TECHNICAL NOTE NO: 16

Sub: Roads –Compaction of soils, Granular layers, Wearing Courses with different type of rollers – Role of Rollers - Guidelines – Communicating - Reg.

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1. Introduction:

Compaction of Soil:

- Compaction is pressing the soil particles close to each other by mechanical methods.
- Air is expelled from the void space in the soil mass and hence the mass density is increased.
- Compaction is done to increase engineering properties of soils.
- Medium cohesion soils are compacted by means of rolling.

Loose Soil Compacted soil

Compaction with rollers is a common construction and civil engineering technique used to increase the density and reduce the voids in soil, asphalt, or other materials. This process is crucial for enhancing the load-bearing capacity, stability, and longevity of various construction projects such as roads, highways, parking lots, foundations, and more. Rollers are heavy machinery designed specifically for compaction purposes, and they come in different types, each suitable for specific applications. This document will be helpful in selecting the appropriate type, and better operation aspects of the compaction equipment.

Here are some key aspects of compaction with rollers:

2. Classification of rollers:

Rollers are broadly classified into the following types depending on their utility in different situations.

a) Static Roller : i) Three wheeled roller
ii) Tandem Roller (Two wheeled roller)
b) Sheepsfoot roller.

c) Tamping foot roller

d) Pneumatic tyred roller

e) Vibratory roller (Single & Double drum)

2.1 Static Roller: A static roller, also known as a static or non-vibratory roller, is a type of road construction or soil compaction machinery used to compact soil, asphalt, and other materials. Unlike vibratory rollers, which use vibration to compact the material, static rollers rely on their weight and the static force they exert to achieve compaction. The capacity of the static or smooth wheeled roller ranges from 2 to 20 Tonne which can be increased by adding sand or water as ballast to the roll.

Fig.1.Three wheeled roller

Fig.2.Two Wheeled Tandem Roller

2.2 Sheepsfoot Rollers: Sheepsfoot rollers have drum-shaped cylindrical drums with round or rectangular lugs. They are used for compacting cohesive soils and achieving higher compaction depths. Sheepsfoot roller has metal projections of various shapes on its rolls for penetrating and compacting the lower portions of a formation or sub-grade. One or more hollow steel cylindrical drums with rows of steel studs like sheeps foot are mounted on it. Sheepsfoot rollers are slow, have high rolling resistance and the cost of compaction per unit volume is very high. The thickness of soil compacted is generally of the order of 30 cm with a foot/lug of 20 to 25 cm. The rolling should continue till the foot does not penetrate the surface fully. This limit is called "walkout" on the surface.

Fig.3. Sheepsfoot Rollers

2.3 Padfoot Rollers: Padfoot rollers have a drum with pad-like protrusions. They are excellent for compacting cohesive soils like clay, as the pads penetrate the soil to provide greater compaction. Tamping foot rollers have working speeds in the range of 24-32 km/h, the forces of compaction are due to pressure and impact which results in increase in the compaction capacity as well as production. They are best suited for large projects. There are also self-propelled padfoot roller weighing equal to or more than 11 tons having a linear load of 30 kg/cm. They can compact clay materials from 30 cm to 40 cm thickness.

Fig.4. Padfoot roller/Tamping roller

2.4 Pneumatic Rollers: These rollers have rubber tires or pneumatic rollers that can be filled with air to adjust the weight and compaction effort. They are used for compacting asphalt and are often used for the final finish on a road surface. They compact soil/bituminous mix by pressure and kneading action. The total weight of the PTR can be increased from 11 tonne to 25 tonne or more by ballasting with steel sections or by ballasting using water, sand or pig iron.

