POCKET BOOK
FOR
ROAD CONSTRUCTION EQUIPMENT

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FOREWORD

It gives me great pleasure to present the first edition of the Pocket Book for Road Construction Equipment.

The highway sector in India is poised for rapid growth and mechanisation plays an important role in achieving economy, speed and quality in highway construction and maintenance. Currently, there exists no single document covering all major equipment involved in road construction. Therefore, an initiative has been taken to come out with a compilation of construction equipment for road, bridge and tunnel works.

The Pocket Book for Road Construction Equipment is meant to act as a single-stop platform for acquainting the practising Highway Engineers and stakeholders with the mechanisation aspect involved in each activity of road making. References to Ministry's Specifications for Road & Bridge Works have been drawn for each construction activity. Critical equipment for road and bridge works as well as tunnel works has been discussed. A summary of various quality control tests along with requisite apparatus and reference IS Codes has also been included for easy reference. This book has been compiled based upon extensive study of the IRC Publications and IS Codes and review of literature and current practices.

The Pocket Book for Road Construction Equipment is the result of the untiring efforts of the officers of the Roads Wing and other professionals who contributed to the drafting of this document. I wish to express my appreciation for the efforts put in by Shri K.C. Sharma, Shri Ananyabrata Maulik, Shri N.K. Nayak and Dr. Sanjay Wakchaure in preparing this document and GSS Committee for reviewing the document.

I hope this Pocket Book, in its present form, will prove to be very useful for day to day reference for all the engineers in highway profession. However, the compilation of this kind of Pocket Book will need to be updated periodically with changes in technology and environment. The Indian Roads Congress would, therefore, welcome suggestions and feedback from users so that any further amplification/ modification/ updating may be attempted in due course.

New Delhi
9th November, 2018

(S.K. Nirmal)
Secretary General, IRC

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POCKET BOOK FOR ROAD CONSTRUCTION EQUIPMENT

1. INTRODUCTION

The highway sector in India has witnessed a rapid growth and this momentum shall continue. Mechanisation has played an important role in achieving economy, speed and quality in highway construction and maintenance. To support the construction industry and the road departments, an initiative has been taken by the Roads Wing of Ministry of Road Transport and Highways (MoRTH) to come out with a comprehensive compilation of construction equipment for road, bridge and tunnel works.

The first draft document was prepared by Shri Ananyabrata Maulik. Inputs from Shri K.C. Sharma, Shri N.K. Nayak, Dr. Sanjay Wakchaure and representatives of Construction and Equipment Industry and professionals from government organisations including Border Roads Organisation(BRO) were incorporated in the document. The document was approved by the General Specifications and Standards Committee(GSS) in its meeting held on 25.04.2018. The Executive Committee of IRC approved the document in its meeting held on 03.05.2018 with some comments. The document, after incorporating necessary changes, was approved by the IRC Council in its 215th meeting held at Aizawl (Mizoram) on 04.05.2018 for printing.

2. SCOPE

This document is intended to act as a one-stop platform for acquainting the practising engineers and stakeholders with the mechanisation aspect involved in each activity of road construction and maintenance. This document has been compiled based upon extensive study of the IRC Publications, BIS Codes, review of literature and current practices.

This document is divided into five parts. Parts A and B cover equipment catering to road and bridge works respectively. References have been made to MoRTH Specifications. Each essential equipment for road and bridge works has been explained separately and specifications provided with respect to equipment performance. Part C covers equipment for tunnel works, where the various tunnelling methods along with types of Tunnel Boring Machine (TBM) and Tunnel Ventilation System (TVS) have been explained. Part D lists out the requisite apparatus for various quality control tests as well as the essential equipment recommended to be maintained in the central and plant laboratories. Part E identifies the essential equipment for restoration works in landslide management. This list of equipment may also be used as reference for mitigation of other disasters like floods.

Important aspects of Bailey bridge have been included along with recommendations on its selection criteria. Emission norms for construction equipment vehicles and diesel gensets are included in the Appendices.

Surveying techniques and equipment have not been included in this document. Instrumentation for bridges and tunnels is also beyond the scope of this document.

PART A : EQUIPMENT FOR ROAD WORKS

3. ACTIVITY WISE EQUIPMENT FOR ROAD WORKS

Table 1 lists out the essential equipment required for each road construction activity.

Table 1: Activity Wise Equipment for Road Works

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
Site Clearance				
1.	Clearing and Grubbing	i) Dozer/ Motor Grader/ Hydraulic Excavator/ Backhoe Loader + Ripper	201	
		ii) Tipper Truck or Tractor-Trolley		For haulage.
2.	Dismantling Culverts, Bridges and Other Structures/ Pavements	i) Air Compressor + Pneumatic Breaker or Hydraulic Excavator/ Backhoe Loader + Hydraulic Breaker	202	For dismantling of cement concrete pavement, cement concrete structures, guard rails/ fencing, electric poles, brick/tile/ stone masonry work.
		ii) Portable Cutting Tools (eg: Sawing Machine, Gas Cutting Machine etc.)		Required for cutting wood/ steel work.
		iii) Mobile Elevating Work Platform (MEWP)		For working at a height above ground level.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		iv) Cold Milling Machine or Tractor/Dozer/ Motor Grader/ Backhoe Loader/ Hydraulic Excavator + Ripper/ Scarifier		For dismantling of flexible pavement.
		v) Diamond Cutter/ Saw		For dismantling of cement concrete pavement.
		vi) Crane		For lifting application (eg: pipes); minimum 8 tonne capacity recommended.
		vii) Tipper Truck or Tractor-Trolley		For haulage.
Earthwork, Erosion Control and Drainage				
3.	Excavation in Soil/ Ordinary Rock/ Hard Rock/ Marshy Soil; Pre-splitting of Rock Excavation Slopes	i) Dozer or Scraper or Hydraulic Excavator or Hydraulic Shovel or Backhoe Loader	301, 302, 303, 304	Dozer for hill cuts and cuts down vertical faces. Suited for short haulage with lead up to 100 m. Scraper best suited for shallow road embankments across generally flat terrains. Suited for haulage up to 300 m.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		ii) Air Compressor + Pneumatic Breaker or Hydraulic Breaker (attached to Hydraulic Excavator/ Hydraulic Shovel/ Backhoe Loader) or Drilling Equipment + Blasting Accessories		For excavation in hard rock.
		iii) Dewatering Pump		Required in case water gets collected in excavation due to springs, seepage, rain or other causes.
		iv) Tipper Truck or Tractor-Trolley		For transportation of excavated material. Front end loader/ backhoe loader/ hand tools (eg: spade) to be provided for loading of the tipper truck in case dozer is used and the haul distance is large.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
4.	Construction of Embankment (including Sub-Grade and Earthen Shoulders) with Material obtained from Roadway and Drain Excavation, Borrow Pits or other Sources	i) Hydraulic Excavator or Backhoe Loader	305, 313	
		ii) Tipper Truck or Tractor-Trolley		For transportation of material to work site.
		iii) Dozer		For spreading operation; also for stripping and storing of topsoil from area of cutting/ covering for re-vegetation purpose **(Clause 305.3.3)**.
		iv) Motor Grader		For grading operation.
		v) Dewatering Pump		Required in case the foundation of the embankment is in an area with stagnant water.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		vi) Ripper/ Scarifier/ Disc Harrow (attached to Tractor/Dozer/ Motor Grader/ Hydraulic Excavator/ Backhoe Loader)		Required for scarification of original ground in case it has to be compacted prior to placement of first layer of embankment **(Clause 305.4.3)**. Also for uniform mixing of water with material in case its moisture content is low.
		vii) Water Tanker		For addition of water to achieve desired moisture content.
		viii) Vibratory Roller or Static Roller or Pneumatic Tyred Roller		
		ix) Dressing Tools		For shaping and dressing the shoulders/ verge/ road-bed/ side slopes.
5.	Turfing with Sods, Seeding and Mulching	i) Water Tanker	307, 308	For watering the sods/seeds.
		ii) Tractor-Trolley or Tipper Truck		For transportation of fertilizers, sods, seed etc.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
6.	Surface (Unlined)/ Sub-Surface Drains	i) Hydraulic Excavator or Backhoe Loader	309	For excavation/ backfilling; Haulage equipment not considered as excavated material is assumed to be used at site in Embankment/ Sub-Grade construction.
7.	Preparation and Surface Treatment of Formation	i) Smooth Wheeled Roller	310	8-10 tonne roller preferred.
		ii) Water Tanker		For addition of water to achieve desired moisture content.
Sub-Bases and Bases (Non- Bituminous)				
8.	Granular Sub-Base with close graded material by Plant Mix Method	i) Wet Mix Plant	401	
		ii) Electric Genset		
		iii) Front End Loader or Backhoe Loader		For loading and transportation of aggregates/ mix.
		iv) Tipper Truck		
		v) Motor Grader		For spreading/ grading operation.
		vi) Water Tanker		For controlling moisture content at the time of compaction.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		vii) Vibratory Roller or Smooth Three Wheeled Roller		
9.	Granular Sub-Base with close graded material by Mix in Place Method	i) Tractor + Rotavator/ Disc Harrow	401	
		ii) Water Tanker		
		iii) Motor Grader		
		iv) Vibratory Roller or Smooth Three Wheeled Roller		
10.	Lime Stabilisation for Improved Sub-Grade/ Sub-Base or Cement Treated Soil and Cement-Flyash Treated Sub-Base/ Base	i) Tractor with Ripper and Rotavator attachments or Tractor-Disc Harrow or Mobile Soil Stabiliser or Soil Stabilisation Plant (Stationary)	402, 403	For stationary plant, Backhoe Loader and Tipper Truck to be provided for transportation of material to plant and treated material from plant to site. Treated material to be laid at site using paver finisher.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		ii) Motor Grader		
		iii) Vibratory Roller		
		iv) Water Tanker		
11.	Water Bound Macadam Sub-Base/ Base	i) Tipper Truck	404	For transportation of aggregates to site.
		ii) Motor Grader		For spreading/ grading operation.
		iii) Smooth Three wheeled Roller or Vibratory Roller		
		iv) Water Tanker		
12.	Crushed Cement Concrete Sub-Base	i) Front End Loader or Backhoe Loader	405	For transportation of crushed cement concrete slabs to site.
		ii) Tipper Truck		
		iii) Motor Grader		For spreading/ grading operation.
		iv) Smooth Three wheeled Roller or Vibratory Roller		
		v) Water Tanker		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
13.	Wet Mix Macadam Sub-Base/Base or Crusher Run Macadam Base by Plant Mix Method	i) Wet Mix Plant	406, 407	
		ii) Electric Genset		
		iii) Front End Loader or Backhoe Loader		
		iv. Tipper Truck		
		v) Paver Finisher(with electronic sensor)		For Crusher Run Macadam, Motor Grader may be used for spreading/ finishing operation.
		vi) Smooth Three Wheeled Roller or Vibratory Roller		
		vii) Water Tanker		
14.	Crusher Run Macadam Base by Mix in Place Method	i) Tipper Truck or Tractor-Trolley	407	For transportation of aggregates to site.
		ii) Tractor + Rotavator/ Disc Harrow		For in situ mixing operation.
		iii) Motor Grader		For spreading operation.
		iv) Smooth Three Wheeled Roller or Vibratory Roller		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		v) Water Tanker		
15.	Construction of median and island with earthen top, using soil from borrow pits or roadway cutting	i) Hydraulic Excavator or Backhoe Loader	408	For excavation in case of borrow pits.
		ii) Tipper Truck		For transportation of soil to site.
		iii) Water Tanker		
		iv) Plate Compactor		
16.	Cement Concrete Kerb and Kerb with Channel	i) Concrete Mixer or Concrete Batching and Mixing Plant	409	Transit Mixer or Agitator Truck to be provided for transportation of mix in case plant site is far from work site.
		ii) Electric Genset		
		iii) Kerb Casting Machine		
		iv) Water Tanker		
		v) Diamond Cutter/Saw		For cutting grooves.
17.	Footpaths and Separators	i) Vibratory Roller or Plate Compactor	410	For preparation of base for cast in situ/precast concrete slabs/ blocks/ panels, tiles or natural stone slabs.
		ii) Water Tanker		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		iii) Concrete Mixer + Electric Genset + Mould		For in situ casting of concrete slab/ block/ panel.
Bases and Surface Courses (Bituminous)				
18.	Prime Coat or Tack Coat or Fog Spray	i) Road Sweeper	502, 503, 513	
		ii) Air Compressor		For cleaning by high pressure air jet.
		iii) Bitumen Distributor		
		iv) Water Tanker		To make surface damp in case of bitumen emulsion.
19.	Bituminous Macadam or Dense Bituminous Macadam or Sand Asphalt Base Course or Bituminous Concrete or Close Graded Premix Surfacing/ Mixed Seal Surfacing or Open Graded Premix Surfacing Using Viscosity Grade Paving Bitumen or Seal Coat Type B (Using Paving Bitumen) or Stone Matrix Asphalt	i) Hot Mix Plant	504, 505, 506, 507, 508, 510.1, 511, 515	

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		ii) Electric Genset		
		iii) Front End Loader or Backhoe Loader		
		iv) Tipper Truck		
		v) Paver Finisher (with electronic sensor)		
		vi) Smooth Wheeled Roller or Vibratory Roller or Pneumatic TyredRoller		Usually 8-10 tonne smooth wheeled roller for Initial Breakdown Rolling; 8-10 tonne static/ vibratory roller or 12-15 tonne pneumatic tyred roller for Intermediate Rolling; 6-8 tonne smooth wheeled roller for Finish Rolling.
20.	Surface Dressing or Seal Coat Type A or Crack Prevention Courses (Stress Absorbing Membrane)	i) Road Sweeper	509, 511, 517	
		ii) Air Compressor		For cleaning by high pressure air jet.
		iii) Water Tanker		For making surface damp; used only in case of bitumen emulsion.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		iv) Bitumen Distributor		
		v) Front End Loader or Backhoe Loader		For transportation of aggregates/ chips.
		vi) Tipper Truck		
		vii) Aggregate Chip Spreader		
		viii) Pneumatic Tyred Roller		
21.	Open Graded Premix Surfacing using Cationic Bitumen Emulsion or Seal Coat Type B (using Bitumen Emulsion)	i) Cold Bituminous Mixing Plant (Mobile type) or Concrete Mixer	510.2, 511	
		ii) Electric Genset		
		iii) Front End Loader or Backhoe Loader		
		iv) Tipper Truck		
		v) Paver Finisher (with electronic sensor)		
		vi) Smooth Wheeled Roller or Vibratory Roller		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
22.	Slurry Seal or Micro-Surfacing	i) Road Sweeper	512, 514	
		ii) Air Compressor		
		iii) Mobile Slurry Seal/ Micro-Surfacing Equipment		
		iv) Pneumatic Tyred Roller		Only in cases where rolling is required on account of inadequate cohesion.
23.	Mastic Asphalt	i) Batch type Hot Mix Plant or Mastic Cooker	516	
		ii) Wheel barrows and Flat Mortar Pans or Towed Mixer Transporter (with arrangements for stirring and heating the mix)		Wheel barrow for short distance haul only.
		iii) Paver Finisher + Aggregate Chip Spreader or Wooden Trowels, Heavy Wooden Floats, Suitable Hand Tools Gauge, Straight Edge and Hand Level, Angle Irons		For laying/ spreading purpose.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
24.	Bituminous Cold Mix (including Gravel Emulsion)	i) Cold Bituminous Mixing Plant or Concrete Mixer	518	Concrete Mixer may be permitted for small jobs.
		ii) Electric Genset		
		iii) Front End Loader or Backhoe Loader		
		iv) Tipper Truck		
		v) Paver Finisher (with electronic sensor)		
		vi) Pneumatic Tyred Roller		For Initial Rolling; 8-10 tonne roller usually preferred.
		vii) Smooth Wheeled Roller		For Finish Rolling; 6-8 tonne roller usually preferred.
25.	Recycling of Bituminous Pavement (Hot In Plant Recycling)	i) Cold Milling Machine or Scarifier/ Grid Roller/ Ripper and Crusher (usually Impact type)	519	For removal of existing bituminous pavement.
		ii) Road Sweeper		For cleaning and preparation of the surface.
		iii) Air Compressor		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		iv) Bitumen Distributor		For application of prime/tack coat.
		v) Hot Mix Plant (with RBP addition facility in Mixer)		
		vi) Electric Genset		
		vii) Front End Loader or Backhoe Loader		
		viii) Tipper Truck		
		ix) Paver Finisher (with electronic sensor)		
		x) Smooth Wheeled Roller		For Initial Breakdown Rolling; usually 8-10 tonne roller used.
		xi) Static or Vibratory Roller/ Pneumatic Tyred Roller		For Intermediate Rolling; usually 8-10 tonne operating weight preferred for static/vibratory roller and 12-15 tonne for pneumatic tyred roller.
		xii) Smooth Wheeled Roller		For Finish Rolling; usually 6-8 tonne roller used.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
26.	Recycling of Bituminous Pavement (Hot in Place Recycling)	i) Hot in Place Recycling Equipment	519	
27.	Recycling of Bituminous Pavement (Cold in Place Recycling)	i) Cold in Place Recycling Equipment	519	
Cement Concrete Pavement				
28.	Dry Lean Concrete (DLC)	i) Road Sweeper	601	For cleaning the subgrade prior to laying of DLC.
		ii) Air Compressor		
		iii) Concrete Batching and Mixing Plant or Concrete Mixer		
		iv) Electric Genset		
		v) Front End Loader or Backhoe Loader		For transportation of aggregates/ dry lean concrete.
		vi) Tipper Truck		
		vii) Paver Finisher (with electronic sensor)		
		viii) Vibratory Roller		
		ix) Water Tanker		For curing operation.
		x) Scabbler		For finishing operation.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
29.	Pavement Quality Concrete (PQC)	i) Road Sweeper	602	For cleaning of sub-base prior to placement of the separation membrane.
		ii) Air Compressor		
		iii) Concrete Batching and Mixing Plant or Concrete Mixer		
		iv) Electric Genset		
		v) Front End Loader or Backhoe Loader		For transportation of aggregates.
		vi) Tipper Truck or Transit Mixer		For transportation of pavement quality concrete.
		vii) Concrete Placer/ Spreader		
		viii) Concrete Paver		
		ix) Dowel Bar Inserter or Dowel Cradle/ Chair		
		x) Tie Bar Inserter or Tie Bar Supporting Assembly		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		xi) Concrete Vibrator		
		xii) Floater		
		xiii) Texturing Equipment		
		xiv) Curing Compound Sprayer		For liquid curing compound.
		xv) Diamond Cutter/Saw		For joint cutting.
		xvi) Water Tanker		
		xvii) Edging Tool		
		xviii) Joint Sealant Melter + Joint Sealant Pourer or Joint Sealing Machine		
Geosynthetics				
30.	Crack Prevention Courses (Bitumen Impregnated Geotextile) or Laying Paving Fabric or Glass Grid Beneath a Pavement Overlay	i) Road Sweeper	517, 708	For application of tack coat; tack coat not required for glass fibre grids with adhesive on one side.
		ii) Air Compressor		
		iii) Bitumen Distributor		
		iv) Mechanical or Manual Laydown Equipment (tractor mounted rig)		For laying of paving fabric/ glass grid/ bitumen impregnated geotextile.
		v) Pneumatic Tyred Roller		12-15 tonne roller recommended.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
Traffic Signs, Markings and Other Road Appurtenances				
31.	Traffic Signs/ Overhead Signs	i) Tractor-Trolley or Truck	801, 802	For transportation of signs.
		ii) Backhoe Loader or Hand Tools		For excavation of foundation.
		iii) Concrete Mixer + Electric Genset + Water Tanker		For in situ concrete foundation.
		iv) Crane		For truss and vertical support in case of overhead signs.
32.	Road Markings	i) Road Marking Machine	803	
		ii) Tractor-Trolley or Truck		For transportation of paint material/ glass beads.
Maintenance of Roads				
33.	Restoration of Rain Cuts	i) Hydraulic Excavator or Backhoe Loader	3002	
		ii) Tipper Truck or Tractor-Trolley		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		iii) Water Tanker		For attaining optimum moisture content.
		iv) Plate Compactor or Rammer		
34.	Maintenance of Earthen Shoulders	i) Hydraulic Excavator or Backhoe Loader	3003	For excavation and transportation of fresh soil to site for making up of earthen shoulder.
		ii) Tipper Truck or Tractor-Trolley		
		iii) Motor Grader or Hand Tools		For achieving required grade/ level and trimming of side slopes. Also, for stripping the earthen shoulder in case of excess soil.
		iv) Smooth Wheeled Roller or Vibratory Roller or Hand Roller or Plate Compactor or Rammer		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		v) Water Tanker		For attaining optimum moisture content.
35.	Filling Potholes and Patch Repairs (using Hot Mix prepared in Hot Mix Plant)	i) Pneumatic Breaker or Hand Tools	3004.2	For preparation of pothole/patch area.
		ii) Air Compressor		For cleaning of pothole/patch area.
		iii) Bitumen Distributor		For application of tack coat.
		iv) Hot Mix Plant		
		v) Electric Genset		
		vi) Front End Loader or Backhoe Loader		
		vii) Tipper Truck		
		viii) Smooth Wheeled Roller or Hand Roller or Plate Compactor or Rammer		
36.	Filling Potholes and Patch Repairs (Hot or Cold Mix using Fully Mechanised Means)	i) Pothole Repair Machine	3004.2	

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
37.	Repair of Joint Grooves with Epoxy Mortar or Epoxy Concrete (Maintenance of Cement Concrete Road)	i) Pneumatic Breaker or Hand Tools (eg: Chisel) or Diamond Cutter/Saw	3005.1	For shaping of spalled or broken edges.
		ii) Air Compressor		For cleaning of spalled area.
		iii) Hand Tools (Trowel, Straight Edge, Brush, Shovel, Tamper, Screed etc.)		For application of epoxy mortar/ concrete.
38.	Repair of Old Joint Sealant (Maintenance of Cement Concrete Road)	i) Metal Raker	3005.2	For raking out existing sealant.
		ii) Diamond Cutter/Saw		For removing sealant stuck to the sides of the grooves and widening of grooves.
		iii) Air Compressor		For cleaning of joint grooves.
		iv) Sand Blasting Machine		
		v) Backer Rod Installation Tool/ Roller Wheel		
		vi) Brush		

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		vii) Joint Sealant Melter + Joint Sealant Pourer or Joint Sealing Machine		For pouring sealant.
		viii) Floater/Trowel		
39.	Landslide Clearance	i) Dozer or Hydraulic Excavator or Backhoe Loader		
		ii) Pneumatic Breaker or Hydraulic Breaker (attached to Hydraulic Excavator/ Backhoe Loader)		For breaking hard rock.
40.	Snow Clearance on Roads	i) Dozer or Snow Blower		
Rock Quarrying and Carriage of Material				
41.	Production of Crushed Stone Aggregates	i) Hydraulic Excavator/ Backhoe Loader + Hydraulic Breaker/ Bucket Crusher or Pneumatic Breaker	116, 520	For breaking rocks at rock quarry site.

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		ii) Tipper Truck		For transportation of material to crushing plant site.
		ii) Integrated Stone Crushing Plant		Consists of Primary and Secondary/ Tertiary Crushers and Vibratory/ Revolving Screening Unit(s) to achieve aggregates of desired size.
42.	Loading and unloading of material, including haulage	i) Tipper Truck or Tractor Trolley	105.7	
		ii) Front End Loader or Backhoe Loader		
Soil Nailing				
43.	Drilled and Grouted Soil Nails	i) Hydraulic Excavator or Hydraulic Shovel or Backhoe Loader or Front End Loader or Scraper	3200	

Sl. No.	Description of Work/Activity	Equipment	MoRTH Specifications (Fifth Revision) Clause/ Section	Remarks
		ii) Tipper Truck		
		iii) Drilling Equipment		
		iv) Grouting Equipment		
		v) Air Compressor + Shotcreting Equipment		For temporary facing.
		vi) Crane		For transportation of precast concrete blocks in case of permanent facing.

