thus catching and excavating the material. The hauling vehicle is loaded by driving the loader to and emptying the bucket into the body of a vehicle. Loaders are generally used to excavate the materials at and for a distance above ground level and can be use d to push or haul material in the bucket over short distances. Modern loaders have hydrostatically powered buckets and the smaller units may be equipped with a back-acter (i.e. backhoe loader).

7.3.1 GENERAL CHARACTERISTICS OF FORWARD LOADER:

•Used for loading, backfilling, grabbing, and light dozing
•Set on pneumatic tyres with wide bucket on front
•Payload capacity-700kg
•Breakout force at bucket edge- 3500kg
•Overall length- 5.35m
•Overall width- 2.00m
•Dump angle- 41 degree
•Rollback- 53 degree
•Max height- 4.165m
•Dump height- 3.365m

Figure 17: Forward loader

7.4 JCB/POCLAIN:

These machineries are used for various earthwork purposes such as excavation of earth and loading etc. Its excavating and loading capacities are given below:-

EXCAVATOR PERFORMANCE: -

•Operating weight-8240kg
•Dig depth- 5.31m
•Reach from side-4.55m
•Reach from swing- 6.38m
•Reach from rear side- 7.57m
•Height max fully raised- 6.24m
•Loading height- 3.96m
•Bucket rotation-185 degree
•Digging force-6124kg
•Dipper cylinder- 4125kg
• Operating weight- 8240kg

7.4.1 LOADER PERFORMANCE: -

•Dump height- 2.69m

•Max operating height- 4.10m
•Reach at ground- 1.65m
•Dig depth- 0.15m
•Rollback at GL- 45 degree
•Max dump angle- 45 degree
•Bucket breakout force- 5624kg
•Loader arm force- 5922kg
•Lift capacity to full height- 3401kg

Figure 18: JCB/Poclain

7.5 DRAGLINE:

Dragline equipment is operated from cranes or similar plant with a long boom. Excavation is done by pulling a bucket suspended on a cable towards the machine by a second cable. Thus, draglines are especially suited for the excavation of soft and loose materials from a distance at a level beneath or slightly above their tracks and may be used to excavate under water. Excavated material can be removed directly to a stockpile or loaded into haulage vehicles or conveyer hoppers by rotating the machine with the bucket in the upward position.

7.6 GRAB:

Grab consists of a cable or hydraulically controlled bottom-opening bucket suspended from a crane or a lifting arm. The bucket is opened and dropped on to a material to be removed: it is then closed and the material caught between the jaws lifted in the grab bucket and discharged on to stockpiles or into waiting haulage vehicles. Grabs are typically used for the excavation of pits or trenches and loading to and from stockpiles.

7.7 GRADERS:

Graders are used to spread fill and finely trim the sub grade. They consist of a blade which can rotate in a circular arc about a sub horizontal axis and which is supported beneath a longitudinal frame joining the front steering wheels and the rear drive wheels. The front wheels are generally articulated whilst the rear wheels are set in tandem beneath the motor and control units. The blade is used to trim and redistribute soil and therefore graders usually operate in the forward direction.

Figure 19: Grader

7.8 ROAD LORRIES:

Road lorries are available in sizes up to 38 tonne gross vehicle weight and generally have steel or steel/aluminium sheeted bodies. Such vehicles require to be loaded by other plant but are generally unloaded by side or rear tipping.

7.9 DUMPERS:

Dump trucks or dumpers generally vary in size from 1 to about 80 tonne capacity; large capacity machines are also available but are generally used in mines, quarries or open cast sites. In recent years articulated dump trucks with capacities upto 35 tonne have become popular as they are versatile and are especially suitable for hauling on softer sub grades. The speed of tipping is increased over a road lorry by the absence of a tailgate. Small dumper units are available for work on small sites and mounted dump trucks are also available with load capacities upto about 20 tonne.

Figure 20: Dumper

7.10 CONVEYERS:

Conveyers are built up with a number of units of endless flat belt conveyers placed in series and major changes in direction can be made at transfer points where material from one belt falls and is channeled on to next. Loading is generally carried out via a hopper, which may be designed to screen out over size material. The conveyer may end either above a stockpile or in a stacker, which allows the material to be spread over a large area. Conveyers are generally used in quarries and pits in areas of very steep or poor access.

7.11 DOZERS:

Bulldozer is a tractor equipped with affront pusher blade, which can be raised and lowered by hydraulic rams. An angle dozer has a blade that is capable of being set at an angle to push material sideways whist the tractor moves forward. The tractor unit is usually mounted on crawler tracks thus allowing it to travel over and push off a wide variety of ground conditions although wheel mounted units is available. Blades are manufactured in a variety of styles but are all of heavy-duty construction with a hardened steel basal leading edge driven into the ground to cut and push the material to be excavated

Dozers have a wide variety of roles including excavating soils and weak rocks, ripping moving excavated material over short distances spreading materials, trimming earthworks and acting as a pusher to boost the effective power of scrapers and other plants. Wide ranges of crawler units are available ranging from 45 to 575 kW.

Figure 21: Dozer

712 SCRAPER:

Scraper can excavate load and deposit material in one cycle and may be towed or self propelled (motorized). It consists of a centrally mounted bowl, the bottom, leading edge of which can be controlled. Both towed and self-propelled scrapers are effectively articulated between the front motorized or towing unit and the bowl and larger self-propelled scrapers may have second engine mounted on the rear. During excavation and loading and as the machine moves forward, the cutting edge scrapes the top layer of soil into the bowl. On completion of loading the apron is lowered and the bowl raised. Deposition of the material is carried out by moving the ejector forward with the apron raised and the bowl partially lowered. The thickness of the layer of deposited soil can be regulated by control of the ejector, apron, and bowl. Ideally haulage should take place over well-maintained haul roads with minimum of steep gradients or sharp turns.

8.0 CONCLUSION:

With the invent of compacting equipments and construction machinery, a lot of work can be done in a short span of time with economy. Some of the important uses of these equipments and machineries are given as following:

1. Working man hours and quantum of work are increased
2. Good quality of work can be maintained
3. Saving in project completion time and cost of project
4. Easy transportation of material from distant locations
5. Better ride quality of embankment can be achieved
6. Different materials can be blended/mixed to find a suitable material for earthwork
7. Typical tasks can be performed which are tough for manual labour

9.0 REFERENCES:

1. Guidelines for earthwork in Railway projects, July 2003
2. Earthworks: A guide by N.A.Trenter
3. State of the art: Compaction of earthwork and sub grades- IRC special report no. 3-1999
4. IS: 2720-1974 (Part-8)- Determination of water content- dry density relation using heavy compaction
5. IS: 2720-1983 (Part-14)- Determination of density index (Relative Density) of cohesion less soils
6. IS: 2720-1974 (Part-28)- Determination of dry density of soils in place by sand replacement method
7. IS: 2720-1975 (Part-29- Determination of dry density relation of soils in place by the core cutter method
8. Pamphlets of M/S L&T, Escorts, Ingersoll Rand and Escorts JCB Ltd.