Fig.5. Pneumatic tyred Roller

Load requirement for compaction at different depth are shown in Table 1

Table 1: Load requirements for compaction at different depths

Passes	Job Characteristics	Maximum Depth of Layer (in mm)	Wheel Load Desired (in tons)
4 to 8	Compaction of loamy sand	300 mm 500 mm 700 mm	1.5 to 1.7 2.0 to 2.5 3.0 to 4.5
4 to 6	Compaction of bituminous material	80 mm 130 mm 200 mm	1.5 2.5 4.0
4-6	Compaction of cement concrete	100 mm 150 mm	4.0 6.0

2.5 Vibratory Rollers: A vibratory roller is an improved version of an ordinary smooth- steel roller by attaching two rotating weights to the axle as shown in Fig.6 Vibratory road roller may be towed, self propelled or manually controlled. Self propelled roller may have single or tandem vibrating drums. Smooth drum vibratory compactors generate three compactive efforts: pressure, impact and vibration.

Fig. 6. Smooth Drum Vibratory Roller

Vibratory Rollers are the following types:

a) Self Propelled Roller: A self propelled roller has a steel drum and two pneumatic wheels at the rear as shown in Fig.7. Its dead weight vary from 8-12 Tonne.

Fig.7. Self Propelled Roller

b) **Tandem Vibratory Rollers:** The term "tandem" refers to the presence of two large and smooth drums positioned one behind the other, which are used for the compaction process. These rollers are also equipped with a vibration system that

helps achieve better compaction results. The roller has vibration and drive on both the drums as shown in Fig.8.

Fig.8. Tandem Vibratory Roller

c) **Double Drum Walk Behind Roller (Duplex Roller)** : This type of roller (shown in Fig.9) is used for compacting soil in restricted areas, trenches etc.

Fig.9 Double Drum Walk Behind Roller

d) **Light Tandem Rollers:** These often referred to as light compactors, are compact and versatile compaction machines (shown in Fig. 10) used primarily for smaller-scale construction and compaction tasks. They are smaller and lighter in weight compared to their larger counterparts, such as heavy tandem rollers or single-drum compactors. Light tandem rollers are typically used for a variety of

purposes in construction and landscaping projects, shoulders , pathways and approach roads. The static weight in the range of 900 – 1500 Kg.

Fig 10. Light Tandem Roller

2.5.1 Effect of Characteristics of Vibratory Roller:

The characteristics of a vibratory roller, including its weight, drum type, vibration frequency, and amplitude, can have a significant impact on the compaction process and the quality of the compacted material. Here are the effects of various characteristics of a vibratory roller on the compaction process:

Weight:

Effect: The weight of the vibratory roller is one of the most critical factors in compaction. Heavier rollers apply more force to the material being compacted, resulting in greater compaction efficiency and increased density.

Impact: A heavier roller is generally more effective at compacting thicker layers of material, such as asphalt or soil. It can also overcome resistance from more resilient or cohesive materials.

Drum Type:

Effect: The drum type can be smooth or have padfoot (also known as sheepsfoot) or segmented designs. Smooth drums are used for finishing and smoothing, while padfoot drums are suitable for cohesive soils.

Impact: The choice of drum type depends on the type of material being compacted. Smooth drums are effective for asphalt and granular materials, while padfoot drums are better for cohesive soils. Segmented drums provide versatility for a wider range of materials.

Vibration Frequency:

Effect: Vibration frequency refers to how many times per second the drum vibrates. Higher frequencies typically result in better compaction of granular materials.
Impact: Higher frequencies are generally used for loose granular materials like gravel, as they help settle the material efficiently. Lower frequencies may be more suitable for cohesive soils.

Vibration Amplitude:

Effect: Vibration amplitude refers to the extent of vertical movement of the drum. Greater amplitude allows for deeper compaction.
Impact: Greater amplitude is useful when compacting thicker layers of material or when deeper compaction is required. It can also help with achieving a higher degree of compaction.

Vibration Mechanism:

Effect: Vibratory rollers can employ different vibration mechanisms, including eccentric weights or hydraulic mechanisms.
Impact: The choice of vibration mechanism can affect the control and precision of the compaction process. Hydraulic systems may provide more precise control of vibration amplitude and frequency.

Operator Skill:

Effect: The skill and experience of the operator play a crucial role in achieving optimal compaction results.
Impact: An experienced operator can adapt the roller's characteristics to the specific material and conditions on the construction site, making adjustments for optimal compaction.