4. DESCRIPTION OF ESSENTIAL EQUIPMENT FOR ROAD WORKS

4.1 Dozer

4.1.1 Dozer (**Figure 1**) is a self-contained tractor-powered unit with a blade attached to the machine's front. It is primarily a pushing unit

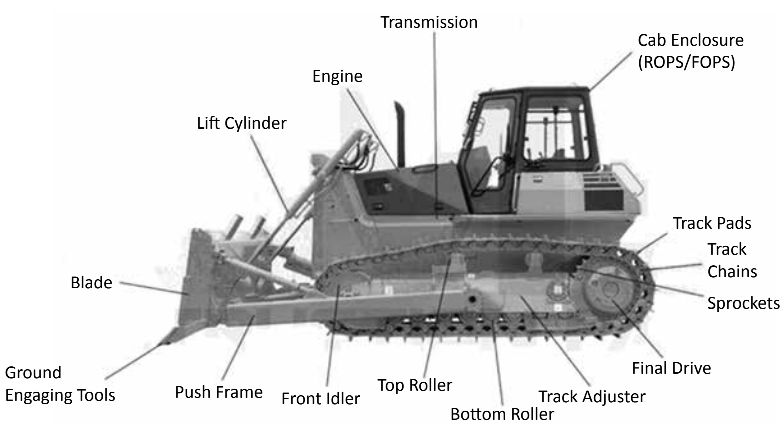


Figure 1: Dozer (Crawler Type)

but can perform a variety of functions depending on the attachment fixed to the basic unit.

A dozer can economically push material up to a distance of 100 m.

Table 2 illustrates the applications of various dozer attachments along with the performance evaluation parameters for each type of attachment.

Table 2: Dozer Applications in the Road Sector

Sl. No.	Dozer Attachment	Attachment Type	Activity/ Application	Performance Evaluation Parameters
1.	Blade	Straight Blade	Backfilling, stumping, stripping, shaping, ditching, grading and spreading fill material.	a) Kilowatt per metre of cutting edge b) Kilowatt per loose cubic metre of material retained in front of blade
2.		Angle Blade	Side casting of material particularly for backfilling or making side-hill cuts, stumping, stripping, shaping, trail pioneering and general dozing of medium to softer materials.	
3.		Universal Blade	Best suited for lighter materials, stockpile works, trapping for loaders and land reclamation.	
4.		Semi-U Blade	Well suited for soft to medium hard soils, stumping, stripping, backfilling, ditching, crowning and levelling.	

Sl. No.	Dozer Attachment	Attachment Type	Activity/ Application	Performance Evaluation Parameters
5.		Cushion Blade	Pushing scrapers to clean up the cut area.	
6.		Power, Angle and Tilt (PAT) Blade	Grading, backfilling, land clearing, ground levelling and spreading fill material.	
7.	Ripper	Radial	Loosen densely compacted materials for better blade penetration and easy pushing by dozer.	
8.		Parallelogram		
9.		Variable		
10.		Impact		
11.	Winch	Manually controlled	Uprooting of trees, skidding of boulders or heavy materials, general/ equipment recovery.	a) Maximum Line Pull b) Maximum Line Speed
12.		Power controlled		
13.	Swinging Drawbar		For haulage purpose.	a) Maximum Drawbar Pull

4.1.2 Dozer can be crawler mounted or wheel mounted and shall be selected based on site conditions, work distance, load volume, difficulty of job etc.

4.1.3 **Table 3** provides recommendations for selection of dozer depending on the size of road project for its deployment. Selection of the dozer will be governed by the dozer output requirement, keeping in view various factors like quantum of work and time horizon for the project at hand, site conditions, experience etc.

Table 3: Recommendations for Dozer Selection Based on Size of Road Project

Sl. No.	Size of Road Project	Engine Power (Gross KW or HP)	Drawbar Pull (KN, in 2nd Gear)
1.	Small	KW>52 (HP> 70)	> 45
2.	Medium	KW>75 (HP> 100)	> 90
3.	Large	KW>104 (HP> 140)	>140

Table 4 provides typical dozer operating weight and blade type for road projects of different sizes.

Table 4: Dozer Operating Weight and Blade Type for Road Projects of Different Sizes

Sl. No.	Size of Road Project	Operating Weight (Kg)	Type of Blade
1.	Small	> 7,500	Angle Blade
2.	Medium	>15,000	Semi-U
3.	Large	> 20,000	Semi-U or PAT

4.1.4 For more information on dozers, refer to IRC:125.

4.2 Hydraulic Excavator

4.2.1 A Hydraulic Excavator (**Figure 2**) is a self-propelled machine on crawler or wheels, having an upper structure capable of a 360° swing and with mounted equipment, which is primarily designed

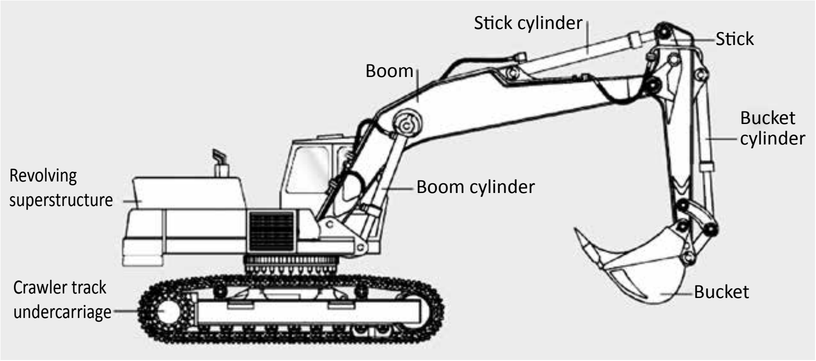


Figure 2: Hydraulic Excavator (Crawler Type)

for excavating with a bucket, without movement of the chassis or undercarriage during any part of the work cycle of the machine. An excavator work cycle normally comprises excavating, elevating, swinging and discharge of material. It can also be used for object or material handling/transportation.

Hydraulic excavators are versatile machines and are characterized by short cycle times, positive and precise control of attachments, high overall efficiency, smoothness and ease of operation.

A hydraulic excavator comprises of the following:

i) Base Machine with a cab or canopy and operator-protective structures (if required) and possessing necessary mountings for equipment and attachments

ii) Equipment or Work Attachment (consisting of boom, arm/stick and bucket) catering to the primary design function of the excavator

iii) Other attachments for specific use

4.2.2 In the road construction sector, the hydraulic excavator finds use for the following applications:

i) Site Clearance and Initial Site Preparation

ii) Quarrying

iii) Cutting and Filling

iv) Construction of Embankment

v) Breaking of Rocks

vi) Demolition of Structures

vii) Material Handling

viii) Lifting Applications

4.2.3 Hydraulic excavator may be classified on the basis of undercarriage, type of equipment (or work attachment) or operating weight.

Based on undercarriage, excavators may be:

i) Crawler (or track) type

ii) Wheeled type

The crawler type machine has advantages of better floatation, better traction, better manoeuvrability and faster repositioning. It can work where ground conditions are severe. The shoe selection of the tracks is determined by the underfoot conditions. The wheeled machine has advantages of better mobility and speed. It does not damage paved surfaces and stability is achieved by stabilisers.

Based on equipment (or work attachment), excavators may be classified as:

i) Hoe type (for cutting towards the machine and generally downwards; primarily used for below-ground level excavation)
ii) Shovel type (for cutting away from the machine and generally upwards; primarily used for above-ground level excavation)
iii) Clamshell type (for digging or grabbing in a generally vertical direction, discharging below and above the ground reference plane)
iv) Telescoping boom type (primarily used for excavation and/or grading of slopes above or below the ground)

Based on operating weight and with respect to application in the highway sector, excavators may be classified as:

i) Class I type (operating weight < 6 tonne)
ii) Class II type (operating weight 6–8 tonne)
iii) Class III type (operating weight 8–12 tonne)
iv) Class IV type (operating weight 12–19 tonne)
v) Class V type (operating weight 19–25 tonne)
vi) Class VI type (operating weight 25–36 tonne)
vii) Class VII type (operating weight > 36 tonnes)

Class V excavators are preferred for most construction activities. Class III excavators are suited for applications in trenching, irrigation and utility works, while Class VI and Class VII excavators are preferred in quarries and pits.

4.2.4 Hydraulic excavators can be equipped with a wide variety of attachments like:

i) Hoe Bucket
ii) Shovel Bucket
iii) Clamshell Bucket
iv) Drainage (Ejector) Bucket

v) Trench (Ditch) Cleaning Bucket
vi) Hydraulic Breaker
vii) Hydraulic Grapple
viii) Hydraulic Demolition Tool (Shearer, Bucket Crusher)
ix) Ripper
x) Ripper Bucket
xi) Hook
xii) Electro Magnet
xiii) Clamp
xiv) Blade
xv) Plate Compactor
xvi) Pile Driver
xvii) Auger
xviii) Quick Coupler

While selecting attachment for excavator, the following factors should be considered:

i) Operating weight of the excavator
ii) Hydraulic capability of the system

4.2.5 Buckets are rated on both their struck and heaped capacities. Bucket capacity is usually expressed in terms of loose cubic metre (lcm).

4.2.6 Hydraulic excavators with engine power ranging from 60 HP to 250 HP and bucket capacity varying from 0.09 cum to 2.10 cum are usually used in the highway sector.

4.2.7 Since an excavator is primarily used for material handling and cutting, its performance can be evaluated by considering two important parameters:

i) Lifting Capacity
ii) Digging Capacity

Major factors that affect excavator performance are:

i) Site Conditions – site topography and geology, geotechnical characteristics of ground/rocks, climate etc.

ii) Cycle Time – angle of swing, depth of cut

iii) Machine Weight

iv) Hydraulic Capability of the machine

v) Bucket Size and Characteristics – bucket size, tip radius

vi) Equipment Downtime – Repairs and maintenance of Equipment

vii) Operator Skill

4.3 Motor Grader

4.3.1 A Motor Grader (**Figure 3**) is a self-propelled wheeled machine having an adjustable blade, positioned between front and rear axles, which cuts, moves and spreads materials usually to grade requirements.

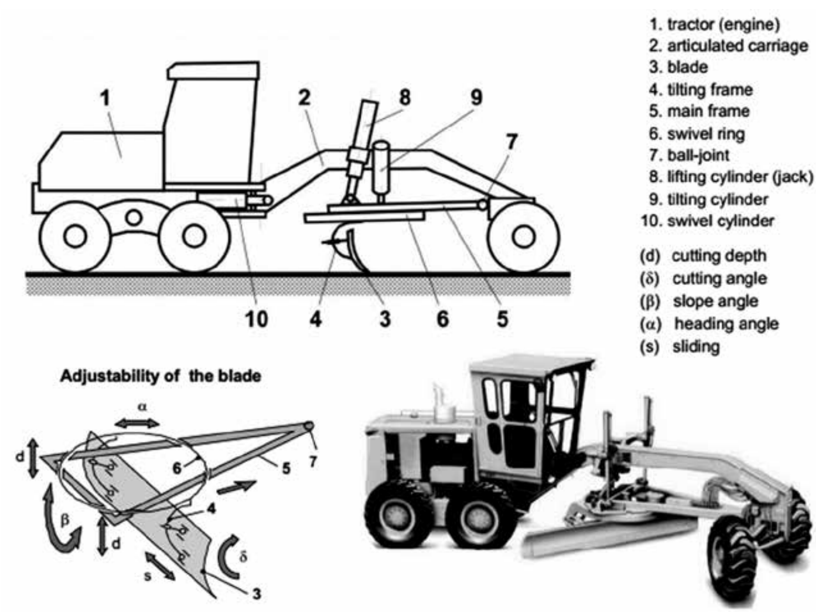


Figure 3: Motor Grader

4.3.2 The blade (also called mould-board) is the main tool of a motor grader. It is carried by a rotating circle and is easily manoeuvrable to a wide range of cutting positions, with the help of hydraulic controls, as indicated below:

i) **Side Shift**– A lever operated blade side shift ram facilitates shifting the blade to either side of the grader as per requirement.

ii) **Vertical Lift** – The blade can be lifted or lowered by levers operating the two rams connected to the blade. Both the rams can be operated separately to raise/ lower the blade at an inclined or horizontal position as required.

iii) **Rotary Movement** – The rotating circle along with the blade can be rotated in either clockwise or anticlockwise direction by a lever operated hydraulic motor to position the blade at the desired angle to the line/direction of travel.

iv) **Blade Pitch** – The blade cutting angle can be adjusted hydraulically in some machines and manually in others.

4.3.3 A motor grader may be equipped with the following optional attachments depending on the job requirement:

i) **Scarifier** – Mechanism having teeth for penetrating and loosening to shallow depths such materials as earth, bituminous and gravel roads, and similar surfaces. The scarifier may be located on the grader ahead of the front wheels or between front and rear wheels.

ii) **Ripper** – Attachment consists of a frame equipped with one or more teeth and is connected to the rear part of the machine by means of a mounting bracket.

iii) **Snowplough** – Structure located ahead of the front wheels, designed to move snow laterally by the ploughing action of a mould-board. The plough may be either one-way or V configuration.

iv) **Front Blade** – Blade usually curved as a mould-board located ahead of the front wheels, designed to scrape and push earth and similar materials generally forward.

4.3.4 Applications of motor grader include finishing, shaping, bank sloping, ditching, moving windrows, mixing, spreading, side casting, levelling and crowning, light stripping operations, landslide/snow clearance, general construction and maintenance of dirt roads and haul roads.

4.3.5 Generally, motor graders with engine power varying from 119 HP to 265 HP are used in the highway sector. Based on data collected from manufacturers, typical range of specifications for motor grader is given in **Table 5**.

Table 5: Specifications for Motor Grader

Sl. No.	Specifications	Range
1.	Max. Speed, forward/rev	40.8/51.7 km/hr
2.	Min. Speed, forward/rev	34 .1/42.5 km/hr
3.	Turning Radius	6.5-12.4 m
4.	Blade Width	3.1-7.3 m
5.	Blade Arc Radius	413-550 mm
6.	Blade Pull	5480-43518 kg
7.	Maximum Blade Position Angle	35°-90°
8.	Mould-board Side Shift – Right	660-4902 mm
9.	Mould-board Side Shift – Left	510-4528 mm
10.	Maximum Lift Above Ground	400-634 mm
11.	Maximum Depth of Cut	400-790 mm
12.	Gross Vehicle Weight (GVW)	12000-65840 kg

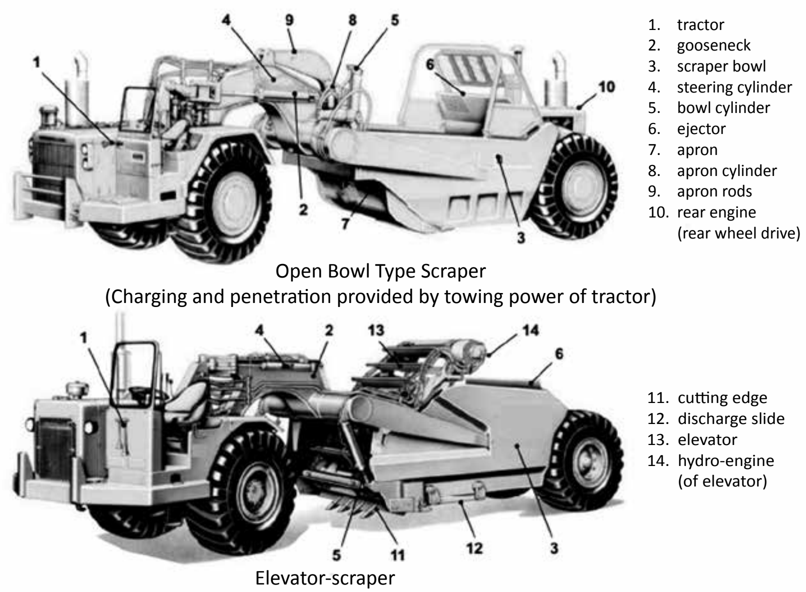
4.4 Scraper

4.4.1 A scraper (**Figure 4**) is a self-propelled or towed, crawler or wheeled machine, having an open bowl with a cutting edge positioned between the axles, which cuts, loads, transports, discharges and spreads material through forward motion of the machine.

It is suited for shallow cuts and haulage up to 300 m.

4.4.2 The basic operating parts of a scraper unit are:

i) **Bowl** – It is the loading and carrying component of a scraper and has a cutting edge that extends horizontally across its front bottom edge. The bowl is lowered for loading/unloading and raised during travel. The bowl capacity (in cum) is specified to indicate the size of the scraper.



Open Bowl Type Scraper
(Charging and penetration provided by towing power of tractor)

Elevator-scraper

Figure 4: Scraper

ii) **Apron** – It is the front wall of the bowl and is independent of the bowl. It is raised during loading and dumping operations to enable the material to flow into or out of the bowl. The apron is lowered during hauling to prevent spillage of material.

iii) **Ejector or Tail Gate** – It is the rear vertical wall of the bowl. It is in the rear position during loading and hauling. During dumping/spreading, it is activated to move forward, thereby providing positive discharge of the material in the bowl.

Each of the above scraper components is controlled hydraulically. **Figure 5** illustrates operation of a typical scraper.

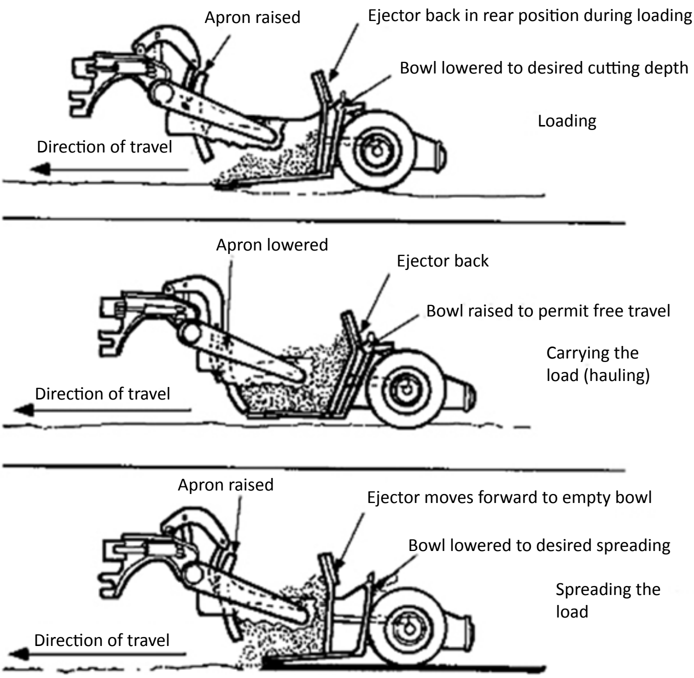


Figure 5: Scraper Operation

4.4.3 *Based on type of loading, scraper may be classified as:*

i) **Open Bowl Type Scraper** – It requires the application of tractive effort to load material into the bowl. This tractive effort may be developed by the tractor-scraper itself, by another tractor-scraper temporarily or permanently connected, or by a pushing tractor.

ii) **Elevating Scraper** – It is a completely self-contained loading and hauling machine and is equipped with a powered mechanism (elevator) fixed to the scraper bowl to assist loading.

4.5 Front End Loader

4.5.1 Front End Loader (**Figure 6**) is a self-propelled crawler or wheeled machine, having front-mounted equipment primarily designed for loading operation (bucket use), which loads or excavates through forward motion of the machine. A loader work cycle normally comprises filling, elevating, transporting and discharging material.

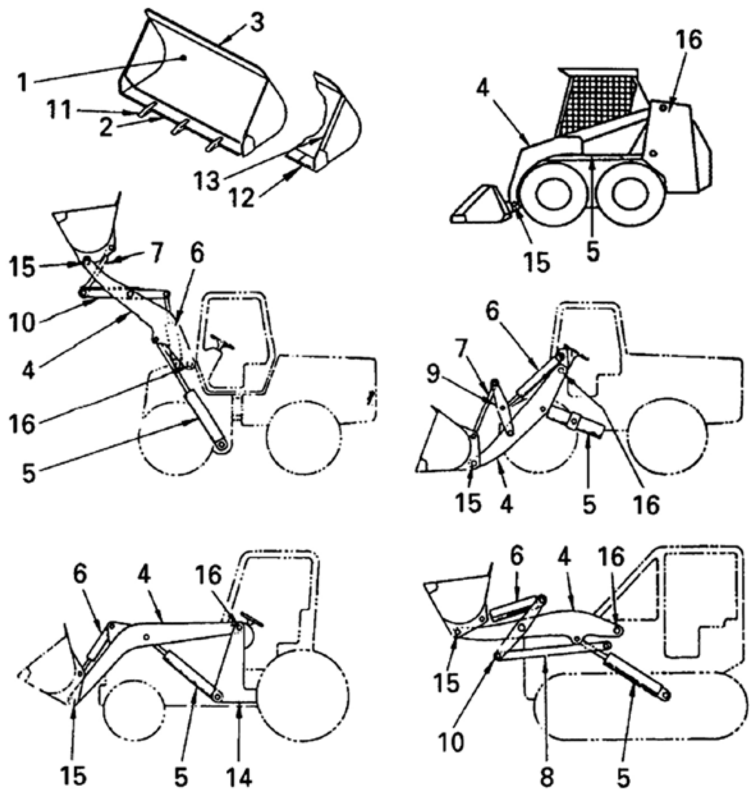
4.5.2 A front end loader serves the following functions:

i) Handle and transport bulk material (eg: earth, rock etc.)

ii) Load Tipper Trucks

iii) Charge aggregate bins at bituminous and concrete plants

iv) Excavation



1	Bucket	9	Lever, bucket
2	Cutting edge	10	Bellcrank
3	Spillguard	11	Tooth, bucket
4	Lift arm	12	Cutter, corner
5	Cylinder, lift	13	Cutter, side
6	Cylinder, bucket	14	Frame, loader (where separate from machine main frame)
7	Link, bucket	15	Pin, bucket hinge
8	Link, guide	16	Pin, lift arm hinge

NOTE– “Front” or “rear” to be used when applicable to items 7, 8, 9 and 10.

Figure 6: Front End Loader

4.5.3 A front end loader may be equipped with the following attachments (operated by means of hydraulic system):

i) **General Purpose Bucket** – It is a single-piece bucket equipped with replaceable cutting edge with or without teeth (replaceable) bolted to the cutting edge.

ii) **Heavy Duty (Rock) Bucket** – It is a single-piece bucket equipped with a protruding V-shaped cutting edge for prying up and loosening rock.

iii) **Side Dump Bucket** – A bucket which loads through forward motion of the machine and can dump to the side from an end of the bucket; it may also dump forward. It allows versatility for working in confined areas.

iv) **Multi Purpose Bucket** – A two-piece bucket having a dozer-type mould-board with hinges at the top to support a clam which can be opened to various positions providing for use as a dozer, scraper, clam or bucket.

v) **Scarifier** – A mechanism having teeth for penetrating and loosening to shallow depth such materials as earth, bituminous and gravel roads and similar surfaces. It is usually mounted on the back of the loader but may be mounted on the back of the bucket.

vi) **Fork** – A structure having tines for lifting, transporting and discharging material.

vii) **Grapple** – A mechanism having tines and a top clamp for lifting, transporting, and discharging material (e.g. logs).

viii) **Winch** – A frame equipped with a drum and connected to the rear part of the base machine. Applications include uprooting of trees, skidding of boulders or heavy materials, general or equipment recovery etc.

ix) **Specialised Attachments** – Attachments are available for specialised jobs depending on work requirement (e.g. sweeper broom, brush rake for clearing application, pipe laying attachment, demolition bucket, plow blade for snow removal, etc.).

4.5.4 Key performance parameters for assessing the performance of a front end loader are:

i) Net Engine Power (as per IS:13116)

ii) **Tipping Load at Maximum Reach** – It is the minimum mass, in kilograms, that, when placed in the loader bucket or on fork at maximum moment arm position, will cause the loader to achieve the tipping limit condition in its least stable configuration, with the loader placed on a hard, level surface and the resultant force acting vertically through the centroid of the rated bucket volume (ISO 7546) or the fork load centre (ISO:14397 Part-I).

iii) Rated Operating Load

iv) **Breakout Force** – This is the maximum sustained vertical upward force generated at a point 100 mm behind the lip of the bucket, when operating the lift cylinders or the tilt cylinders, and with the bottom of the cutting edge parallel with and 20 mm above the Ground Reference Plane (GRP). For buckets with a curved or pointed cutting edge, the forces shall be measured at the centre of the bucket width.

v) **Raising Time** – This is the time required to raise the bucket with stated operating load from a position resting on the Ground Reference Plane(GRP), fully rolled back to full height.

vi) **Lowering Time** – This is the time required to lower the empty bucket from full height to the position with bucket bottom lying on the Ground Reference Plane(GRP).

vii) **Dump Time** – This is the time required to rotate the bucket from the maximum rollback - not exceeding the horizontal strike plane - fully raised position to the full dump position while dumping an operating load.

viii) **Maximum Travel Speeds** – These are the maximum speeds that can be obtained on a hard level surface in each of the forward and reverse gear ratios with bucket empty.

ix) Braking Performance (Wheel Loader) (ISO 3450).

4.6 Backhoe Loader

4.6.1 Backhoe Loader (**Figure 7**) is a self-propelled crawler or wheeled machine having a main frame designed to carry both front-mounted equipment (with loader attachment) and rear-mounted equipment (with backhoe attachment), normally with outriggers or stabilisers. When used in the backhoe mode, the machine is stationary and normally digs below ground level. When used in the loader mode, the machine loads through forward motion.

A backhoe work cycle normally comprises excavating, elevating, swinging and discharging of material. A loader work cycle normally comprises filling, elevating, transporting and discharging of material.

Figure 7: Backhoe Loader

4.6.2 Backhoe Loader is the most common piece of construction equipment for any road project. It is ideal for light excavation, trenching, backfilling, material moving, light underground utility works, site clearance, loading and other miscellaneous jobs.

Besides being used as a hoe or a loader, this machine can also accommodate different accessories and attachments for different operations, thereby increasing its versatility on a job site. Some of the common attachments are hydraulic rock breaker, trenching bucket, broom, auger, log fork, pallet fork etc.

4.6.3 Loader bucket capacity of backhoe loader is usually about 1–1.2 cum, while the backhoe bucket capacity is about 0.18–0.3 cum.

4.7 Crusher

4.7.1 A crusher is a machine designed to reduce large size rocks into smaller size aggregates, gravel or stone dust.

4.7.2 Crushers use one or combination of the following four mechanisms for size reduction – impact, attrition, shearing and compression.

4.7.3 Crushing operation is usually carried out in multiple stages through step reduction. This is because the amount of size reduction achieved is directly related to the energy applied. When there is a significant difference between the feed size and the desired final size of the crushed product, a large amount of energy is required. Providing this energy in a single-step process will generate excessive fines, leading to wastage. Hence, the degree of crushing is spread over three or four stages as a means of closely controlling the product size.

Figures 8 and **9** illustrate basic stages of crushing activity. Crushing operation begins with a primary crusher (jaw crusher). ROM (run-of-mine) boulders/rocks received in tipper trucks feed a dump hopper. Grizzly feeder located below dump hopper takes out the ROM feed at a controlled rate to feed the jaw crusher. It also prevents oversized material from entering the crusher and blocking its opening. Jaw crusher produces the first reduction in stone size, and its output is fed to a secondary crusher (cone crusher). Cone crusher is mostly operated at 25 mm CSS (Closed Side Setting) to produce (−) 55 mm product. Since product requirement is (−) 40 mm for road projects, (+) 40 mm product is recirculated to the cone crusher. A tertiary cone crusher may be used to achieve further size reduction in case of a four stage crushing plant. However, product from cone crusher may not be cubical shaped. To obtain cubical aggregates maintaining combined flakiness and elongation index within 30% as per specifications, a vertical shaft impactor (VSI) is required.

Screen decks are used in between the crushing stages to separate the aggregates into different specification sizes.

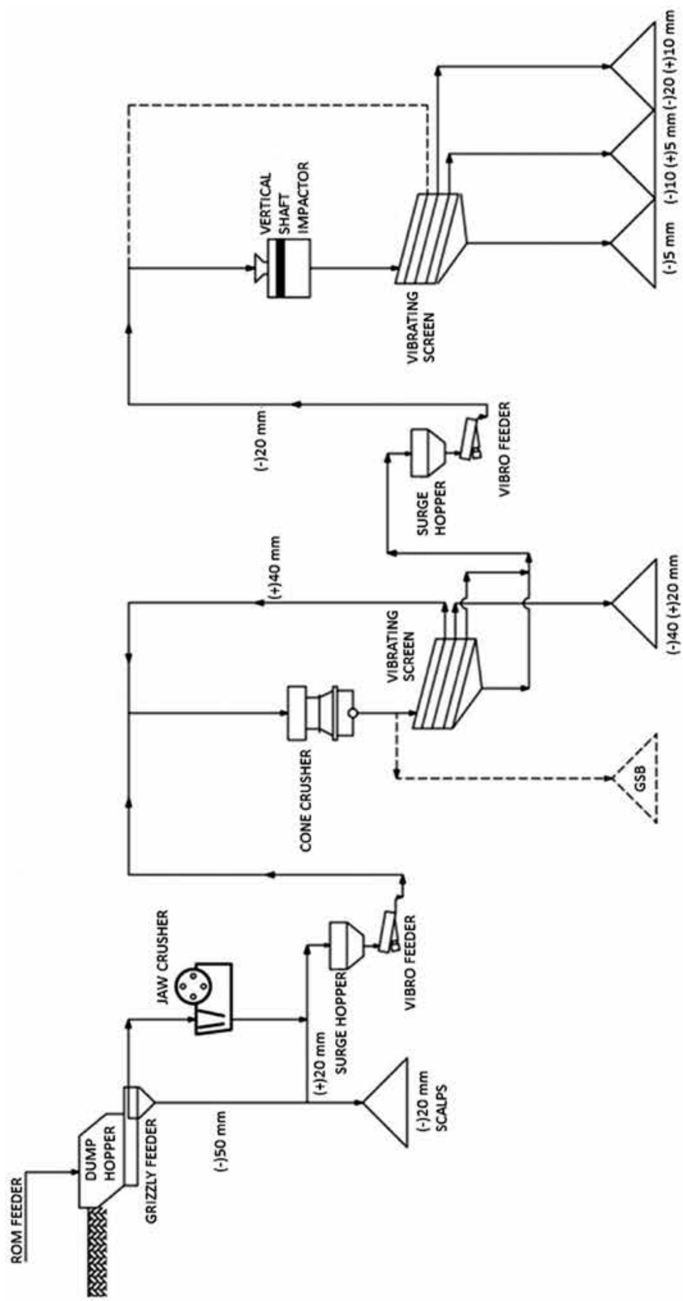


Figure 8: Three Stage Crushing Plant (200/300 TPH Capacity)

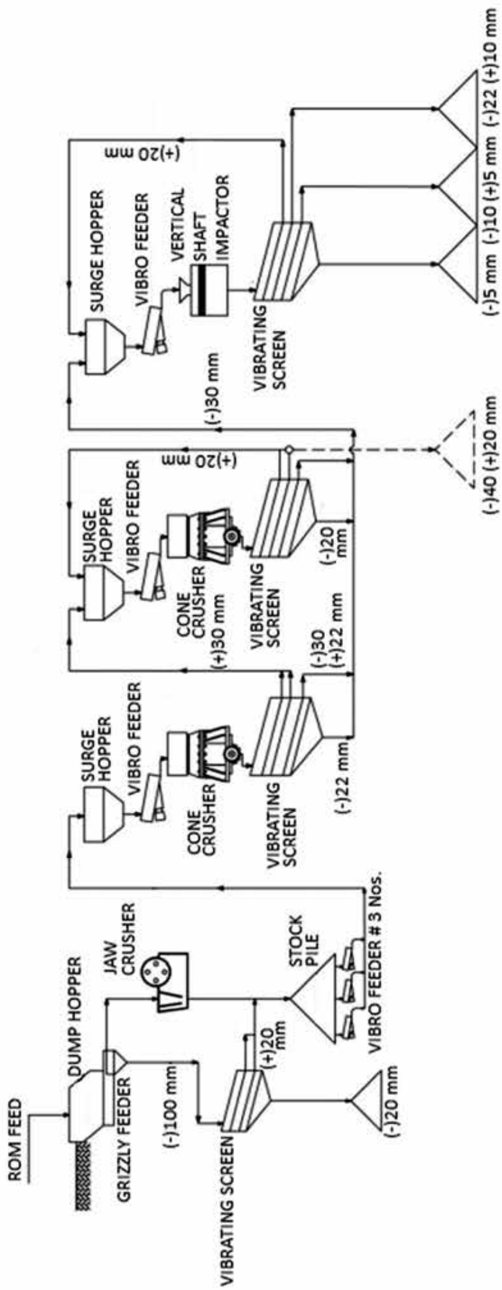


Figure 9: Four Stage Crushing Plant (450 TPH Capacity)

4.7.4 Jaw Crusher (Figures 10 and 11): It is used as a primary crusher. It is selected on the basis of maximum lump size and plant capacity.

The jaw crusher contains two rectangular surfaces of jaws, one of which alternately approaches and recedes from the other. The jaws contain an angle and, together with two side plates, enclose a wedge shaped cavity which is wider at the upper or feed end. The material fed at the upper end gets crushed mainly by compression between the two jaws and discharges through the lower outlet. Maximum dimension of feed opening (gape) and the product size is determined by the width of discharge aperture when the jaw has retreated fully (open side setting).

The moving jaw may be actuated by one of the two principal mechanisms - 'single toggle' or 'double toggle'.

The size of a jaw crusher is indicated by the jaw width and the charging gap width, expressed in mm.

For more information on Jaw Crusher, refer to IS:4254.

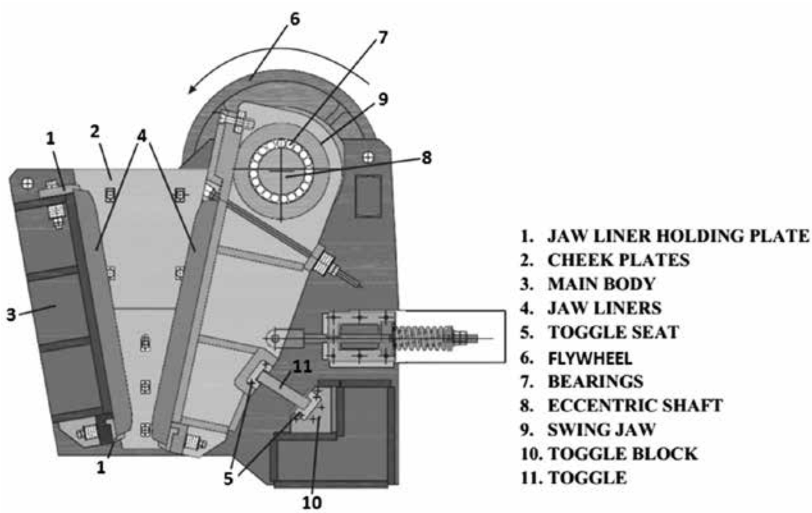


Figure 10: Jaw Crusher (Single Toggle Type)

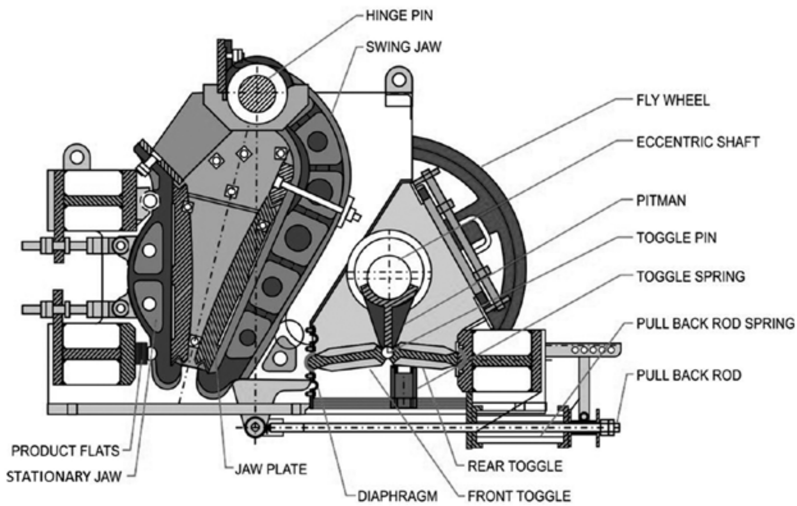


Figure 11: Jaw Crusher (Double Toggle Type)

4.7.5 Cone Crusher (Figure 12): It is used for secondary and tertiary crushing. The upper half of a cone crusher consists of a conical crushing chamber lined with manganese steel plates called concaves within which an upright conical crushing head moves with an eccentric motion. The crushing head is mounted on a vertical steel shaft and suspended from the spider at the top of the frame. The lower half of the crusher consists of support for the shaft and driving gears. Eccentric rotation of the shaft causes the crushing head to gyrate within the crushing chamber, thereby varying the space between the concaves and the head and crushing the stones by attrition and compression.

Depending upon the type of cone and throw, cone crusher can be classified as:

i) **Standard Cone Type** – It is suited for application as a secondary crusher. It has a steeply inclined crushing chamber with shallow angle of cone and a flatter, less steeply inclined conical crushing head. It has a wider and longer crushing cavity to accommodate larger size feed material.

ii) **Short-Head Cone Type** – It is suited for application as a tertiary crusher or fine cone crusher. It has a shorter crushing head and a smaller throw. Both the crushing chamber and crushing head are steeply inclined to promote the gravitational flow of more finely sized material, resulting in a shorter and a more parallel crushing cavity compared to the standard cone type.

The size of a cone crusher is indicated by the diameter of the discharge annulus.

For more information on Cone Crusher, refer to IS:4255.

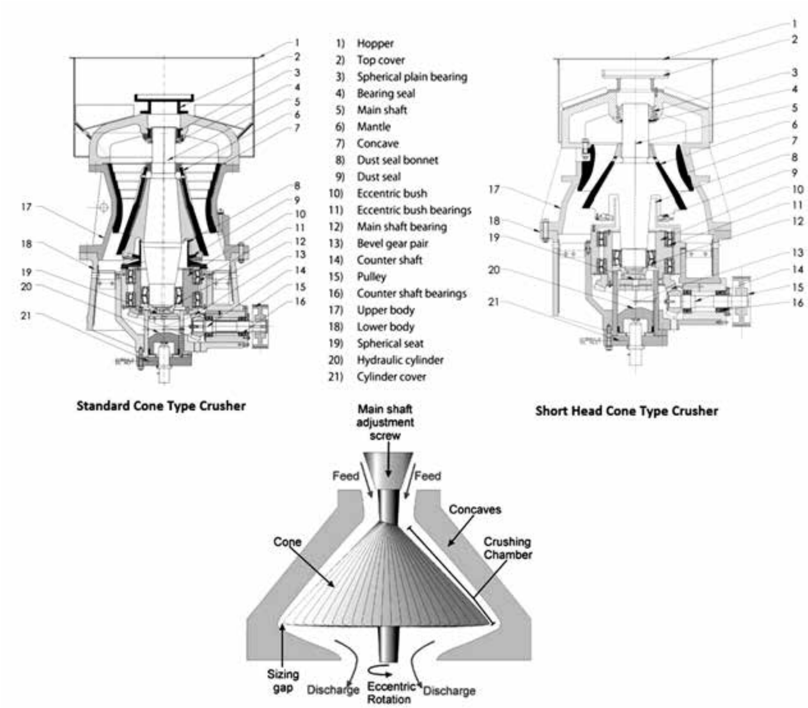


Figure 12: Cone Crusher

4.7.6 Vertical Shaft Impactor (VSI) (Figure 13): It consists of an open or closed type impeller/rotor fitted with specially developed carbide tip ports. This impeller is mounted on a vertical shaft assembly, with special bearing arrangement suitable for high speeds. An outer ring with anvils or rock-on-rock crushing chamber is arranged around the impeller. Drive to the shaft assembly is given through 'V' belts with belt tensioning arrangement. Hydraulic lid lifter is provided for easy and quick access to major parts.

The feed material enters through feed hopper and then feed tube into feed cone at the centre of the impeller, which is rotating at a high speed. Material particles that enter the impeller attain kinetic energy and come out of the impeller into the crushing chamber with required centrifugal force (i.e. high tangential velocity) and hit the stationary anvils or rock box. Thus, these particles crack under their own force at natural fault lines and joint surfaces, and the flaky ends of the particles are sheared to form into cubical shape. Once particles have lost their kinetic energy, they will fall down, out of the crushing chamber, usually onto a conveyor belt at the bottom of the crusher.

Instead of sending the entire feed material into the rotor, a portion of the feed material may be cascaded in controlled quantity into the crushing chamber turbulence to increase the particle population within the crushing chamber, thereby improving the energy transfer and rock-on-rock chain reaction of crushing and grinding.

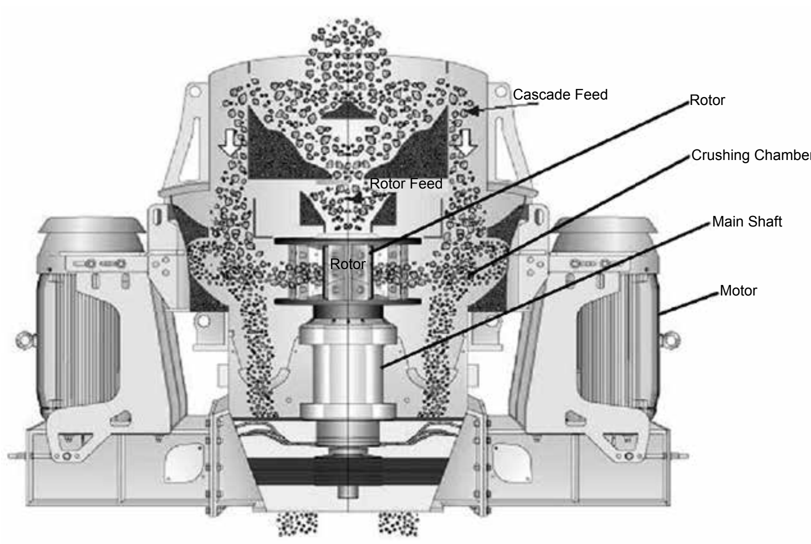


Figure 13: Vertical Shaft Impactor

4.7.7 The performance of a crusher is indicated by its output/ capacity (in TPH). The capacity will vary with the type of stone/rock, feed size, final product size and extent to which the stone is fed uniformly into the crusher.

4.7.8 Crushing plants with capacities ranging from 200 to 450 TPH are usually preferred in the road sector for processing of aggregates.

Execution period for most of the road projects in a particular stretch is usually two to three years and, thereafter, the infrastructure machinery has to be shifted to a new location. Hence, track mounted crushing stations (**Figure 14**) are favoured these days on account of the following advantages:

i) They are totally shop assembled without any site related activity for erection.

ii) They do not require any type of RCC works (e.g. retaining wall, foundation works etc.).

iii) They can be directly positioned at the working site and started immediately.

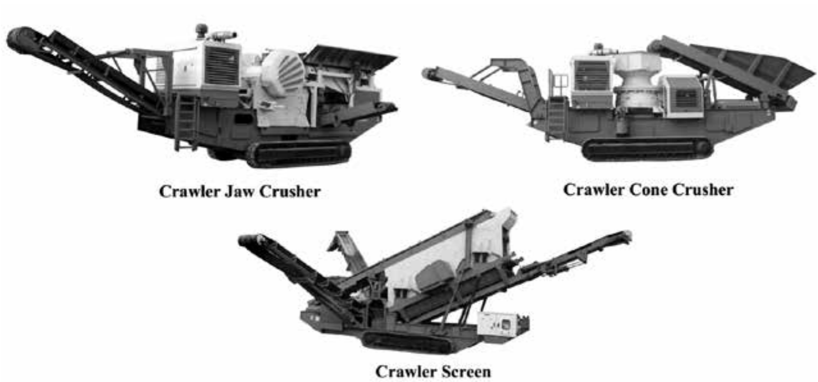


Figure 14: Track Mounted Crushing Station

4.7.9 Sand Preparation Plant (Manufactured Sand) – Natural sand is a scarce resource and its mining from river bed may lead to adverse environmental consequences. Hence, there is a need for an alternative source of sand. Moreover, sand requirement in the road and bridge construction sector has gone up, which cannot be met with standard crushing plant operations. This has led to the introduction of special type of cone crushers known as sanders to operate at lower settings to maximise the production of manufactured sand (M-sand). This equipment is added to standard crushing circuit where part of higher sized products can be converted to sand.

4.7.10 Sand Classifier – The purpose of a sand classifier is to improve the quality of sand by removing unwanted material like silt, clay, dirt etc. and to reduce the percentage of ultrafines (−150 μ size) in sand to permissible limits as per specifications. This in turn will optimise the consumption of bitumen/cement in road/bridge construction.

Sand classification can be done either by wet or dry process. In dry process, air is used as medium to separate fine and coarse particles while in wet process, water is used as the separating medium.

i) **Dry Classifier (Figure 15)** – It consists of two coaxial cylinders, which work like an external cone and an inner cone. The circulating fan creates a centrifugal air flow that rises within the inner cylinder and then descends in the intermediate zone between the two cylinders. At the return vanes, air flow returns to the central cylinder. Sand particles are fed into the centre of the classifier, where they are dispersed by a rotating distributor and then meet the rising centrifugal air flow. The air vortex separates the coarser and finer particles – the finer particles will rise with the air flow and pass through the circulating fan while the coarser particles will be pushed outwards, due to greater centrifugal force, against the surrounding wall (of the inner cylinder) and fall downwards on to a chute and stockpiled on the ground through a conveyor belt. As the fines descend with the air flow to the return vanes, they lose momentum and continue downwards while the air flow turns into the centre of the classifier. These fines are discharged from the classifier bottom into a conveyor and transferred to a closed tank.

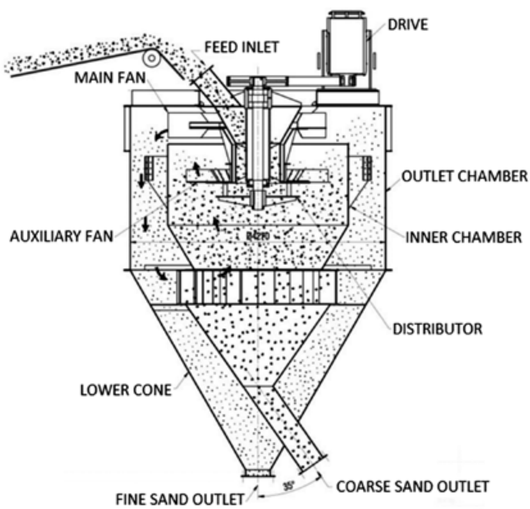


Figure 15: Dry Classifier

ii) **Wet Classifier** – Two types of wet classifiers are commonly used: hydro cyclone sand washer and bucket wheel sand washer.

a) **Hydro Cyclone Sand Washer (Figure 16)** – It consists of a slurry tank, a hydro cyclone and dewatering screen. Sand is fed to the feed chute through a belt conveyor. It then passes through the feed box, where water is added. The slurry is fed to the first half portion of the dewatering screen, which separates out coarser sand particles [(−)5 (+)2.36 mm] and finer sand [(−)2.36 mm] along with water is discharged to slurry tank below screen and, thereafter, pumped to the hydro cyclone. The feed slurry enters the hydro cyclone tangentially under pressure through the feed pipe into the top of the cylindrical section of the cyclone. It then follows a circulating path with high velocity within the cyclone, causing centrifugal forces to accelerate the movement of the particles towards the outer wall. The particles migrate downward in a spiral pattern through the cylindrical section and into the conical section. At this point the smaller mass particles migrate toward the centre and spiral upward and out through the vortex finder, discharging through the overflow pipe. This product, which contains the finer particles and the majority of the water, is

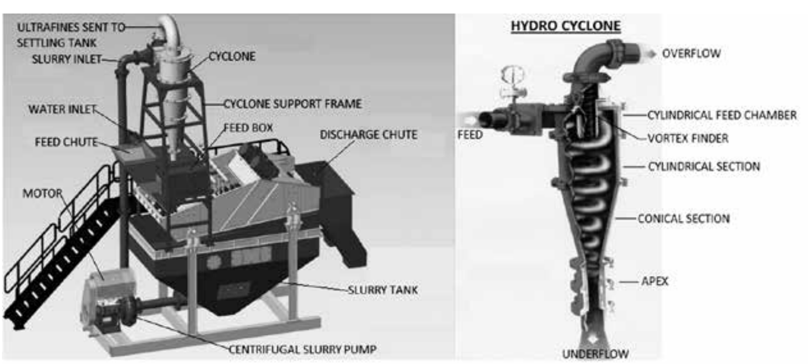


Figure 16: Hydro Cyclone Sand Washer

termed the overflow and is sent to slurry settling pond. The higher mass (i.e. coarser) particles remain in a downward spiral path along the walls of the conical section and gradually exit through the apex orifice. This product is termed the underflow and is discharged on to the second half portion of the dewatering screen to reduce the moisture percentage.