Surface Conditions:

Effect: The characteristics of the existing surface, including its texture and moisture content, can influence the compaction process.
Impact: It's essential to consider the surface conditions when choosing the appropriate settings for the vibratory roller. Proper preparation of the surface, such as moisture control, can enhance compaction efficiency.

3. Factors Affecting Compaction:

Moisture Content: The moisture content of the material significantly impacts its compaction. The right moisture content is essential for achieving optimal compaction results.

Type of Material: The type of material being compacted (e.g., granular, cohesive) dictates the choice of roller type.

Layer Thickness: The thickness of the compacted layers can affect the compaction process. Thin layers require less effort compared to thick ones.

Roller Speed: The speed at which the roller is operated also impacts compaction. Too fast or too slow may lead to suboptimal results.

In summary, the characteristics of a vibratory roller have a direct influence on the compaction process, including its efficiency and the quality of the compacted material. Selecting the right roller with the appropriate characteristics and settings for the specific job and material is crucial for achieving optimal compaction results in construction projects.

4. Safety Precautions:

Safety is paramount when using heavy machinery like rollers. Operators should be properly trained, and construction sites should implement safety measures to protect workers and the public.

Proper compaction with rollers ensures that construction projects meet structural and durability requirements. The choice of roller type and the compaction process are determined by the specific needs of the project and the type of materials being compacted.

5. SELECTION OF ROAD ROLLER

Selection Based on Type of Work is shown in Table 2 below.

Table:2

S. No.	Layer	Layer Thickness (mm)	Type of Roller
1)	WMM	≤100 mm	Static Roller (8-10 Tonne)
		100 mm - 200 mm	Vibratory Road Roller with a minimum static weight of (8-10 Tonne) Speed not to exceed 5 km/h
2)	Bituminous Compaction		
		Initial or Breakdown Rolling	Roller with a dead weight of 8-10 Tonne
		Intermediate Rolling	Roller with a dead weight of 8-10 Tonne or Vibratory Roller or Pneumatic tyre Road Roller of 12-15 Tonne weight Or combination roller of 8-10 Tonne weight
		Finish Rolling	6-8 Tonne Smooth wheeled Tandem Roller
3)	Embankment		Static Roller of 8-10 Tonne or Padfoot Roller or Heavy Pneumatic Tyred Roller
4)	Special Applications on soils	250 mm	Vibratory Roller of 8-10 Tonne static weight
		500 mm	Vibratory Roller of 15-20 Tonne static weight

The selection of Road Roller based on the specification of the job being undertaken is as under. This is shown in Table 3.

S. No.	Layer	Layer Thickness (mm)	Roller in Order of Preference
1)	BM	50 mm - 75 mm	Static Roller (8-10 Tonne) Vibratory Roller (8-10 Tonne) Pneumatic Tyred Roller, Or combination roller of 8-10 Tonne weight Tandem Static Road Roller (6-8 Tonne)
		80 mm - 100 mm	Static Roller (8-10 Tonne) Vibratory Roller (8-10 Tonne) Pneumatic Tyred Roller, Or combination roller of 8-10 Tonne weight Tandem Static Road Roller (6-8 Tonne)
2)	SDBC	25 mm - 50 mm	Static Roller (8-10 Tonne) Vibratory Roller (8-10 Tonne) Pneumatic Tyred Roller, Or combination roller of 8-10 Tonne weight Tandem Static Road Roller (6-8 Tonne)
3)	DBM	50 mm - 125 mm	Static Roller (8-10 Tonne) Vibratory Roller (8-10 Tonne) Pneumatic Tyred Roller, Or combination roller of 8-10 Tonne weight Tandem Static Road Roller (6-8 Tonne)
4)	BC	25 mm - 50 mm	Static Roller (8-10 Tonne) Vibratory Roller (8-10 Tonne) Pneumatic Tyred Roller, Or combination roller of 8-10 Tonne weight Tandem Static Road Roller (6-8 Tonne)
5)	WMM	75 mm - 100 mm	Static Roller (8-10 Tonne)
6)	WMM	100 mm - 200 mm	Vibratory Roller (8-10 Tonne)