There are various factors that govern the performance of the hydro cyclone – cyclone diameter, area of inlet nozzle, difference between pressure at inlet and outlet, amount of particles versus water, size and shape of the particles etc.

b) **Bucket Wheel Sand Washer (Figure 17)** – It requires low drive power and consists of a fabricated tank/trough equipped with a helical screw and a dewatering wheel (with perforated buckets to drain water).

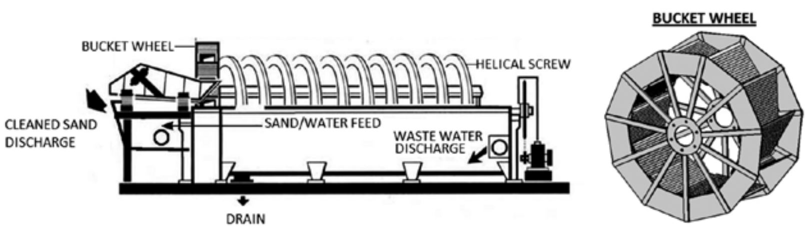


Figure 17: Bucket Wheel Sand Washer

Sand and sufficient quantity of water enters the trough in a non-turbulent section on the bucket wheel. Sand gets settled at bottom of the trough, and the principle of decantation is used with low turbulence flow – the slow and continuously revolving screw churns and moves the sand up a slope towards the rotating bucket wheel in the opposite direction of water flow. During this action, the silt/clay/dirt content in sand is dissolved in water and washed away by the cross-flow. To avoid saturation of silt/clay/dirt, a continuous supply of water is maintained depending upon the silt/clay/dirt content in sand. The waste water flows over a weir at the opposite end of the bucket wheel. The cleaned sand, segregated at the upper portion of the trough, is dredged by the rotating dewatering bucket wheel and then dropped on to the discharge chute or dewatering screen for getting a washed product at outlet.

The output of the bucket wheel classifier can be adjusted with the following factors – speed of screw, quantity of water and the inclination of the trough.

4.8 Tipper Truck

4.8.1 Tipper trucks (**Figures 18, 19 and 20**) are used for transportation of excavated material, processed aggregates and construction material.

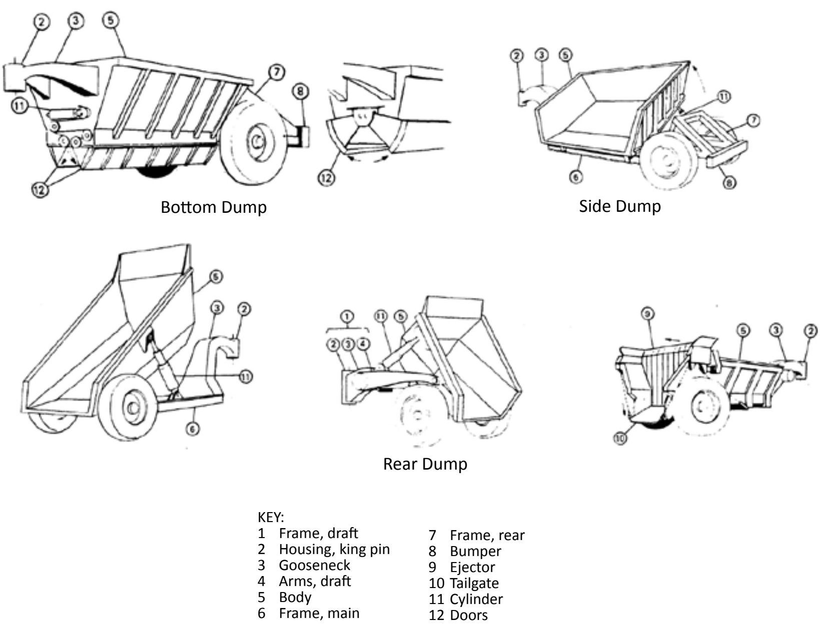


Figure 18: Types of Tipper Trucks based on Method of Dumping the Load

Figure 19: Rigid Tipper Truck

Figure 20: Articulated Tipper Truck

The use of trucks as the primary hauling unit provides a high degree of flexibility, as the number in service can usually be increased or decreased easily to permit modifications in the total hauling capacity of a fleet.

Tipper trucks varying in size from 5 cum to 14 cum are usually preferred for road construction works. Tippers with 18 cum capacity are also available and are suited for large bridge/tunnelling works.

4.8.2 Classification of tipper trucks is indicated in **Table 6**.

Table 6: Classification of Tipper Trucks

Sl. No.	Basis/Criterion	Classification
1.	Method of dumping the load	a) Rear Dump b) Bottom Dump c) Side Dump
2.	Type of frame	a) Rigid Frame b) Articulated

4.8.3 Advantages and disadvantages of different types of tipper trucks are illustrated in **Tables 7, 8, 9, 10, 11**.

Table 7: Advantages and Disadvantages of Rear Dump Tipper Truck

Advantages	Disadvantages
1. Can withstand high impact of loading 2. Versatility–can handle a variety of materials 3. Good gradeability because of favourable kilowatt to weight ratio 4. Good traction because of favourable weight distribution 5. Good performance under unfavourable road conditions 6. Good for dumping into restricted hoppers or fill	1. Considerable time required for dumping load as the truck must stop, reverse and then dump its load

Table 8: Advantages and Disadvantages of Bottom Dump Tipper Truck

Advantages	Disadvantages
1. Good for long distance, high speed haul 2. Favourable rated payload to GVW (Gross Vehicle Weight) ratio 3. Suitable for dumping load in wind rows	1. Material must be free-flowing 2. Not suitable for severe loading impact

Table 9: Advantages and Disadvantages of Side Dump Tipper Truck

Advantages	Disadvantages
1. Suitable for dumping load along narrow length or on one or both sides of a road (road shoulders) 2. Less time required for dumping load	1. Limited versatility

Table 10: Advantages and Disadvantages of Rigid Tipper Truck

Advantages	Disadvantages
1. Generally higher top speed especially on good quality haul roads 2. Long economic life under moderate conditions	1. Not suitable for continuous operation in rugged conditions 2. Not suitable for steep grades 3. Restricted payloads

Table 11: Advantages and Disadvantages of Articulated Tipper Truck

Advantages	Disadvantages
1. Ability to cope with steeper grades and difficult ground conditions 2. High manoeuvrability through articulation	1. Top speeds are generally lower 2. More expensive than rigid truck.

4.9 Wheel Barrow

4.9.1 Wheel Barrow (**Figure 21**) is suitable for very short hauls. It may be manually operated or powered (electric). Manually operated barrows usually have one or two wheels.

Manually Operated Wheel Barrow

Electric Wheel Barrow

Figure 21: Wheel Barrow

4.9.2 Steel Wheel Barrows with single wheel shall be of the following nominal capacities as per IS:2431 – 60 litres, 85 litres.

Steel Wheel Barrows with two wheels shall be of the following nominal capacities as per IS:4184 – 75 litres, 85 litres, 110 litres, 140 litres.

4.10 Wet Mix Plant

4.10.1 A central mixing plant used for producing wet mix macadam is called a Wet Mix Plant (**Figure 22**). It has provision for:

i) Controlled feeding of aggregates of different sizes in the required proportion.

ii) Addition of specified quantity of water.

iii) Addition of specified quantity of other ingredients like lime or cement.

iv) Forced/positive mixing of all the ingredients to produce a consistent homogeneous mix.

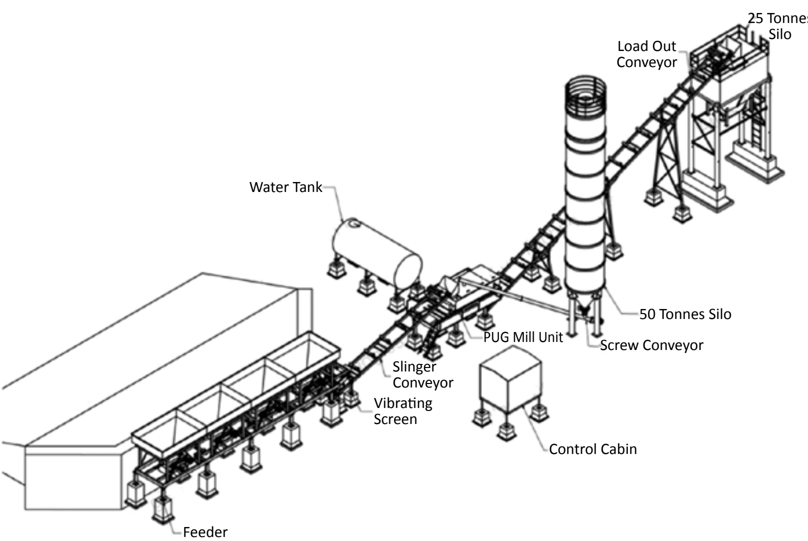


Figure 22: Typical Layout of a 200 TPH Wet Mix Plant with Filler Silo

4.10.2 A wet mix plant can also be used with slight modification and other optional devices for:

i) Production of cold bituminous mix – addition of emulsion

ii) Certain type of soil stabilisation – addition of cement or lime

iii) Blending of material for Granular Sub-Base (GSB)

4.10.3 Efficient wet mix plant operation starts with the cold aggregate feeder (consisting of four or more bins). The functions of the feeder system are to provide an even flow of accurately metered aggregates (meeting the gradation requirements) and provide surge storage capacity between the feeders and aggregate stockpiles.

Only graded aggregates are to be fed to the feeder system. Otherwise, grizzly screens are to be put over the bins. Aggregate flow may be regulated by adjustment of gate opening and/or belt speed of the auxiliary conveyor below each bin.

Gathering conveyor collects aggregates of different sizes from the auxiliary conveyors fitted under each bin and discharges it into the slinger conveyor through an oversize rejection screen.

A continuous electronic weighing arrangement with load cell is mounted on the slinger conveyor to continuously monitor the total weight of aggregates being fed into the pug mill and synchronize it with the feed of water and other filler additives.

The twin-shaft pug mill receives aggregates from slinger conveyor and requisite, precise amount of water from water system and filler additives from filler fines feeding system, and thereafter facilitates forced action-mixing of the mix ingredients to ensure continuous outflow of uniform, homogenous mix at its discharge end.

The gob hopper arrangement at the discharge end of pug mill (or at the end of load-out conveyor) allows the discharge of mix into tipper truck without any segregation.

4.10.4 A pug mill's ability to achieve a homogeneous, thoroughly coated mix in a given number of seconds is influenced by many design variables:

- i) Pug Mill's shape, proportions and volume
- ii) Paddle tip number, size and peripheral speed
- iii) Paddle arm and tip shape
- iv) Paddle arrangement
- v) Power input

In order to have a consistent output capacity, a minimum of 230 cm^2 face area is suggested for paddle tip size. However, this may vary from manufacturer to manufacturer.

The number of paddle tips provided should be sufficient to ensure consistency of homogeneous mixing. Based on data available for various reputed manufacturers, the thumb rule of 1 paddle tip for every 4.6 TPH of plant output capacity may be considered to work out the requirement of paddle tips. This is given in **Table 12**.

Table 12: Requirement of Paddle Tips for various Wet Mix Plant Output Capacities

Plant Output Capacity (TPH)	Minimum No. of Paddle Tips
100	22
200	44
300	66

4.10.5 **Table 13** lists out the recommendations on frequency of calibration and maximum permissible tolerance to be followed for various components of a Wet Mix Plant to ensure optimum plant performance.

Table 13: Recommended Frequency of Calibration and Permissible Tolerance for a Wet Mix Plant

Sl. No.	Component	Recommended Frequency of Calibration	Maximum Permissible Tolerance in Accuracy of Measuring Device
1.	Load Cell (Slinger Conveyor)	200 working hours	± 4%
2.	Water Metering System	200 working hours	± 2%
3.	Filler Fines Feeding System	200 working hours	± 3%

4.10.6 Wet Mix Plants with capacities ranging from 60 TPH to 300 TPH are being used in India and, accordingly, a genset with matching capacity (usually ranging from 37.5 KVA to 150 KVA) is to be used to meet the power requirement.

4.10.7 For more information on Wet Mix Plant, refer to IRC:126.

4.11 Soil Stabilisation Equipment

4.11.1 Soil Stabilisation improves the soil properties by mixing with binding agent and water, thereby producing high quality construction material. The binding agent can be lime, cement, fly ash or any special chemical stabiliser specifically oriented to the soil to be treated. The choice of binding agent depends upon the soil type and conditions.

Soil Stabilisation offers the following advantages:

i) Improved soil strength and bearing capacity

ii) More economical in terms of cost and energy to increase the bearing capacity of the soil than going for replacement of the existing soil

iii) Increased soil stability in slopes or other places

iv) Prevent soil erosion and dust formation, which is very useful particularly in dry and arid weather

v) Soil water-proofing (which prevents water from entering into the soil) and prevent soil from losing its strength

vi) Reduce change in soil volume due to change in temperature or moisture content

vii) Improved soil workability and durability

Soil can be stabilised either by Mix In Place or Plant Mix method. The Mix In Place method is usually more economical.

4.11.2 For in situ soil stabilisation (**Figure 23)** depicts the typical equipment train involved), binder is first pre-spread by a binder spreader on the soil to be treated. The spreader is usually truck-mounted or tractor-mounted and should be equipped with an electronically controlled dosing system for accurately proportioning and uniformly distributing the binder, regardless of the spreader's drive speed.

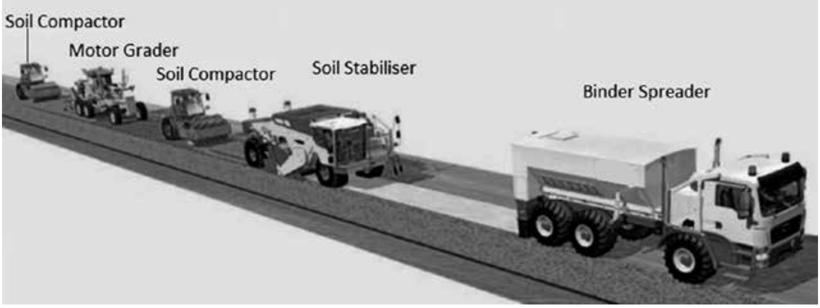


Figure 23: In Situ Soil Stabilisation Train

The spreader is followed by a mobile soil stabiliser (**Figure 24**), which is a self-propelled construction vehicle on four wheels (with independent power to these wheels) and equipped with suitable hydraulic flow distributer to avoid slippage of wheels and ensure maximum stability. The stabiliser has a powered milling cum mixing drum with a number of tools mounted on it in spatial alignment for milling up the existing soil and pre-spread binder and blending them with water to produce a homogeneous soil mixture. The mixing chamber should have a microprocessor-controlled spraying system for accurately metering and monitoring the quantity of water added.

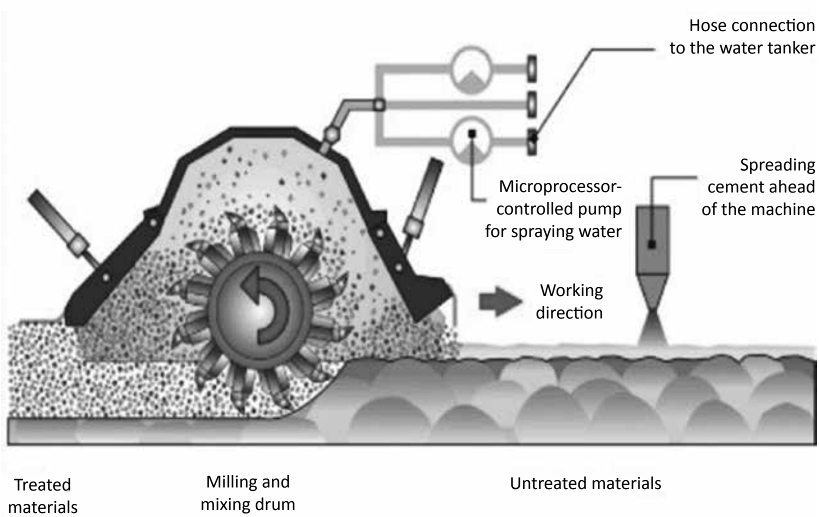


Figure 24: Mobile (In Situ) Soil Stabiliser

The stabiliser should have in built engine of suitable capacity, preferably with belt drive system to drive the milling/pulverising drum. In case, belt drive system is used, it should have automatic belt tensioner system.

The milling cum mixing drum should have minimum working width of 2000 mm with provisions for variable depth control and variable drum speed to meet site requirements. The working depth can be varied by lowering or raising of the complete drum and automatic adjustment of the mixing space in response to the particular working depth (i.e. larger mixing space with greater working depth). Variable drum speed can be obtained by combination of selectable engine speeds and adjustable drive belt pulley arrangements to achieve optimum working results.

The mobile stabiliser should have an air-conditioned cabin with operator console for all controls and safety features.

Other than the self-propelled type, it is also possible to use a tractor-driven stabiliser with the above features.

The stabiliser is followed by a soil compactor (usually padfoot) and then a motor grader and, subsequently, another soil compactor for compacting and grading the soil mixture to the required specifications.

4.11.3 A Wet Mix Plant can be used with slight modification and other optional devices (e.g. addition of lime or cement) for soil stabilisation by Plant Mix method. Such a soil stabilisation plant is stationary.

4.12 Tractor-Rotavator and Disc Harrow

4.12.1 A rotavator (**Figure 25**) is usually tractor-driven. It is equipped with rotating blades that break up soil for mixing and blending the soil with additives. Power to the rotary shaft can be transferred either from one of two ends or from the centre through chain and sprocket.

Figure 25: Rotavator

4.12.2 Alternatively, Disc Harrow (**Figure 26**) is used for pulverisation and mixing of soil/aggregates and additives. It consists of multiple numbers of iron or steel discs which have slight concavity and are arranged into sections. The discs are also offset so that they are not parallel with the overall direction of the implement. This is so, they slice the ground they cut over a little bit to optimize the result. The concavity of the discs as well as their being offset causes them to loosen and pick up the soil they cut. Modern disc harrows are tractor-driven and are raised hydraulically.

Figure 26: Disc Harrow

4.12.3 Although a mobile soil stabiliser is the preferred equipment for the Mix in Place method of soil stabilisation, tractor driven rotavator and disc harrow may be used for small scale works.

The ability of a tractor driven rotavator or disc harrow to pulverise and mix soil efficiently for in situ soil stabilisation is determined by its engine power and depends upon the plasticity of the soil material. For cohesive soils, a factor of the plasticity index of the soil multiplied by the percentage of the fraction of the soil finer than 425 micron in particle diameter may be used to suggest the choice of equipment (**Table 14**).

Table 14: Selection of Rotavator/Disc Harrow for In Situ Soil Stabilisation

Sl. No.	Equipment	Plasticity Index x Percentage of Fraction finer than 425 micron	Normal Maximum Depth (in mm) capable of being processed in one layer
1.	Disc Harrow	< 1000	120 – 150
2.	Light Duty Rotavator (< 100 HP)	< 2000	150
3.	Heavy Duty Rotavator (> 100 HP)	< 3500	200 – 300 (depending on soil type and equipment power)

4.13 Road Sweeper

4.13.1 A road broom or sweeper (**Figure 27**) performs the following functions:

- i) Sweeping/Cleaning – Removal of dust and loose foreign material from the pavement prior to application of binder.
- ii) Drag Brooming – Uniformly distribute inconsistently spread aggregate chips in case of chip seal application.
- iii) Removal of loose aggregate chips from completed work in case of chip seal application.

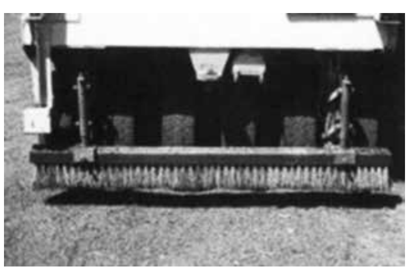
In dry conditions, sweeping may cause considerable dust pollution. This is controlled with water applied by water tanker.

The following types of road sweepers are available:

- i) Rotary Broom
- ii) Suction Broom
- iii) Vacuum Broom

(a) Rotary broom

(b) Vacuum broom



(c) Drag broom

Figure 27: Road Sweeper

4.13.2 Rotary Broom – The most common form of rotary broom is a cylindrical broom that can range from 500 mm to 1000 mm in diameter and from 2 m to 3 m in length. The broom bristles should be of even length to ensure best performance. The broom is usually tractor-mounted or towed. It may also be mounted on the front of truck.

The broom may be equipped with a dust collection bin at its rear for collection of dust and debris. It is then taken to a pit where it disposes the waste via a manual or hydraulic dump mechanism. In case, it is required to sweep the dust sideways, the broom shaft may be swung relative to the longitudinal direction of travel via a manual adjustment pin or hydraulic cylinders.

For efficient operation, the rotating speed of the broom needs to be matched to the forward speed of the tractor/truck. If the machine is travelling too fast relative to the broom rotation, the bristles will tend to scuff over the surface (causing excess wear and tear of the bristles) and leave dirt behind.

Pressure settings of the broom should be selected such that the bristles apply minimum pressure on to the pavement, which is consistent with the cleaning operation. Pressure settings may be manual or automatic.

Rotary brooms may be of two types:

i) **Mechanical Broom** – The broom shaft is mechanically driven through Power Take Off (PTO) from the tractor engine. Raising and lowering of the broom is achieved manually.

   The broom is mounted on two wheels, which are capable of spinning in both clockwise and counter-clockwise directions in response to the broom being moved forward or backward.

ii) **Hydraulic Broom** – In a hydraulic broom, circular motion of the broom is achieved hydraulically through a hydraulic pump coupled with the tractor engine. Raising and lowering of the broom is also a hydraulic function.

4.13.3 Suction Broom – A particular form of rotary broom is the suction sweeper. This type of unit uses a main rotary broom to direct swept material to a suction head that collects all swept material into a storage tank for disposal elsewhere. A second smaller rotary broom assists in removing loose material from the kerb and channel.

However, suction broom is not as efficient as the vacuum broom.

4.13.4 Vacuum Broom – It is designed specifically for chip seal application. It removes loose material from the surface by suction only. It consists of a suction unit positioned close to the road surface, a closed hopper to collect the material, a water sprayer and, where necessary, filter bags. The absence of contact with the surface minimises damage to new seals and is the preferred method of removal of loose chips from new seals. However, care must be taken to ensure that the broom is not stopped over a new seal surface (sensitive), while the suction is still operating, or the surface may be damaged.

Vacuum brooms can also be used for cleaning the pavement free of dust and debris.

4.13.5 Drag Brooming – For chip seal applications, when the chip is applied at the correct rate, some areas will be chipped too lightly and others too heavily, even with good control. This can be rectified by drag brooming. A drag broom is a soft bristle broom attached to a light timber or steel frame used after the aggregate spreading operation. It is used to assist in correction of any spreading deficiencies. Dragging the broom across the surface, without any applied pressure, results in minor redistribution of loose chips and filling of open gaps between them. When the surface is warm, extra precautions are needed to avoid dislodging of chips. It is important to closely control the speed of dragging as excessive speed may damage the seal and cause scattering of chips.

4.14 Bitumen Distributor

4.14.1 It is usually a self-propelled (**Figure 29**) or towed (**Figure 28**) unit and performs the following functions:

i) Spreading binder uniformly

ii) Spreading binder at a pre-determined rate

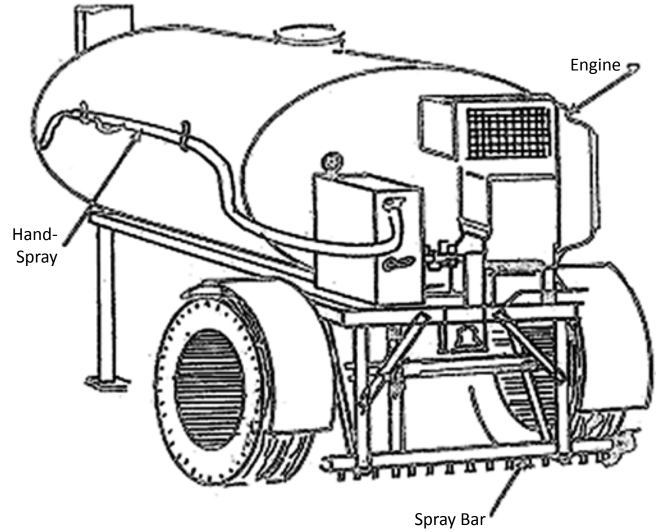


Figure 28: Bitumen Distributor (Towed Type)

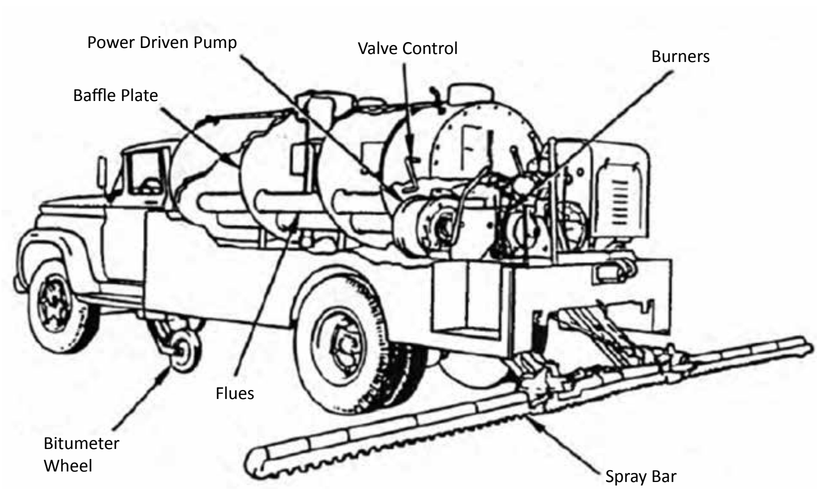


Figure 29: Bitumen Distributor (Self-Propelled Type)

4.14.2 There are four types of bitumen distributors:

i) **Pressurised Tank Type** – The bitumen tank is pressurised by an air compressor, thereby generating the necessary constant pressure at the spray bar. The application rate is achieved by controlling the vehicle speed. It can be used successfully only for low viscosity binders such as emulsions. Hence, machines of this type are rare in practice.

ii) **Constant Rate of Spread Type** – Bitumen is supplied to the spray bar by a metering pump which is driven at a speed proportional to the vehicle speed by a power take-off from the main transmission of the vehicle through a multiple ratio transfer gearbox. The supply of bitumen to the spray bar is 'non-return', which means that during spraying operation, bitumen is not allowed to bypass the spray bar and recirculate to the tank. The required application rate is obtained by selecting the appropriate gear ratio at the transfer box. If a certain minimum (pre-determined) road speed is maintained, the metering pump will deliver the required amount of bitumen to the spray bar regardless of speed variations. This type of distributor suffers from the disadvantage that if it is required to close off some jets, the overall rate of spread is affected. Very few machines of this kind are in use.

iii) **Constant Volume Type** – This machine is fitted with a metering pump, the output of which can be pre-set. The entire quantity of bitumen delivered by the pump is fed to the spray bar when spraying is in progress and there is no bypass arrangement for recirculating binder to the tank. The desired application rate is achieved through precise control of the pump output and the vehicle speed. Constant volume distributors are suited for heavy applications of binder.

iv) **Constant Pressure Type** – Here, the spray bar pressure is held constant and the application rate is achieved by precisely controlling the vehicle speed. A relief valve controls the pressure in the spray bar and permits excess bitumen to bypass the spray bar and return to the tank. Constant pressure distributors are suited for light applications of binder.

For all bitumen distributors (except constant rate of spread type), the application rate is inversely proportional to the vehicle speed.

4.14.3 A typical self-propelled bitumen distributor consists of the following:

i) Heated, insulated bitumen storage tank (of capacity 5,000 to 20,000 litres)

ii) Spray bar with spray jets (or nozzles)

iii) Pump for delivering bitumen to spray bar

iv) Spray Bar (plus a hand held spray to attend to difficult areas and corners where the bitumen distributor cannot reach)

v) A dial type of thermometer fitted on the body to indicate the bitumen temperature.

vi) An accurate tachometer capable of measuring travel speed and a locking device for fixing the desired speed.

vii) An electronic control device that will control the quantity of bitumen sprayed as well as the parameters of spraying (e.g. number of nozzles, speed of truck, temperature of the fluid etc.)

The bitumen distributor sprays the bitumen through a spray bar (and spray jets) to which the bitumen is supplied by a pump, drawing the bitumen from a heated, insulated storage tank. The bitumen pump is usually of gear type with positive displacement. Bitumen pressure is usually controlled by using either a variable speed pump or a constant speed pump with a pressure relief valve. The correct pump speed or pressure is that which neither atomizes the bitumen nor distorts the spray fan/ nozzle. Bitumen atomization and distortion of spray fan may occur if the bitumen pressure is too high. At the same time, too low a pressure may result in streaking from a non-uniform discharge of bitumen from the spray nozzles. Hence, the proper pump speed or pressure must be selected based upon manufacturer's charts and data for determining the volume per minute discharge for each nozzle size.

The system of heating bitumen is generally through a hot oil boiler, installed on board the distributor and thermic fluid oil circulated through a set of coils installed in the tank. The thermic fluid oil can be heated either through flue/flame tubes fitted with burner (using diesel or kerosene) or electronic heater. Control systems range from manual to fully automatic with thermostatic control and flame-out protection devices. A dipstick is provided to indicate the level of bitumen in the tank.

The spray bar can be of 3 different categories. While the first one just distributes the bitumen, the second category involves circulation of the bitumen, i.e., the bitumen is circulated in a closed loop from the tank to the spray bar and then back to the tank, thereby avoiding the possibility of bitumen solidifying in the spray bar and keeping the spray bar at the temperature of the bitumen. The third category has circulation of the bitumen plus a set of coils built in to allow circulation of hot oil into the spray bar, thus maintaining accurate temperature at all times.

Spray jets are usually of two types – slotted jets and whirling jets. While the former are high output jets and are suitable for grouting operations and very heavy application rates, the latter are relatively lower output jets and are suitable for surface dressing operations. The ideal viscosities of bitumen for spraying through different types of jets are distinctly different (check manufacturer's recommendation), and, therefore, the recommended temperatures at which each individual type and grade of bitumen should be sprayed, through each type of jet, will vary.

The spray bars cover width from 1.8 to 9.1 m in one pass, depending on their width and pump's capacity. In order to ensure that the spray nozzles do not interfere with each other, the angle of the long axis of the nozzle openings needs to be adjusted. The nozzle angle varies with the make of the equipment but is usually between 15^0 to 30^0 (**Figure 30**).

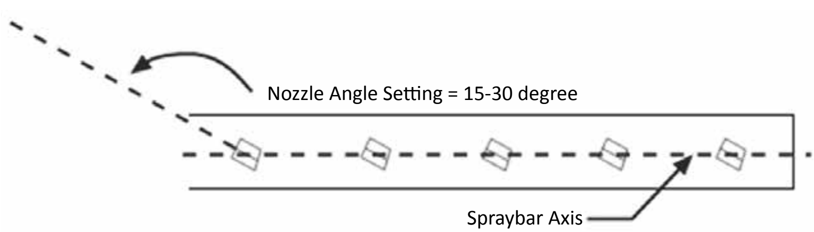


Figure 30: Proper Nozzle Angle Setting

Adjusting the height of the spray bar above the road surface is important to ensure uniformity of spray. The required height should be maintained throughout the spraying operation. The height needed for a double coverage is double that of a single coverage, and that of a triple coverage is 1.5 times that of a double coverage.

A triple coverage with 100 mm spacing of nozzles is shown in **Figure 31**. If the spacing in between nozzles were 150 mm, the needed height of the spray bar for a triple coverage would have been so high above the road surface that wind could possibly distort the spray fans. In such a case, a double coverage pattern is preferable to use. Under no condition should a single coverage pattern be used for bitumen spraying.

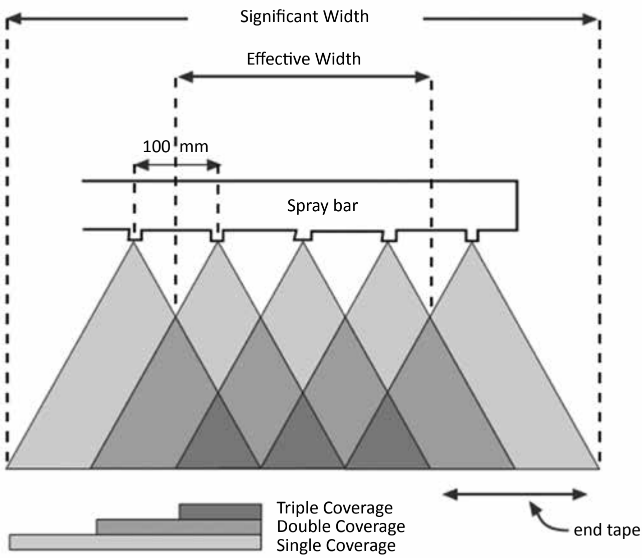


Figure 31: Overlapping of Spray Nozzles to give Triple Coverage of Bitumen

The nozzles have to be controlled individually. The opening and closing of these nozzles can be operated manually or pneumatically. A control system should be installed which makes it possible for the operator to modify, at any time, the various parameters of spraying (e.g. either 'start' or 'stop' or 'modify' the number of nozzles opened, etc.). Basically, the rate of spread is a function of four parameters, viz. viscosity of the binder, speed of the pump, speed of the truck and the number of nozzles in the spray bar. The operator has to ensure that the quantity of bitumen passing through a nozzle is the one specified and that the binder has the desired characteristics. While spraying double or triple coverage, the quantity of bitumen sprayed from 1st and 2nd nozzles of the spray bar will have lesser quantity at the edges of the road compared to other nozzles. Hence, the 1st and 2nd nozzles of the spray bar will have different sizes to have uniform spray of bitumen.

All distributors should have a bitumeter wheel or tachometer, which can measure the rate of the travel and distance covered. Electronically and laser operated speedometers are common in modern bitumen distributors. Modern distributors have interlocks between the bitumen pump and the forward speed of the distributor. As the distributor changes speed, the pump speed is adjusted to compensate for the change in speed of the distributor. As the distributor is required to move at slow speeds (of the order of 5-10 km/hr), there are usually arrangements to lock the accelerator at the required speed.

Though, heated bitumen distributors can also be used for emulsions, specially designed emulsion distributors are available.

4.14.4 It is important to regularly check and calibrate both the uniformity of rate of spray of bitumen along the entire length of the spraybar and the accuracy of the tachometer. The frequency with which these checks are carried out will depend to some extent on the regularity with which the equipment is used, but in no case should the interval between checks be more than six months or as recommended by the manufacturer, whichever is earlier.

4.14.5 The following points need to be given adequate attention in using bitumen distributors:

i) The spray bar and nozzles should be cleaned regularly to ensure flow of jets.

ii) The height of the spray bar above the road surface must be correctly adjusted and kept constant throughout the operation.

iii) The rate of application depends upon speed of travel and the operator should have a calibration chart that relates proper rate of application at any given point of time.

iv) The uniformity of application should be checked periodically by a tray test.

v) Fire extinguishers should be kept in readiness for emergency use.

vi) Suitable arrangements of side flaps should be installed for protecting kerbs and side-walks from getting sprayed.

vii) The operator and helper operating the bitumen distributor should be trained personnel.

4.15 Hot Mix Plant

4.15.1 A central mixing plant used for producing the hot bituminous mix (Bituminous Macadam, Dense Bituminous Macadam, Bituminous Concrete etc.) is called a hot mix plant. It has provisions for:

i) Controlled feeding and blending of aggregates of different sizes in the specified proportion.

ii) Drying of aggregates and heating them to the specified temperature.

iii) Uniform heating of bitumen at the specified temperature.

iv) Controlled feeding of bitumen and filler in the specified proportion.

v) Forced/ positive mixing of all the ingredients to produce a consistent, uniform, homogeneous mix at the specified temperature and as per the job mix formula.

4.15.2 Hot Mix Plant may be classified based on methodology of preparation of hot mix as follows:

i) **Continuous/Drum Type Hot Mix Plant (Figure 32)** – In this type of plant, aggregates, fines and bitumen are continuously fed into pug mill/ drum mix in desired proportion and hot mix is discharged without interruption.

The typical capacities of drum mix plant used in the road construction sector are 40-60 TPH, 60-90 TPH and 90-120 TPH.

The hot mix plant of capacity 40-60 TPH specifies that the output of plant shall be 40 TPH at 6 percent moisture content present in aggregates and 60 TPH at 2 percent moisture content present in aggregates.

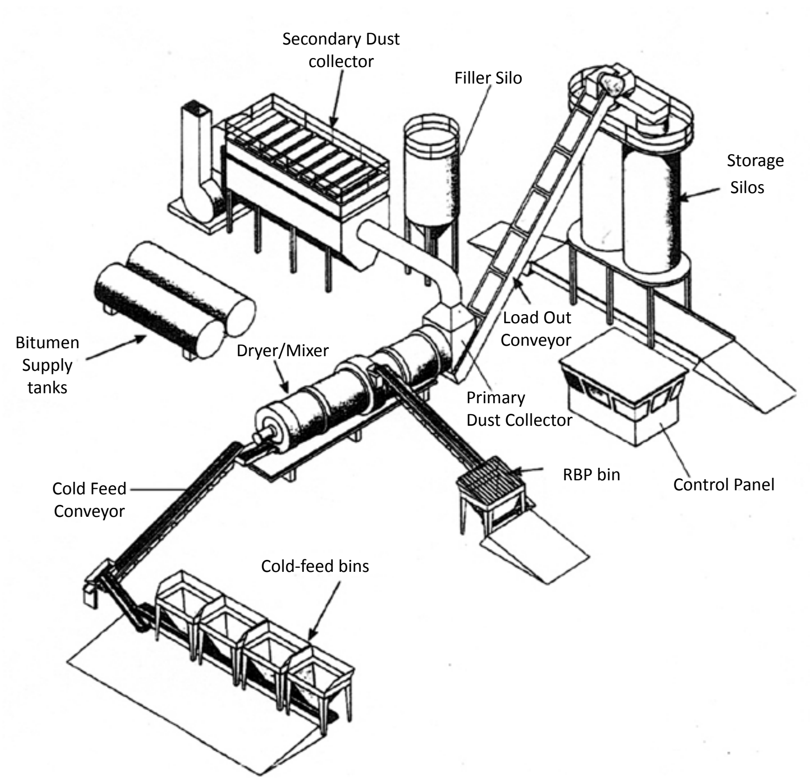


Figure 32: Drum Type Hot Mix Plant

ii) **Batch Type Hot Mix Plant (Figure 33)** – In batch type plant, hot bitumen is added with the batch of hot aggregates and filler (if necessary) at required temperature in desired proportion in mixing unit and the hot mix is prepared in batches.

The typical capacities of batch mix plant used in the road construction sector are 120 TPH, 160 TPH, 200 TPH, 240 TPH and 320 TPH.

Generally, Batch type Hot Mix Plant should be preferred for the works involving hot bituminous mix owing to better gradation control.

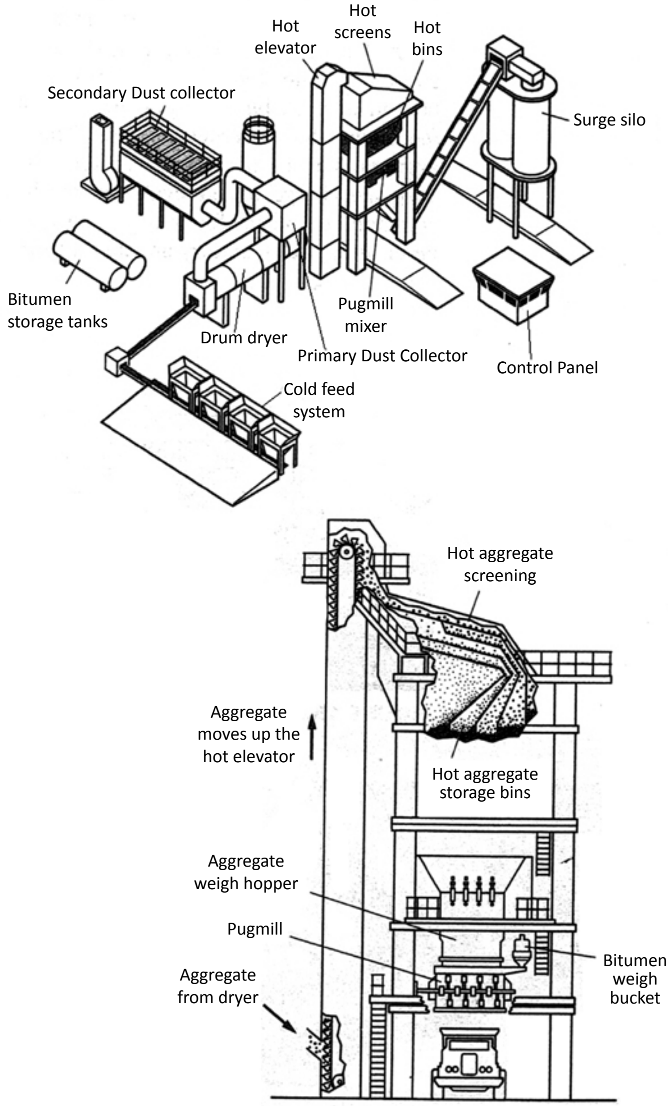


Figure 33: Batch Type Hot Mix Plant

4.15.3 Hot Mix Plant may be classified based on direction of flow of aggregates and hot gases in dryer drum as – counter flow type and parallel flow type.

4.15.4 Hot Mix Plant may be classified based on mobility as – stationary type and mobile type. Mobile plant is preferred where quantum of work is small and plant requires frequent shifting.

4.15.5 The Hot Mix Plant should have following essential features:

A. The general features which are common for both drum and batch types of plant are as follows:

i) Cold Aggregate Storage and Supply Unit with minimum four bins having belt conveyor arrangement for initial proportioning of aggregates from each bin in the required quantities. The bin containing fines is fitted with a bin vibrator to ensure free flow of fines. Each bin has easily adjustable bin gate and Low Level/ No Flow warning device.

ii) Variable speed drive below each bin to control belt speed and, thus vary aggregate proportion. An electronic load sensor on the main conveyor measures the flow of aggregates.

iii) Rejection unit for oversized aggregate for preventing damage to dryer flights/blades.

iv) Dryer unit having properly designed and arranged dryer flights with automatic burner (i.e. auto flame failure detection and auto ignition system) capable of heating the aggregate to the required temperature without any visible unburnt fuel or carbon residue on the aggregate and reducing the moisture content of the aggregate to the specified minimum.

v) The plant is fitted with suitable type of thermometric instruments at appropriate places so as to indicate or record the temperature of heated aggregates, bitumen and mix.

vi) Bitumen storage and supply unit capable of heating, measuring and spraying of bitumen at specified temperature with automatic synchronization of bitumen and aggregate feed in the required proportion.

vii) A mineral filler system capable to feed filler material into the mix in the correct quantity wherever required.

viii) Pollution/dust control system for the dryer unit to prevent the exhaust of fine dust into atmosphere for environmental control and recycle permissible fines into the mix.

ix) Arrangement for storage of hot mix, if necessary.

x) Centralized control panel capable of presetting, controlling/synchronizing all operations starting from feeding of cold aggregates to the discharge of the hot mix to ensure proper quality of mix. It should have indicators for any malfunctioning in the operation.

B. For Batch Type Plant:

i) Secondary gradation of aggregates, in hot condition, is carried out in screening unit. Screening (Gradation Control) unit has multi-deck vibratory screen, or rotary screening drum for heating and accurate sizing of hot aggregates and storing them in separate hot bins.

ii) The plant has a separate mixer unit (pug mill) for producing homogeneous mix unlike drum mix plant (where heating of aggregates as well as preparation of mix takes place in the same dryer drum).

In case of Hot in Plant Recycling, the plant must have suitable provision for addition of RBP (Reclaimed Bituminous Pavement) in required proportion in the mixer/ dryer drum.

For more information on Hot Mix Plant, refer to IRC:90.

4.16 Paver Finisher

4.16.1 A Paver Finisher (**Figure 34**) is used in bituminous road construction for laying non-bituminous as well as bituminous mixes. Following are the main functions of a Paver Finisher:

i) To lay and spread the mix to attain specified surface.

ii) To facilitate the attainment of specified surface quality and correct grade/level/ finish to meet the road design specifications for a safe and comfortable ride.

iii) To achieve specified camber and super elevation.

iv) To achieve required thickness, uniform degree of compaction, homogeneous quality of mix during laying and uniform bearing capacity over the entire surface.

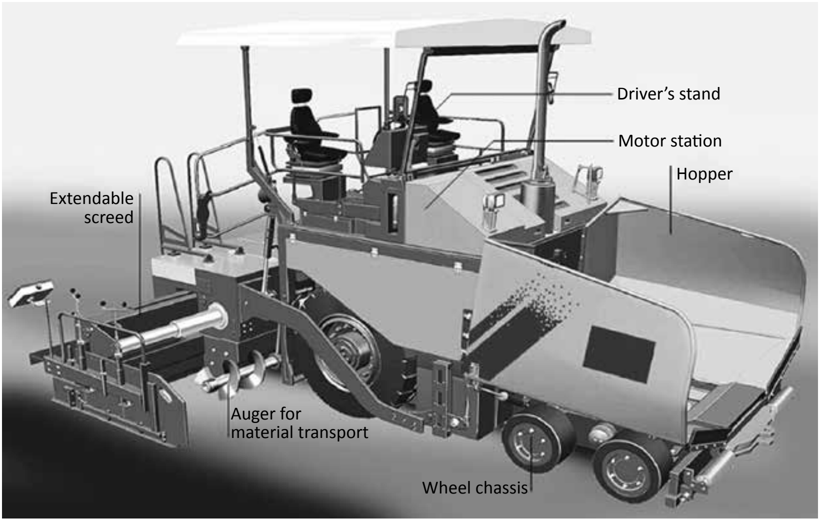


Figure 34: Paver Finisher

4.16.2 Classification of Paver Finishers is given in **Table 15**.

Table 15: Types of Paver Finishers

Sl. No.	Basis	Types
1.	Control of Screed Extension and Control Mechanism for Screed Elevation via tow point mounting/actuation	a) Mechanical Paver b) Hydrostatic Paver
2.	Type of Traction	a) Wheeled Paver b) Track Chain Paver

In case, paving width requirement is 8 m and above, use of track chain paver is recommended for better control over traction and pavement quality.