The choice of a roller for the compaction of embankment and sub grade is as mentioned in Table 4 below

Table. 4

S. No.	Type of Soil	Choice of Roller	Remarks
1)	Granular	i) Static three wheeled roller (8-10 Tonne) ii) Vibratory Roller (8-10 Tonne) iii) Pneumatic Tyred Roller (12-15 Tonne)	
2)	Uniformly graded soil	i) Static three wheeled roller (8-10 Tonne) ii) Pneumatic Tyred Roller (12-15 Tonne) iii) Vibratory Roller (8-10 Tonne)	
3)	Clay and silty soil	Sheepsfoot Roller	

6. Relationship between Field Dry Density (FDD), Moisture Content (MC), and the number of passes required for compaction:

The relationship between Field Dry Density (FDD), Moisture Content (MC), and the number of passes required for compaction is not typically expressed through a simple mathematical equation due to the complex nature of compaction processes. However, these three factors are closely related in achieving the desired compaction in soil or other materials. Here's how they are interconnected:

Field Dry Density (FDD): This is the density of the compacted material after compaction, expressed as mass per unit volume (e.g., kg/m³ or g/cc). Achieving the specified FDD is one of the primary goals of compaction.

Moisture Content (MC): Moisture content is the percentage of water present in the material being compacted. It plays a critical role in compaction because the amount of moisture affects the material's compaction properties. The optimum moisture content (OMC) is the moisture level at which the material compacts most effectively.

Number of Passes: The number of passes required for compaction depends on several factors, including the initial state of the material, the type of compaction equipment, and the specified FDD. As compaction progresses, the number of passes may vary, typically decreasing as the material becomes denser.

However, researchers derived approximate relationship between the above three parameters for arriving the number of passes required for desired compaction of Embankment soils which is as shown below.

*FDD= 1.065+0.033(MC) + 0.084 (NP), Where

FDD: Field Dry Density in g/cc, MC: Moisture Content in %, NP: Number of Passes.

Limitations to use this equation:

i) Layer thickness should be < 300 mm
ii) Minimum Roller Capacity: 8- 20 Tonne/ Vibratory Roller
iii) Speed of Roller : <= 5 Km/Hour.

Example:

If FDD: 1.90 g/cc, OMC: 11%, then

1.90= 1.065+0.033(11) +0.084(NP)

NP: 0.472/0.084 = 5.61 or say 6 Passes required.

7. Compaction requirements of different components in the road crust:

MoRD has specified that the MDD should be determined in the lab based on Light Compaction only for Low Volume Roads as per IS :2720 (Part 7), whereas MoRT&H specified that the lab MDD should be determined based on heavy compaction for SHs, MDRs , NHs and Express ways as per IS: 2720 (Part 8).

The details of relative compaction requirements are as follows.

S.No	Type of work/Material	Low Volume Roads (VRs and ODRs) (MoRD). Traffic < 2 msa		MDRs, SHs, NHs and Express Ways (MoRT&H) - Traffic > 2 msa	
		Lab MDD	Relative compaction %	Lab MDD	Relative compaction %
1	Earth work for Embankment	As per IS : 2720 (Part 7) - Standard Proctor's Test	Not less than 98%	As per IS: 2720 (Part 8) - Modified Proctor's Test	Not less than 95%
	Expansive Clays		90% – 95%		90%-95%
2	Sub Grade		Not less than 100%		Not less than 97%
3	Granular Sub Base		Not less than 100%		Not less than 98%
4	Granular Base (WMM)		Not less than 100%		Not less than 98%
5	Cement Treated Subbase/Base		Not less than 100%		Not less than 98%

8. Quality Control:

Quality control is crucial during the compaction process. Engineers and inspectors often use tests, such as the Proctor compaction test or nuclear density gauge, to ensure that the compaction meets the required specifications.

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References:

1) IRC: SP:97-2013: Guidelines on compaction equipment for Road works.

2) IRC: 2018- Pocket Book for Road Construction Equipment

3) *IRJET Journal: Vol 3, Issue: 05, May 2016

4) MoRT&H: 5th Revision- 2013

5) MoRD: First Revision- 2014.