4.16.3 The Paver Finisher consists of two units – tractor unit and screed unit. The tractor unit is the front part of the paver and houses the prime mover, pushing rollers, receiving hopper, feeding conveyors, spreading augers, hydraulic system, operator's cabin and driving system. The primary function of the tractor is to propel the tipper truck, to convey and distribute the paving material through the augers and tow the screed. The screed unit is the rear part of the paver and consists of levelling screed, tow arms and mat thickness adjustment mechanism. The screed is of ‘floating, self-levelling’ type and is free to rise and fall, thereby seeking its own angle of attack and establish the desired mat thickness. The key to the levelling performance of the screed is to fill in low spots and decrease the influence of high spots, thus acting as an averaging device.

4.16.4 There is a need to maintain a constant head of material in front of the screed to maintain correct depth of the mat, which is facilitated by proper setting of the flow gates and augers on the paver.

4.16.5 The screed has a tamping and vibrating arrangement with adjustable amplitude and variable frequency for compacting the mix being paved. The compaction effect of the screed is determined by the screed weight, contact area of tamping or vibrating element, paving speed, frequency and amplitude of the tamping unit and screed plate.

4.16.6 The screed has an internal heating arrangement to preheat the screed plate and tamper to the desired temperature before starting the paving of hot bituminous mixes and, thus prevent picking up or sticking of bitumen. There are three types of heating devices – diesel/oil fired burner, gas burner and electric heater.

4.16.7 The screed assist system provides partial neutralization of screed load and ensures constant pressure of the screed on the mix regardless of the bearing capacity of the mix and width being paved. It also enables transferring part of the screed weight to the drive axle/tracks of the machine in order to avoid spinning of the wheels/tracks under adverse gradients or underfoot conditions.

4.16.8 Another adjustment on the screed is the crown control mechanism, which allows adjustment of the crown to meet the geometric requirements of the paving lane by adjusting a turnbuckle device to flex the bottom of the screed to produce the desired crown.

4.16.9 Paver finishers with paving width ranging from 1.2 m to 1.8 m and hydraulically extendable up to 3.4 m (which can further be extended with bolt extension upto 5 m) and paving thickness ranging from 150 mm to 250 mm may be used for small road projects or in confined space.

Typical range of specifications for paver finishers used in medium and large road projects is given in **Table 16**.

Table 16: Specifications for Paver Finishers used in Medium/Large Road Projects

Sl. No.	Specifications	Wheeled Paver	Track Chain Paver
1.	Basic Paving Width	2.5 m to 3.0 m	2.5 m to 3.0 m
2.	Hydraulically Extendable Width	Upto 6.0 m	Upto 6.0 m
3.	Max. Paving Width with Bolt Extension	Upto 8.0 m	Upto 16 m
4.	Paving Thickness	10 to 300 mm	10 to 500 mm
5.	Laying Capacity	300 – 700 TPH	600 – 1600 TPH
6.	Paving Speed	0 – 45 m/min	0 – 24 m/min
7.	Travel Speed	0 – 20 km/hr	0 – 4.5 km/hr

4.16.10 For laying bituminous mixes on highway projects, self-propelled hydrostatic paver finisher with electronic sensing instrument is used for automatic levelling and profile control.

Three basic types of grade reference systems have been developed – the erected stringline, the mobile reference and the joint matching shoe. These reference systems typically use a combination of longitudinal grade sensors to establish position in the direction of traffic and may include a slope control device to control transverse cross slope of the paving lane.

4.16.11 For more information on Paver Finishers, refer to IRC:SP:86.

4.17 Roller

4.17.1 A Roller is a compactor used to compact embankment, subgrade, Granular Sub-Base (GSB), Dry Lean Concrete (DLC) or bituminous mix. Selection of the roller depends on the type of application, thickness of the layer and the properties of the material to be compacted.

4.17.2 Rollers are broadly classified into the following types (**Figure 35**) depending on their utility in different situations:

i) Static Roller [Three wheeled type and tandem (two-wheeled) type]

ii) Sheepsfoot Roller

iii) Padfoot Roller (static padfoot roller is called tamping roller)

iv) Pneumatic Tyred Roller

v) Vibratory Roller (Single Drum and Double Drum types)


Padfoot Roller/Tamping Roller


Pneumatic Tyred Roller


Smooth Drum Vibratory Roller


Conventional Three-Wheeled Roller

Figure 35: Types of Rollers

4.17.3 Compaction mechanisms available in different types of rollers are indicated in **Table 17**.

Table 17: Rollers and their Compaction Mechanisms

Type of Roller	Type of Compaction Mechanism			
	Impact	Pressure	Vibration	Kneading
Static		√		
Vibratory	√	√	√	
Pneumatic		√		√
Sheepsfoot		√		√
Tamping Foot	√	√		

4.17.4 Selection of roller based on type of activity is indicated in **Table 18**.

Table 18: Selection of Roller based on Type of Activity

Sl. No.	Layer	Remarks	Type of Roller
1.	WMM	For layer thickness ≤100 mm	Static Roller (8-10 tonne)
		For layer thickness of 100-200 mm	Vibratory Roller with a minimum static weight of 8-10 tonne
2.	Bituminous Layer (BM, SDBC, DBM, BC etc.)	Initial or Breakdown Rolling	Static Roller (8-10 tonne)
		Intermediate Rolling	Static Roller (8-10 tonne) or Vibratory Roller (8-10 tonne) or Pneumatic Tyred Roller (12-15 tonne) or Combination Roller (8-10 tonne)
		Finish Rolling	Tandem Static Roller (6-8 tonne)
3.	Embankment/ Subgrade		Static Roller (8-10 tonne) or Vibratory Roller (8-10 tonne) or Pneumatic Tyred Roller (12-15 tonne) or Sheepsfoot/Padfoot Roller (for clay and silty soil)
4.	Dry Lean Concrete (DLC)		Vibratory Roller (8-10 tonne)
5.	Maintenance Work (Shoulders and Potholes)		Static Roller (2-3 tonne) or Hand Roller or Plate Compactor or Rammer (500-750 blows per minute)

4.17.5 Rollers should move at uniform speed. The speed should not exceed 5 km/hr for static roller and 6.5 km/hr for pneumatic tyred roller.

Speed of a vibratory roller will depend upon the operating frequency and desired impact spacing (determined by the number of impacts per metre). For example, a vibratory roller operating at a frequency of 60 Hz can provide 39 impacts per metre at a speed of 5.5 km/hr. The impact spacing should be such that it allows the entire surface to be impacted as the roller travels in vibratory mode. Since drum diameter controls the length of arc of drum contact with the pavement surface, impact spacing can be adjusted narrower or wider depending upon the drum diameter.

The general thumb rule for optimal impact spacing in case of bituminous compaction is 33–46 impacts per metre, with the higher value suited for smaller drum diameter (up to 1 m) and the lower value suited for larger drum diameter (1.2 – 1.4 m).

4.17.6 While operating any vibratory roller, it is advisable to select the highest frequency setting recommended for a particular job and, thereafter, choose the lowest amplitude setting consistent with achieving target density. Creating excessive drum force by selecting amplitude too high for the material layer thickness or mix properties risks aggregate damage. However, with increase in lift thickness, the requisite amplitude setting will also be higher.

The suitable frequencies and amplitudes for different applications in case of vibratory rollers are indicated in **Table 19**. Nowadays, vibratory rollers with frequencies as high as 70 Hz are also available in the market.

Table 19: Application Guidelines for Vibratory Rollers

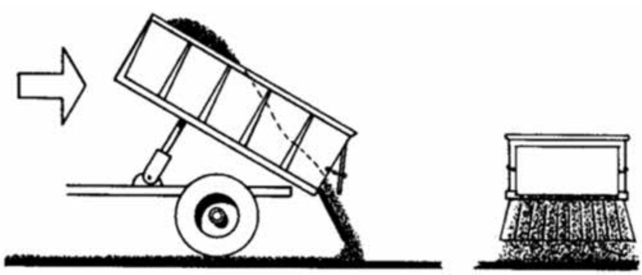
Sl. No.	Application	Static Linear Load (kg/cm)	Amplitude (mm)	Frequency (Hz)
1.	Earthwork	≥ 30	≥ 1.5	28–35
2.	Granular Base	≥ 10	≥ 0.4	28–60
3.	Granular Sub-Base			
4.	Bituminous Base Course	10 – 30	0.35 – 0.9	30–60
5.	Bituminous Wearing Course	10 – 30	≤ 0.5	40–60

4.17.7 For more information on rollers, plate compactor and rammer, refer to IRC:SP:97.

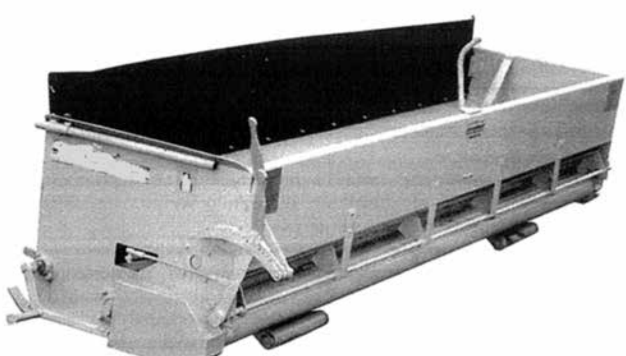
4.18 Aggregate Chip Spreader

4.18.1 An aggregate chip spreader receives and dispenses an aggregate material in predetermined quantities and in a layer having substantial uniformity in thickness. The rate of dispensing the aggregate material is controlled to achieve the desired weight of aggregate per unit area and depends upon the speed of the machine. Aggregate chip spreaders are of three basic types:

i) **Tail Gate Spreader (Figure 36)** – The spreader is connected directly to the tail gate of a tipper truck. Traditionally, tail gate spreaders range from the simple vane type to the more sophisticated hydraulically operated roller spreader. Only the latter type is capable of consistently providing the necessary control of evenness and application rate.



Vane Spreader



Roller (Hopper Type) Spreader

Figure 36: Tail Gate Aggregate Chip Spreader

The vane spreader has a steel plate with a series of vanes to spread aggregates over the desired lane width.

The roller spreader has a hopper with a feed roller. Chips are gravity discharged from the hopper through an adjustable gate and onto the rotating feed roller. The peripheral speed of the roller and degree of gate opening will determine the rate at which the chips will flow through to the roller and onto the pavement. To ensure even distribution of the chippings, metering is done by the feed roller which is activated by small wheels that are driven by truck wheels. In this way, variations in speed of truck produce corresponding variations in the rate of discharge of the aggregate material.

Modern spreaders use pneumatically operated cut-off plates for varying the width of spread.

ii) **Truck Mounted (Towed) Spreader** – It is connected to the tail gate of the tipper truck just like a tail gate spreader but has wheels to support the spreader. It is basically a hopper on wheels which is hooked on to and propelled by the backing aggregate truck. The feed is driven by the wheels of the hopper and the chippings in the hopper are replenished from the raised body of the tipper truck. The hopper contains feed gate, auger and roughened spread/feed roll for distributing aggregates uniformly to the full width of the box. There is an adjustable hitch on the front of the spreader by means of which it is attached to the truck.

This type of spreader has controls to regulate the feed gates, feed roll, auger and truck hitch height.

iii) **Self-Propelled Spreader (Figure 37)** – It supplies the power for the spreading operation rather than being dependent on the truck itself. It is connected to the aggregate truck by means of a self-locking hook that locks on to the truck as the truck backs into the rear of the machine. The spreader then pulls the truck along the spread area. The spreader consists of a receiving hopper at the rear into which aggregates are discharged from the delivering truck. Two individual (usually automatically controlled) conveyor belts transfer the chippings from the receiving hopper to a spreading hopper at the front of the machine. The spreading hopper is fitted with a feed gate and spread roll for controlling/ metering the spread of the chips relative to the machine speed. The gate is also used for varying the spread width.

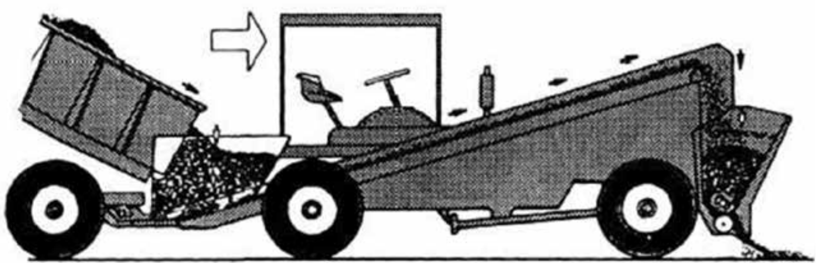


Figure 37: Self-Propelled Aggregate Chip Spreader

The self-propelled spreader usually has a scalping screen at the top of the spreading hopper, which allows scalping of oversized material that may get into the receiving hopper from the truck. A sloped screen may alternately be used to allow larger aggregates to drop into the bituminous surface first with the finer aggregates falling afterwards through the screen. This will ensure that the larger aggregates are sufficiently embedded in the bitumen to hold them in place.

A self-propelled spreader has the advantage of being able to closely follow behind the bitumen distributor with minimum stoppage to change aggregate trucks. Other advantages of the self-propelled spreader are the considerably greater spreading width & speed and better control, because only one machine has to be set up and controlled. The disadvantages of a self-propelled chip spreader are cost, manoeuvrability is difficult in very tight areas, and transportation as it needs to be trucked to the site.

4.19 Concrete Batching and Mixing Plant

4.19.1 A Concrete Batching and Mixing Plant combines various ingredients like sand, water, aggregates, chemical and mineral admixtures (fly ash, plasticizer etc.), and cement by weight to form concrete. The aim is to produce homogenous and uniform concrete, as indicated by physical properties such as unit weight, slump, air content, and strength in individual batches and successive batches of the same mix proportions. Capacity of the plant is measured in cubic metre per hour. It depends upon capacity of mixer, number of mixers, charging, mixing and discharge time of each mixer.

4.19.2 Classification of concrete batching and mixing plant based on different criteria is indicated in **Table 20**.

Table 20: Classification of Concrete Batching and Mixing Plant

Sl. No.	Basis/ Criterion	Classification
1.	Mobility	i) Stationary ii) Mobile
2.	Batchers	i) Manual ii) Semi-Automatic iii) Automatic
3.	Mixer	i) Drum/ Free Fall Mixer a) Tilting b) Non-tilting c) Reversible d) Self-loading ii) Power Mixer a) Pan or Vertical Shaft Mixer b) Trough or Horizontal Shaft Mixer

4.19.3 A central (stationary) concrete batching and mixing plant (**Figure 38**) prepares the concrete mix after which it is loaded into a truck or transit mixer for transportation to the work site. Small plant may have an output as low as 12 cum/hr, medium plants may have an output in the range of 30 to 100 cum/hr and larger plants may have an output of more than 100 cum/hr. Plants of more than 300 cum/hr are also available in India.

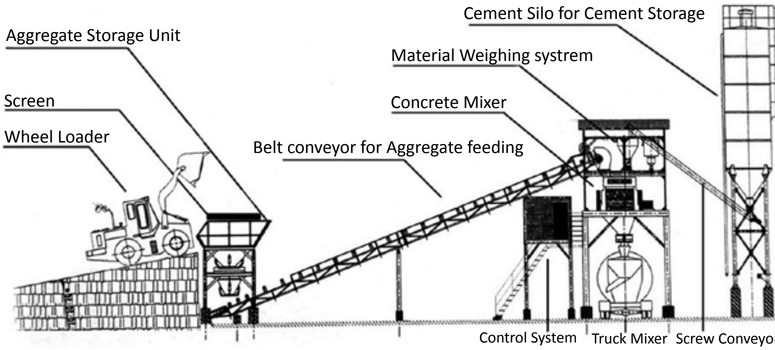


Figure 38: Concrete Batching and Mixing Plant (Stationary)

The plant consists of the following main components:

i) Storage Equipment
   a) Aggregate Storage (Star type, Compartment type or Inline Bin type)
   b) Cement Storage (Godown Storage or Silo Storage)
   c) Water Storage
   d) Admixture Storage

ii) Batching Equipment (load cell based weigh batching of cement, aggregates, water and admixtures) – For concrete batching plant of capacity below 20 cum/hr, the aggregates, sand, and cement may be weighed one after the other cumulatively in the same weigh batcher whereas for concrete batching plants more than 20 cum/hr capacity, individual batchers are provided for each ingredient. Water and admixture measurement is preferred by weight. However, for plants up to 30 cum/hr capacity, water and admixture may be measured by volume. The batching plant shall have facility for injecting at least two admixtures in the mixing pan.

iii) Conveyors

iv) Mixer

v) Control System - The annunciations like operating conditions, fault indications etc. can be very easily displayed on the computer screen with the help of SCADA (Supervisory Control and Data Acquisition). This software makes the data storage and printout very flexible and easy. The live weight of the ingredients in the weigh hoppers are continuously upgraded on the computer along with the operating status of various equipment. SCADA based system with GPRS technology provides the real-time batch data to the client server.

The concrete is said to be adequately mixed if the samples taken from different portions of a batch will have essentially the same unit weight, air content, slump and coarse aggregate content within permissible limits.

The mixing action of concrete involves two operations:

i) A general blending of different particle sizes of the ingredients to be uniformly distributed throughout the concrete mass.

ii) A vigorous rubbing action of cement paste on to the surface of the inert aggregate particles.

The operation flowchart of a concrete batching and mixing plant is shown in **Figure 39**.

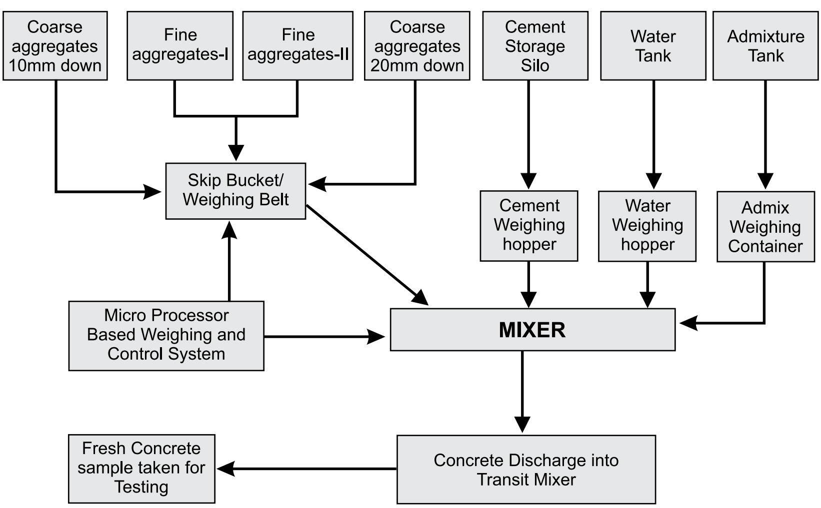


Figure 39: Operation Flowchart of Concrete Batching and Mixing Plant

4.19.4 A portable concrete batching and mixing plant will generally be built onto a truck trailer having the framework carrying batchers, mixer, conveyor and control equipment to facilitate transportation from site to site.

4.19.5 Concrete mixers are suited for smaller works.

4.19.6 Minimum mixing time and capacity for different types of mixers is indicated in **Table 21**.

Table 21: Mixing Time and Capacities of Different Concrete Mixers

Sl. No.	Type of Mixer	Usage	Capacity of Mixer (in litres)	Minimum Mixing Time (in seconds)
1.	Non-tilting reversible drum type	Low workability, large size of aggregates, small works	375, 500, 750, 1000, 1500, 2000	40
2.	Pan type	Large projects and Precast works	375, 500, 750, 1000, 1500, 2000, 3000	30
3.	Single shaft/ twin shaft/ compulsory type/pug mill type	Large works	500, 750, 1000, 1250, 1500, 2000, 2500, 3000, 3500, 4000, 5000, 6000	30

4.19.7 Typical range of specifications for Concrete Batching Plant is indicated in **Table 22**.

Table 22: Specifications for Concrete Batching Plant

Sl. No.	Equipment	Specifications	Range
1.	Stationary Plant	Capacity	12 - 360 cum/hr
		Batch Count	40 - 60 cycles per hour
		Mixer Capacity	0.5 - 6 cum
2.	Mobile Plant	Capacity	18 - 140 cum/hr
		Batch Count	40 - 60 cycles per hour
		Mixer Capacity	0.5 - 6 cum

4.19.8 For more information on concrete batching and mixing plant and concrete mixers, refer to IRC:SP:86.

4.20 Transit Mixer

4.20.1 Transit Mixer is used to transport concrete from the concrete batching and mixing plant to the work site. It prevents segregation of already mixed concrete during transit by agitation, as a result of slow revolution of the drum.

4.20.2 Transit Mixer (**Figure 40**) has a revolving drum with the axis inclined to the horizontal. Inside the shell of the mixer drum are pair of blades (with opposite direction of helix) that wrap in a helical (spiral) configuration from the head to the opening of the drum. The drum is mounted on two sets of twin rollers with suitable cover for protection against dust/dirt.

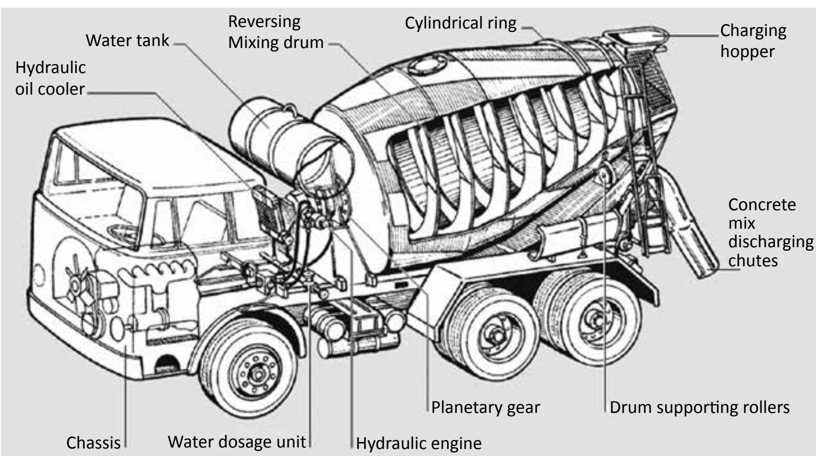


Figure 40: Transit Mixer

The drum is rotated by a low speed planetary gear box bolted to the closed end of the mixer drum, which is powered by high torque reversible type hydraulic motor through variable displacement hydraulic pump. The drum drive shall be hydrostatic type and through power take-off unit from the vehicle engine itself or a separate diesel engine.

The Transit Mixer is also equipped with a water tank for supply of flush water to the mixer drum.

The charging hopper at open end of the mixer shall be stationary and properly supported in concentric position with the drum opening. It may be equipped with a drum closure plate arrangement to prevent spillage as encountered on hilly terrain, especially in the case of concrete of higher slump.

The discharge chute consists of a fixed U-chute and a set of foldable distributing chute. The distributing chute is of swing-away type with fold-over extensions. The swing out fixture prevents the need to remove or replace the chute for direct discharge into high forms, hoppers or buckets. Means shall be provided for locking the distributing chute components in position when the mixer is in transit. The distributing chute shall be equipped with ratchet type or mechanical screw jack type or hydraulic chute lift for its quicker positioning.

4.20.3 The action of the helical blades prevents the concrete from segregating when the drum spins in one direction and causes it to discharge when the direction of spin is reversed. The mixing drum can rotate at different rotational speeds – at the highest speed while being filled or emptied and at the lowest speed during travel. For this reason, a hydraulic drive is commonly used for rotation of the drum. After the concrete is loaded, it is normally hauled to the work site with the drum rotations at a speed in the range of 2 to 6 rpm.

During movement of the transit mixer on temporary/uneven roads, the drum speed shall not exceed 4 rpm and the truck speed shall not exceed 20 km/hr to avoid accident due to overturning. However, in case of good road condition, drum speed may be increased to 6 rpm and truck speed to 40 km/hr.

4.20.4 The factor limiting the distance over which concrete mix can be transported by the transit mixers is the setting time, determined mainly by the ambient temperature, temperature of the mix and the type of cement.

Concrete must be unloaded from the transit mixer within the following time limits after its receipt from concrete batching and mixing plant:

i) Within 1.5 hours when atmospheric temperature is above 20^0 C.

ii) Within 2 hours when atmospheric temperature is at or below 20^0 C.

4.20.5 The size of a transit mixer is indicated by the nominal batch capacity of its mixer drum.

However, it may be noted that the carrying capacity of the mixer will reduce with concretes of higher slump and/or the uphill road gradient.

4.20.6 Typical specifications for transit mixer used in the highway sector are indicated in **Table 23**.

Table 23: Specifications for Transit Mixer

Sl. No.	Specifications	Range
1.	Capacity	2 - 10 cum
2.	Drum Speed	0 -14 rpm
3.	Water tank	200 - 650 litres
4.	Drum angle	12 -15 degrees
5.	Filling ratio	50 - 59 %

4.20.7 For more information on transit mixers, refer to IS:5892.

4.21 Concrete Placer/Spreader

4.21.1 It places a metered supply of concrete mix in front of the concrete paver using a series of conveyor belts, augers, ploughs and strike off devices. Using a placer/spreader allows the contractor to receive material from transport vehicles and place a uniform amount of concrete mix in front of the entire paver width, while minimizing segregation.

4.21.2 Tipper trucks delivering concrete shall normally not run on plastic sheathing nor shall they run on completed slabs until after 28 days of placing the concrete.

The placing of concrete in front of the PQC paver should preferably be from the side placer to avoid damage to DLC by concrete tipping trucks. In case of unavoidable situation, truck supplying concrete to the paver may be allowed to ply on the DLC with the approval of the Engineer.

4.21.3 The sub-base must be thoroughly moistened ahead of the spreader to prevent rapid loss of water from the concrete. Care must be taken to see that the correct quantity of concrete is placed; too much will overload the following paver, and too little will result in having necessarily to halt the paving while additional material is being added.

The distance between the spreader and paver is important and should be kept as short as possible because the concrete will set in about 20 minutes.

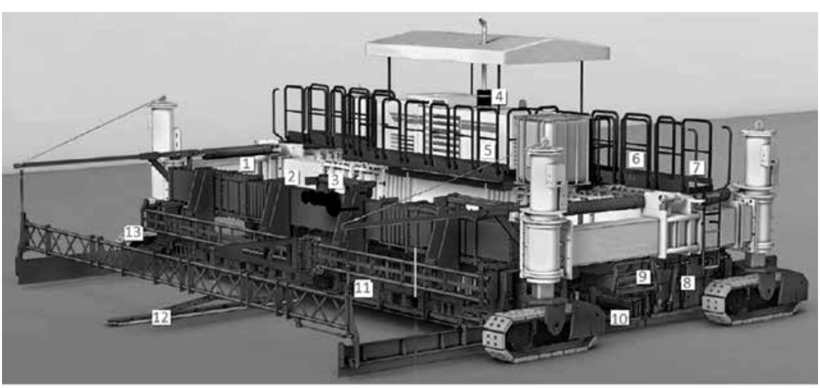
4.21.4 The total time taken from the addition of water to the mix until the completion of the surface finishing and texturing shall not exceed 2 hours when concrete temperature is less than 25°C and 1.5 hours when concrete temperature is between 25°C and 30°C.

4.21.5 For more information on concrete spreader, refer to IS:7242.

4.22 Concrete Paver

4.22.1 There are two basic methods of paving concrete pavements – slip form paving and fixed form paving.

4.22.2 Slip Form Paver (Figures 41 and 42) – Slip form paving is defined as a process used to consolidate, form into geometric shape and surface finish a PQC mass by pulling the forms continuously through and surrounding the plastic concrete mass. Slip form paving is most appropriate for larger jobs that require high production rates. Slip form paver usually uses string lines/guide wires for line and grade control. The paving unit is equipped with sensors at its four corners. The alignment of the paver shall be controlled automatically from the guide wire by at least one set of sensors attached to the paver. The alignment and level of ancillary machines for finishing, texturing and curing of the concrete shall be automatically controlled relative to the guide wire or to the surface and edge of the slab.



KEY:
1. Telescoping Machine Frame, 2. Self-loading Feature, 3. Longitudinal Joint Tie Bar Inserter, 4. Operator's Platform, 5. Power Unit, 6. Concrete Spreading, 7. Vibrators, 8. Inset Paving Moulds, 9. Dowel Bar Inserter, 10. Side Tie Bar Inserter, 11. Oscillating Beam, 12. Super smoother, 13. Track Units

Figure 41: Concrete Slip Form Paver

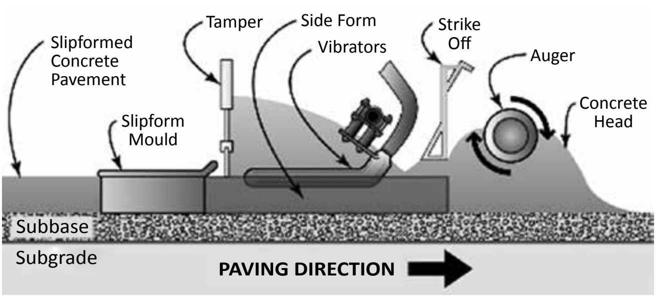


Figure 42: Section View of Concrete Slip Form Paver

Components of the slip form paver are:

i) Distributor (auger or plough)

ii) Metering Gate/ Front Panel

iii) Vibrators for compaction

iv) Mould and slip forms

v) Dowel Bar Inserter (DBI), Central Tie Bar Inserter (CTBI), Side Tie Bar Inserter (STBI)

vi) Oscillating beam

vii) Super Smoother/ Auto Float for finishing the surface

viii) Texturing and curing compound spraying unit

Slip form paving is accomplished by the use of several self-propelled machines in a line which is commonly known as a paving train.

The first machine in line is a concrete placer/spreader, which facilitates rough placement of concrete without segregation across the paving area and to a height, which at all times is in excess of the required surcharge, before the second machine, which is the slip form paver. Sometimes, this first machine is eliminated if the concrete can be deposited directly in front of the paver from the concrete delivery unit or if a concrete placing attachment is installed in the front of the slip form paver.

The slip form paver usually performs screeding, consolidation and initial finishing. Some pavers are equipped to place reinforcing steel (if needed), dowel bars and tie rods as well. Slip form pavers use their own weight to mould the plastic concrete into the correct shape.

The paver spreads/distributes the concrete uniformly across the paving area using an auger or plough, strikes off the top of the concrete to the necessary average and differential surcharge to feed into the mould that shapes the pavement into the proper geometric configuration, and consolidates the concrete with internal vibrators. The equipment for striking off the concrete shall be capable of being rapidly adjusted for changes of the average and differential surcharge necessitated by change in slab thickness or crossfall. Depending on the manufacturer, some slip form pavers also utilize what is known as a tamping bar. The tamping bar assists in consolidation and finishing by tamping large aggregates into the top of the concrete slab to prevent the paver's mould from snagging the aggregate and causing a tear in the top of the slab.

Typically, the most effective vibrator position is after the strike-off mechanism and at the final slab elevation. Most pavers use fully adjustable vibrator spacing to account for different conditions and mix types, while still providing adequate influence zone overlap. The paver shall have vibrators of variable output with a maximum energy output of not less than 2.5 KW per metre width of slab per 300 mm depth of slab for a laying speed up to 1.5 m/min. Vibrators shall operate at a frequency of 8000-10000 impulses per minute under load at a maximum spacing of 600 mm.

Initial finishing is accomplished by extruding the PQC mass through a moving form made up of the base course (bottom), the side forms (vertical edges of the paver) and the mould (flat paver pieces mounted behind the vibrator). Extruding PQC through the resulting rectangular shape provides the final slab dimensions and also serves to imbed larger aggregate particles below the surface, which results in a smooth finish.

Placing of dowel/ tie bars at their pre-designed locations is done through the machine integrated Dowel Bar Inserter (DBI) and Tie Bar Inserter (TBI).

The third machine in the paving train is a tube float. This machine smoothens and seals the top of the pavement by dragging diagonally mounted aluminium tubes forward and back along the top of the pavement. This machine is sometimes eliminated by attaching a super smoother/ auto float to the back of the slip form paver. The auto float automatically travels across the top of the pavement while simultaneously oscillating in a forward and backward motion to smoothen and seal the top of the pavement. The aim of this operation is to minimise surface irregularities caused due to various reasons like frequent stoppages of work, surface deformation due to plastic flow etc.

The last machine in the train is a Texturing and Curing Machine (TCM) (**Figure 43**). Although separate equipment may be used for texturing and curing operations, typically, in most cases, the slip form paver is followed by a Texturing and Curing Machine (TCM), which imparts macro texture as well as applies a curing membrane over the pavement while the concrete is still in plastic state. The TCM may be wheel-mounted or track-mounted with controls for optimised longitudinal or transverse texturing and curing. Texturing Equipment and Curing Compound Sprayer are discussed separately in **Sections 4.26** and **4.27** respectively.

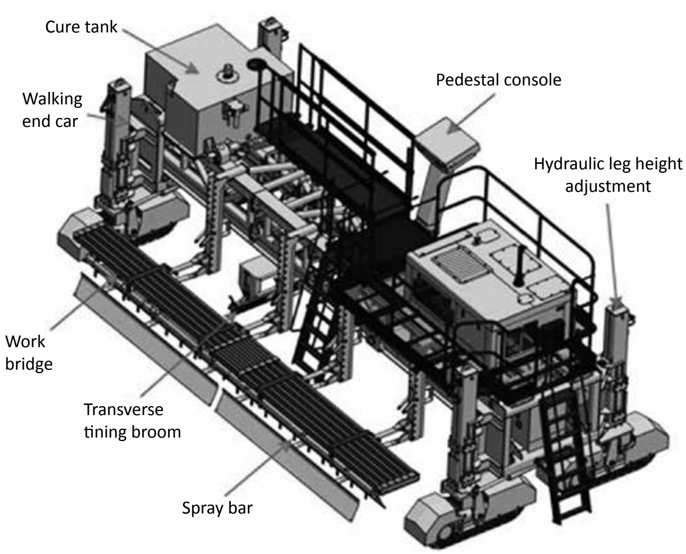


Figure 43: Texturing and Curing Machine (TCM)

Advantages of slip form paving are:

i) **Use of Low-Slump PQC** – Low-slump PQC of the order 25±10 mm is necessary so that the fresh PQC is able to hold its shape once the slipform paver has passed. Low slump PQC can be made with less water and usually has higher compression and flexural strengths than comparable high slump mixes.

ii) **High Productivity** – Large jobs generally require high production rates.

iii) **Smooth Riding Surface** – Automation and computer control allow the paver to produce very smooth riding surface.

Typical specifications for slip form pavers are given in **Table 24**. Paving speed shall not be less than 1 m/min.

Table 24: Specifications for Slip Form Paver

Sl. No.	Specifications	Range
1.	Paving Width	2 – 16 m
2.	Paving Thickness	0.4 – 0.5 m
3.	DBI (Diameter Range/ Length Range)	20 – 40 mm/ 500 – 600 mm
4.	TBI (Diameter Range/ Length Range)	20 – 40 mm/ 400 – 1200 mm

4.22.3 Fixed Form Paver (Figure 44) – Despite the speed and ease of slip form paving, there are still applications where fixed form paving is more practical and cost-effective. These include streets, intersections, local roads, and complicated short-run of variable width pavements.

Figure 44: Concrete Fixed Form Paver

4.22.4 Stationary side forms are used in fixed form paving to hold the concrete in place. The forms are built to the line and grade of the finished pavement and shall be of depth equal to the thickness of pavement or slightly less to accommodate the surface irregularity of the sub-base. Side forms for use with wheeled paving machines shall incorporate metal rails firmly fixed at a constant height below the top of the forms. The forms shall be sufficiently robust and rigid to support the weight and pressure caused by the paving equipment. The formwork should consist of mild steel channels for straight lengths and wooden sections reinforced with mild steel angles for curved portions. Manufactured sections are also available for form work as given in IRC:15.

The fixed form paving train consists of separate powered machines which spread, compact and finish the concrete in a continuous operation.

The concrete shall be discharged without segregation to a uniform uncompacted density by a traversing hopper spreader. It is mounted on a self-propelled, rail-mounted frame such that it moves across the frame and discharges concrete at a controlled rate on to the sub-base as the frame moves forward. The underside of the hopper then strikes off the deposited concrete up to the desired surcharge level as it returns with the frame remaining stationary.

The spreader is conventionally followed by a distributor (with rotary strike-off paddles) and a transverse vibrating compaction beam. The strike-off paddles trim any minor surface irregularities in the surcharged concrete. The vibratory compaction beam thoroughly compacts the layer and has adjustable amplitude and frequency to suit the characteristics of the PQC. If necessary, poker vibrators shall be used adjacent to the side forms and edges of the previously constructed slab. After compaction, dowel bars and tie bars, which have not been previously attached to the sub-base, are vibrated into position. The vibratory compaction beam shall be set to strike off the surface slightly high so that it is cut down to the required level by the oscillating beam. The machine shall be capable of being rapidly adjusted for changes in average and differential surcharge necessitated by changes in slab thickness or crossfall. The final finisher shall be able to finish the surface to the required level and smoothness as specified.

Particular advantages of fixed form paving are:

i) Tight tolerances and side clearances. Existing curbs or other features can be used as forms.

ii) Custom geometry. Forms can be placed in just about any pavement geometry, which allows for multiple changes in pavement width, smooth curves, blockouts and other abnormalities.

iii) Better construction staging. Forms can be placed such that staged construction can be used to maintain traffic flow or intersection use.

iv) Less expensive equipment and mobilization. Forms and equipment are less expensive than slip form paving equipment. If paving operations are small enough, cost savings in fixed form paving can more than conpensate for the higher production rates of slip form paving.

For fixed form pavers, paving width usually varies from 2.74 to 15 m.

4.23 Concrete Vibrator

4.23.1 Concrete vibrators are used for compaction of Pavement Quality Concrete (PQC) and structural concrete and, therefore, remove the air voids. In addition to consolidating the concrete for maximum density, they also internally blend the different lifts of concrete together into a single solid mass with few to no air pockets and no lift lines on the finished exposed surface. After deciding whether to use internal or external vibration, following parameters shall be considered in making an appropriate choice:

i) Frequency

ii) Amplitude

iii) Power and

iv) Size

Since concrete contains particles of varying sizes, the most satisfactory compaction would be obtained by using vibrators with different speeds of vibration.

4.23.2 The various types of concrete vibrators are described below:

i) **Internal or Immersion or Needle or Poker Vibrators**

It is the most commonly used vibrator and can be satisfactorily used for consolidation of plain as well as reinforced concrete by adequately dipping the vibrating needle in concrete either perpendicularly or at an angle. However, it should not be used where the thickness of concrete is less than 100 mm.

Internal vibrator (**Figures 45** and **46**) essentially consists of a steel tube (with bottom cap end closed and rounded) having a vibrating needle inside it. The vibrating needle can consist of either an eccentric shaft or a rotor and runner assembly (pendulum type vibrator). The prime mover is connected to the vibrating needle directly at its head or through a flexible shaft.

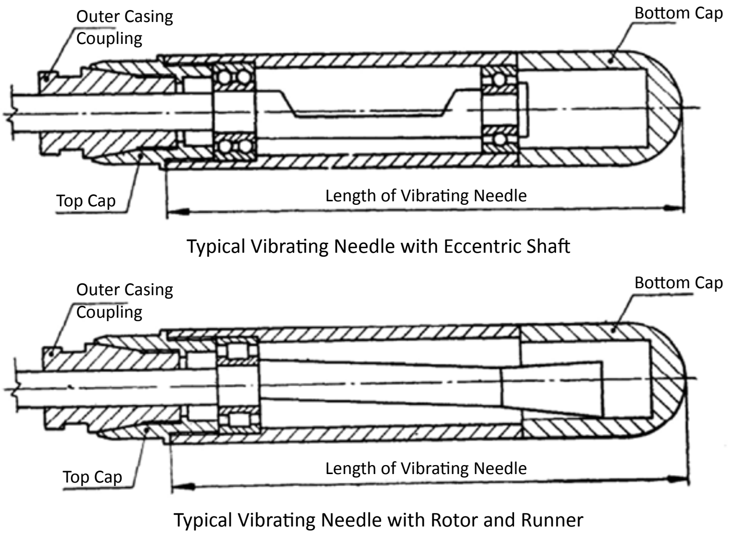


Figure 45: Types of Vibrating Needle for Internal Vibrator

Figure 46: Internal Vibrator

The vibrator may be powered by any of the following power units:

a) Electric Motor, driving the vibrator needle through flexible shaft or situated at the head of the vibrator.

b) Internal Combustion Engine, driving the vibrator needle through flexible shaft.

c) Compressed Air Motor, situated near the head of the vibrator.

The size of the immersion vibrator is denoted by the nominal outside diameter of the vibrating needle. The standard nominal outside diameter of the vibrating needle shall be – 25, 35, 40, 50, 60, 75 and 90 mm.

The operational frequency and optimum amplitude measurement in the middle of the vibrating needle under no load (operation in air) condition for different sizes of needle shall be as per **Table 25**.

Table 25: Performance Parameters for Internal Vibrator

Sl. No.	Diameter of Vibrating needle (in mm)	Frequency of Vibration (in Hz)	Amplitude (in mm)	
			Eccentric Shaft Type Vibration	Pendulum Type Vibration
1.	25 – 35	200 – 270	0.85 – 0.55	0.65 – 0.40
2.	40 – 60	150 – 200	1.10 – 0.75	0.85 – 0.55
3.	75 – 90	100 – 150	1.60 – 1.30	1.20 – 0.95

For more information on internal vibrators, refer to IS:2505 and IS:3558.

ii) **External or Shutter or Form Vibrators**

These vibrators are clamped rigidly to the form work at the pre-determined points so that the form and concrete are vibrated. They consume more power for a given compaction effect than internal vibrators.

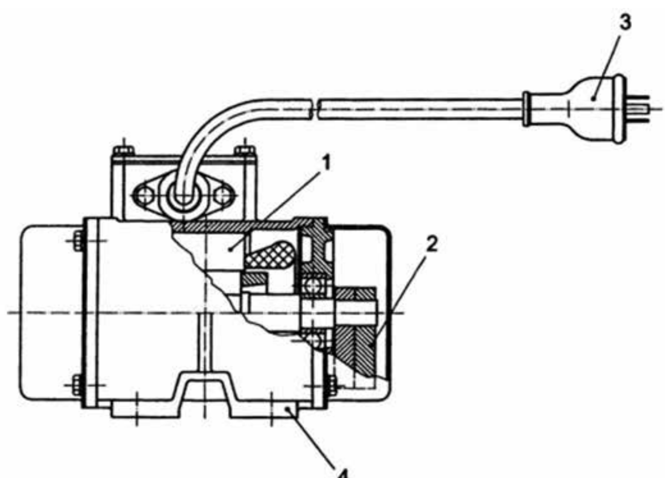
These vibrators can compact up to 450 mm from the face but have to be moved from one place to another as concreting progresses. The external vibrators are more often used for pre-casting of thin in situ sections of such shape and thickness as cannot be compacted by internal vibrators. Very stiff mixes respond better to high amplitude and lower frequency. The high frequency use tends to give a better surface appearance.

External Vibrators are classified according to frequency, power source and structure, as indicated in **Table 26**.

Table 26: Classification of External Vibrator

Sl. No.	Class	Frequency	Power Source	Structure
1.	NF	Normal Frequency	Electric Motor	Fixed Type
				Removable Type
2.	HF	High Frequency		Fixed Type
				Removable Type
3.	P	–	Pneumatic	Fixed Type
				Removable Type
4.	H	–	Hydraulic	Fixed Type
				Removable Type

An electric external vibrator (**Figure 47**) is one in which the prime mover is an electric motor. It can

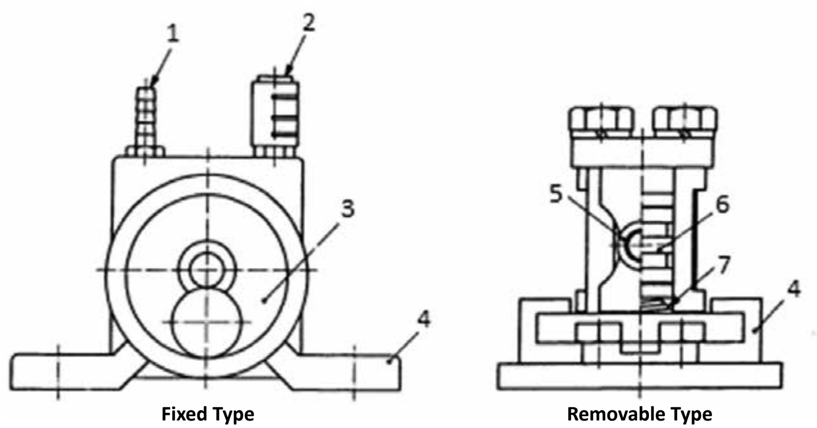


KEY:
1. Stator; 2. Eccentric Mass; 3. Plug; 4. Fixture Base

Figure 47: Electric External Vibrator (Fixed Type)

be of two types – High Frequency (HF) and Normal Frequency (NF). The High Frequency vibrator operates at a frequency of 70 Hz and above with the induction motor typically being fed from converter. The Normal Frequency vibrator operates at a frequency below 70 Hz with the induction motor being supplied with the current of the power network frequency.

A pneumatic external vibrator (**Figure 48**) operates on the principle of bearingless turbine with pneumatic drive. It has typically a rotary vibration generator in the form of a bushing or ball located in a housing, which rolls on a fixed axle. The vibrator set is composed of the vibrator itself, supply hose with on/off stopcock and various fixtures for use with metal and wooden type shuttering. The on/off stopcock makes it possible to change the vibration parameters.



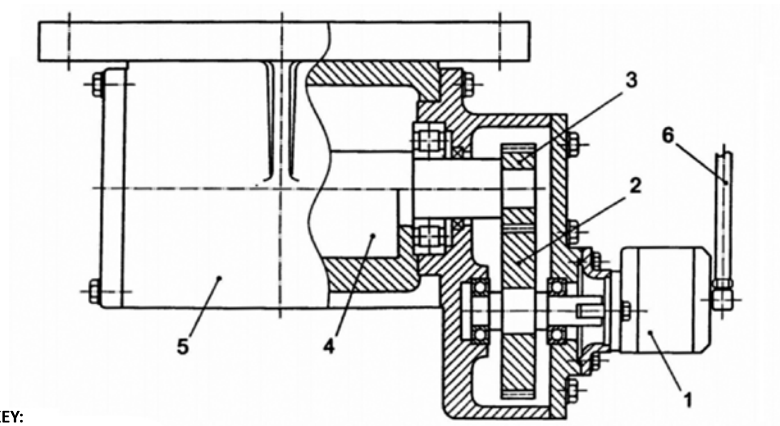
KEY:
1. Hose Stern; 2. Silencer; 3. Ball; 4. Fixture Base; 5. Cylinder; 6. Piston; 7. Spring

Figure 48: Pneumatic External Vibrator

A hydraulic external vibrator (**Figure 49**) consists of a rotating eccentric mass directly coupled to a specially designed hydraulic motor. It is supplied with a feeder containing hydraulic pump, pressure and flow controls, with the aim of precise regulation of vibration frequency to suit requirements.

A fixed vibrator is one which is fixed to the vibrating object directly by means of treads.

A removable vibrator is one which is fixed to the vibrating object indirectly by means of a quick-action clamping and releasing device.



KEY:
1. Hydraulic Motor; 2. Gear; 3. Toothed Wheel mounted on Roto's Shaft; 4. Eccentric Mass; 5. Housing; 6. Hydraulic Supply Hose

Figure 49: Hydraulic External Vibrator

External vibrators with power not less than 500 W should be used for road works.

For more information on external vibrators, refer to IS/ ISO:18652.

iii) **Surface or Screed or Pan Vibrators**

These are placed directly on the concrete mass. These are best suited for compaction of concrete pavements and shallow elements (e.g. thin slabs), where the area to be compacted is large or the thickness is too small to allow the use of internal vibrators. Very dry mixes can be most effectively compacted with surface vibrators.

Screed vibrator (**Figure 50**) consists of one or more vibrating units mounted on a screed board (usually beam or truss type). It is powered by a suitable integral power unit, that is an electric motor or an internal combustion engine. Suitable arrangement may be provided for adjusting the vibration characteristics of the vibrating unit such that constant uniform performance of the vibrator is assured for the entire range of operating conditions.

The screed vibrator should have arrangement to adjust a sagging curvature of the concrete which is produced due to amplitude of vibration. To compensate the sagging depression the bottom surface of screed should be provided with reverse sag. The amount of adjustment depends upon the span of screed, the thickness and workability of concrete being vibrated.

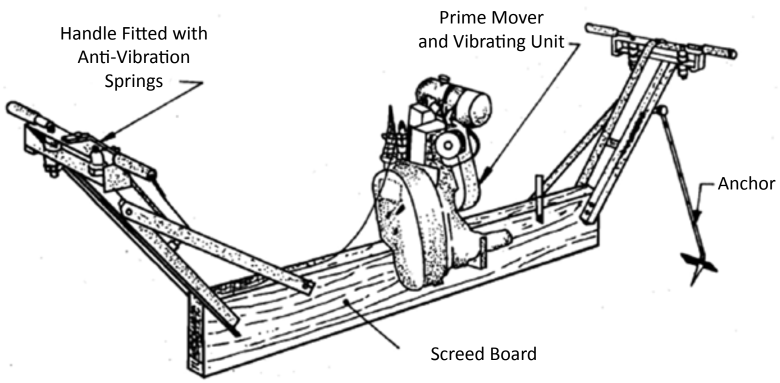


Figure 50: Screed Vibrator

The size of the screed vibrator is designated by the overall length of the screed board. Common sizes are 3, 4 and 5 m.

The frequency and amplitude of the screed vibrator under no load (operation in air) condition shall not be less than 3000 vpm (vibrations per minute) and 1.5 mm respectively in order to achieve satisfactory compaction.

For more information on screed vibrators, refer to IS:2506 and IS:11993.

Hand Tamper Board – The hand tamper used in lieu of screed board vibrator for compacting concrete for minor jobs or as an emergency stop-gap arrangement in case of breakdown of the screed board vibrator should consist of a hard wood beam of rectangular section of sufficient weight to ensure adequate compaction and should be fixed securely with sturdy handles to withstand the tamping action. The lower face of the tamper board should conform to the desired profile of the pavement cross-section and be fitted with a mild steel shoe of appropriate width as in the case of screed board to prevent wear.

iv) **Vibrating Tables**

Vibrating tables are generally used for compaction of precast concrete units because of advantages they offer with respect to uniformity of treatment given to the casting. With their use, vibration can start from the moment concrete is placed on the base of the mould, so that the expulsion of air is facilitated and compaction increases steadily with the addition of each batch of concrete.

Vibrating tables can be considered as a case of form work clamped to the vibrator instead of the other way round. They shall include all appliances creating rapidly alternating horizontal, vertical or circular vibrations and capable of transmitting these to moulds filled with concrete and placed or clamped on the table top.

The vibrating table shall be capable of being operated either through an eccentric rotor driven by a prime mover, such as electric motor, internal combustion engine, pneumatic power, or directly by electro-magnetic pulsators.

The frequency of vibration for the table operating at its maximum load capacity shall be between 3000 to 6000 vpm (vibrations per minute).

The size of the vibrating table is designated by the overall length and breadth of the table top, expressed in metres. The capacity is indicated by the maximum weight, expressed in tonnes, of the mould plus the concrete in the mould, which can be effectively vibrated by operating the table at specified vibration characteristics.

Different sizes and capacities of the vibrating table are indicated in **Table 27**.

Table 27: Sizes and Capacities of Vibrating Table

Sl. No.	Size (in m)	Capacity (in tonnes)
1.	1 x 1	0.25, 1.0
2.	2 x 1	0.5, 1.0
3.	3 x 1	1.5

Recommendations for minimum output rating of the power unit for various capacities of the vibrating table are given in **Table 28**.

Table 28: Power Output Rating of Vibrating Table

Sl. No.	Capacity (in tonnes)	Minimum Power Output Rating (in KW)
1.	0.25	0.75
2.	0.5	0.75
3.	1.0	1.5
4.	1.5	2.2

For more information on vibrating tables, refer to IS:2514.

4.24 Floater/Trowel

4.24.1 It is used for smoothening the compacted concrete (PQC or structural concrete) to obtain a high quality concrete surface. Finish/ Final floating is called troweling. Prior to floating operation, a screed may be required to shape the concrete surface to correct elevation by striking off the excess concrete.

4.24.2 Traditional floater is made of hard wood or aluminium magnesium board, planned to true surface and fixed with a suitable handle. Mechanised floater (power floater), in addition to finishing operation, can also make the surface abrasion resistant using some commercial hardener.

4.24.3 Mechanized floating operation includes two main steps:

i) Floating is aimed at removing protruding aggregate grains, levelling off swells, filling cavities, and compacting the face of the concrete. At this stage, the blades of the power floater are kept flat.

ii) Troweling is aimed at polishing, smoothening and hardening the face of the concrete. At this stage, the blades of the power trowel are slightly angled.

4.24.4 Power floaters are normally of two types – single rotor (**Figure 51**) and double rotor (**Figure 52**).

A single rotor power floater is of the walk-behind type and consists of a disc or rotor (having 4 to 6 blades) that is driven by combustion engine or electric motor. Use of a combustion engine allows step-less control of the floating tool's rotational speed, whereas, in a two-step electric motor, one has to select the appropriate speed of rotation as per requirement (rough floating or finish floating). The angle of inclination of the blade can be adjusted from the long handle connected to the floating tool.

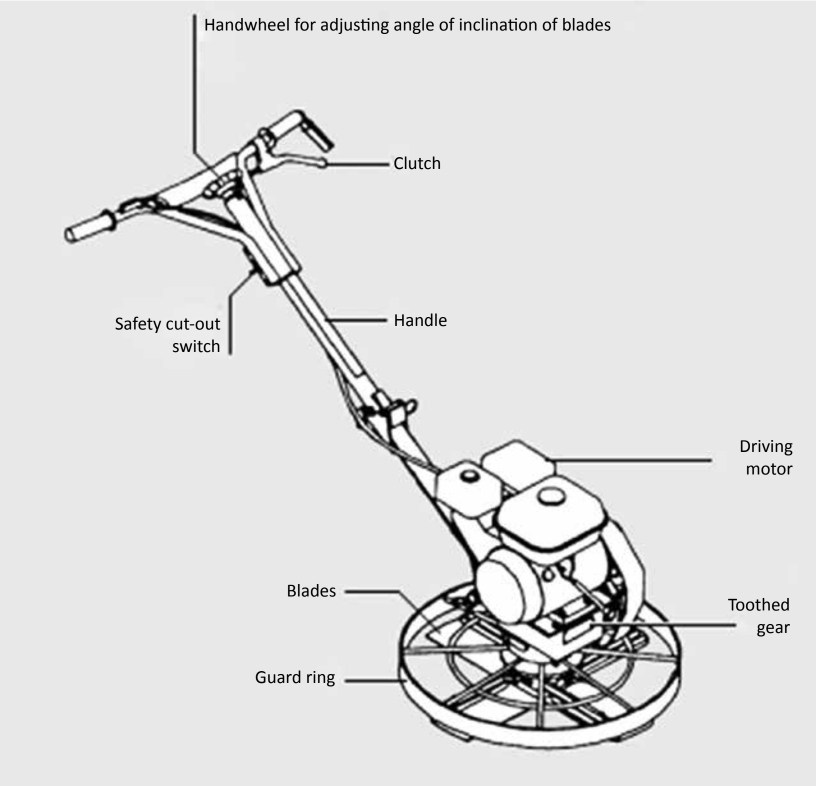


Figure 51: Single Rotor Power Floater

A double rotor power floater is of the ride-on type and consists of two rotors, which may be overlapping or non-overlapping. It is larger and heavier than the single rotor power floater and is used for floating large surfaces.

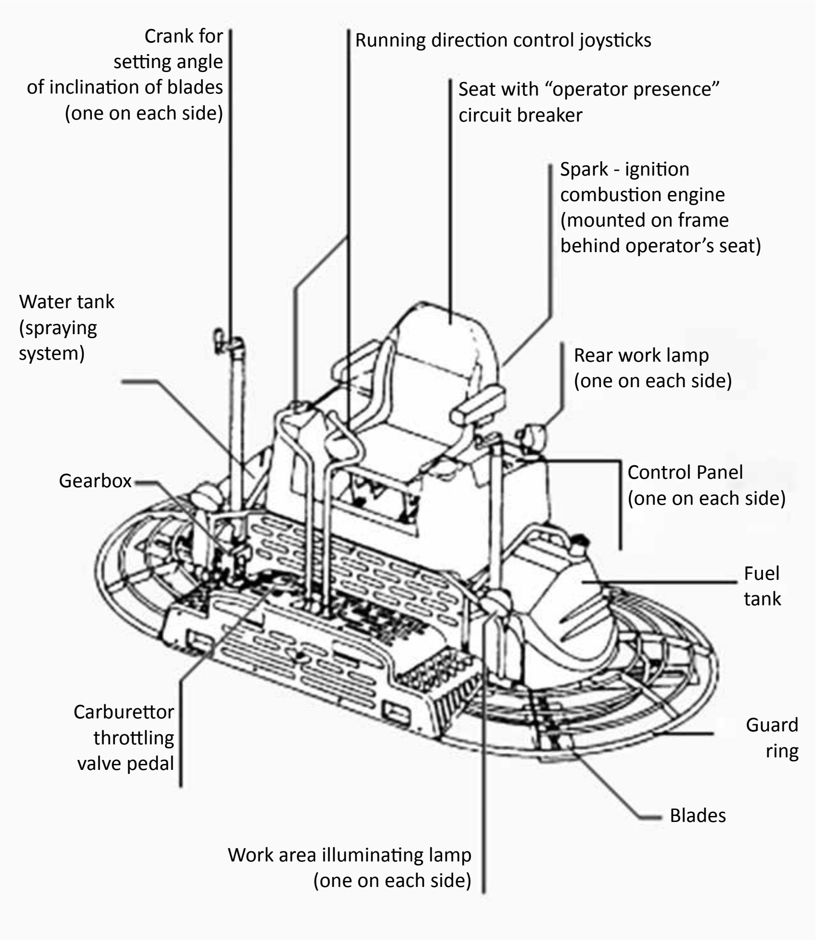


Figure 52: Double Rotor Power Floater

4.25 Scabbler

4.25.1 Scabbler (**Figure 53**) is used for concrete reduction and finishing. It is used for the following purposes:

i) Scabbling down high spots or levelling uneven joints

ii) Removing delaminated concrete surface materials

iii) Removing spalled or deteriorated concrete

4.25.2 Scabbler uses compressed air to hammer piston mounted bits into the concrete surface. It may be hand-held, push-type or self-propelled.

Figure 53: Scabbler (Push Type)

4.26 Texturing Equipment

4.26.1 Surface texture is required to provide skid resistance. Texturing is achieved by using a tining device (**Figure 54**) or texturing brush/broom or other suitable means as approved by the Site Engineer. The texturing equipment should be capable of moving over the concrete slab in transverse or longitudinal direction. Wooden or steel beam/bridge is used for stradding (spanning across the nascent slabs without touching it) the slabs to enable the masons to carry out surface finishing operations on the compacted concrete.

Figure 54: Mechanical Tining Device

4.26.2 The beam/bridge mounted with tines shall be equipped and operated with automatic sensing and control devices from main paver or auxiliary unit.

The tining unit shall have facility for adjustment of the downward pressure on the tines as necessary to produce the desired finish.

In case of transverse tining, a beam of at least 3 m length mounted with tines shall be used. The grooves produced shall be at random spacing of grooves but uniform in width and depth. The spacing shall conform to a pattern shown in **Figure 55**.

10	14	16	11	10	13	15	16	11	10	21	13	10

Figure 55: Random Spacing (in mm) for Transverse Tining

In case of longitudinal tining, the texturing bridge shall be wide enough to cover the entire width of the carriageway but within 75 mm from the pavement edge. The centre to centre spacing between the tines shall be 18 to 21 mm.

Tined grooves shall be 3 mm wide and 3 to 4 mm deep for both transverse and longitudinal tining.

4.26.3 In case of brush texturing, a wire brush of not less than 450 mm width shall be used to brush evenly across the slab in one direction. Normally, wider brushes of 3 m length are preferred. The brush shall be made of 32 gauge tape wires grouped together in tufts placed at 10 mm centres. The tufts shall contain an average of 14 wires and initially be 100 mm long. The brush shall have two rows of tufts. The rows shall be 20 mm apart and the tufts in one row shall be opposite the centre of the gap between tufts in the other row. The brush shall be replaced when the shortest tuft wears down to 90 mm long.

4.26.4 Before commencing texturing, the bleeding water, if any, shall be removed using suitable means and texturing shall be done on a firm surface.

4.27 Curing Compound Sprayer

4.27.1 Curing compound sprayer (**Figure 56**) consists of an assembly of tank for storing curing compound and a hose which can be mounted on a frame that enables an easy movement of the equipment. It may also be provided with a pump that helps in generating the required rate and pressure. Pressure settings can also be adjusted in some equipment.

Figure 56: Curing Compound Sprayer

4.27.2 The curing compound sprayer shall incorporate an efficient mechanical device for continuous agitation and mixing of the compound during spraying.

4.28 Diamond Cutter/Saw

4.28.1 A Diamond Cutter/Saw (**Figure 57**) is used for cutting, grooving or grinding concrete, bituminous, stone or masonry works. It may be hand-held or walk-behind and is either electric or petrol/diesel driven type.

Walk Behind Saw **Hand Held Saw**

Figure 57: Diamond Saw

As the name suggests, cutting is facilitated by grinding action using a rotating diamond blade mounted on a shaft and clamped tightly into place between two collars or flanges. A diamond blade is made up of two basic parts:

i) A Steel Core, which is in the shape of a circular steel disc.

ii) Diamond Segment or Rim, which is made up of diamond crystals dispersed through a metal matrix and is attached to the steel core by means of brazing, laser welding or diffusion bonding of rim to core.

4.28.2 A diamond saw allows two types of cutting:

i) **Wet Cutting** – Water is used as a coolant to keep the blade from overheating through friction during cutting.

Water also reduces dust and helps removing cuttings from the bottom of the cut. Wet cutting blades are recommended for continuous or deep cutting.

ii) **Dry Cutting** – Dry cutting blades are air-cooled and should be used only for intermittent or shallow cutting to allow the air flow around the blades to dissipate the heat.

4.28.3 For a walk-behind diamond saw (e.g. joint cutting machine used in construction of cement concrete pavement), there should be appropriate arrangement for lowering or raising the blade to any desired level. It should also have suitable guides for enabling a straight cut to be made along the desired line. Since a joint cutting machine is usually used for continuous cutting, it should have a water feeding arrangement for cooling.

4.28.4 Selection of diamond blade diameter depends upon the job at hand. The blade for cutting concrete must be compatible with the output and speed of the saw, concrete strength and application.

4.29 Joint Sealing Machine

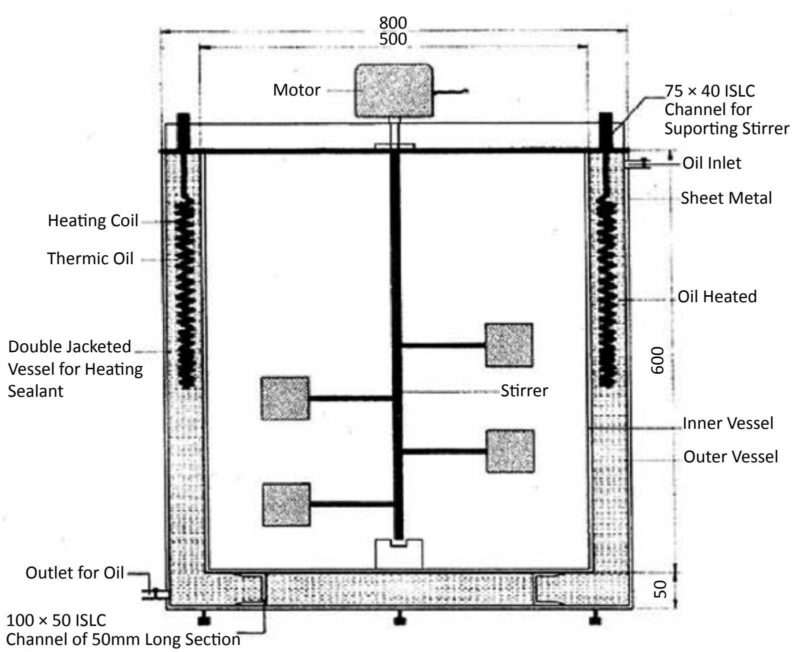
4.29.1 Joint Sealing Machine (**Figure 58**) is meant for application of joint sealant in cement concrete pavement. It consists of the following:

Figure 58: Joint Sealing Machine

i) Melter in case of hot applied material. The sealant is heated in a melter cum storage vessel to the specified temperature. Heating should be done in a controlled and uniform manner by indirect method (preferably by oil jacketing). The melter should be thermostatically controlled to prevent overheating and degradation of the sealant. Provision of mechanical agitator in the melter helps control local overheating.

ii) Compressed Air powered Pump and Applicator/ Extruder for hot as well as cold applied material. Sealant material from the storage vessel is pumped to the applicator wand equipped with flexible hose and nozzle for application into the sealing groove.

4.29.2 The traditional technique of joint sealing, however, involves use of a separate joint sealant melter (for heating hot applied sealant) (**Figure 59**) and a joint sealant pourer/ kettle (**Figure 60**) for sealing manually.



Section on A-A

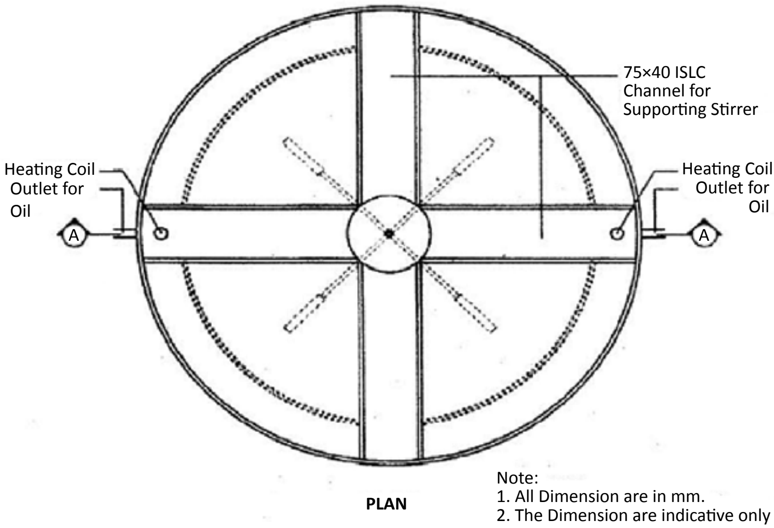


Figure 59: Joint Sealant Melter

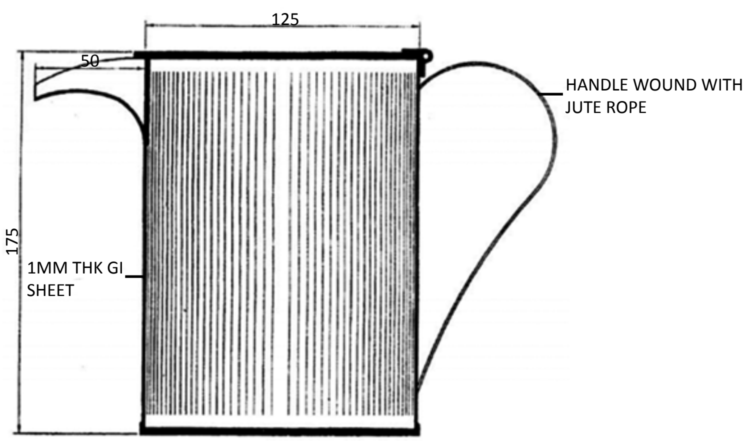


Figure 60: Joint Sealant Pourer

4.30 Kerb Casting Machine

4.30.1 The kerb casting machine is meant for casting/laying continuous concrete kerbs, channel and other concrete formation of different dimensions to close tolerances.

4.30.2 A slip form kerb casting machine (sometimes also referred to as an offset slip form paver) (**Figure 61**) consists of the following:

i) A hopper which is filled with concrete mix prepared in a concrete mixer or concrete batching and mixing plant.

ii) An extrusion mould of desired profile for extruding the concrete mix onto the ground.

iii) Sensors for automatic horizontal and vertical controls to be used in conjunction with at least one guideline (stringline) to achieve the desired grade, slope and alignment.

iv) Internal vibrators of sufficient number, size and frequency to provide uniform consolidation to the entire cross section.

Figure 61: Slip Form Kerb Casting Machine

4.31 Road Marking Machine

4.31.1 It is meant for application of thermoplastic paint on to the road surface. It may be manually controlled or fully automated.

4.31.2 A road marking machine (**Figure 62**) consists of the following:

i) A jacketed kettle or melting pot for uniformly heating and melting the thermoplastic material and with provisions (e.g. mechanical stirrer) to keep the material from segregating or scorching. The kettle should be equipped with an automatic temperature control device and material thermometer for positive temperature control and to prevent overheating or scorching of the thermoplastic material. In case the melting pot is not an integral part of the machine, the thermoplastic material is first melted in a separate preheater and then transferred to a storage tank in the machine, where it should be maintained within the temperature range specified by the manufacturer to achieve the desired consistency for laying. The storage tank should have a mechanical stirrer to prevent segregation and a thermometer to monitor material temperature.

ii) Extrusion/ Screed Device (e.g. die or shoe) or Spray Gun for application of hot thermoplastic material on to the road surface. The spray process differs from extrusion process in that the hot thermoplastic material is combined with pressurised air to force its application on to the road surface.

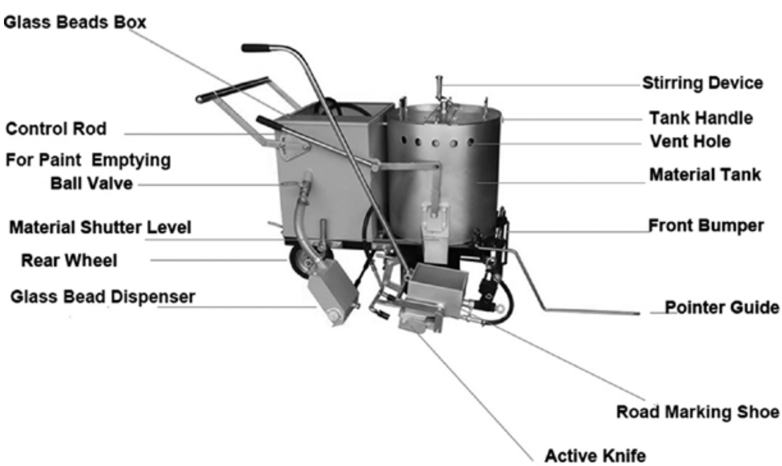


Figure 62: Road Marking Machine

iii) Glass Bead Hopper and Dispenser. The bead dispenser shall be attached to the road marking machine in such a manner that the glass beads are dispensed closely behind with the thermoplastic material. The bead dispenser should be equipped with an automatic cut-off control system that is synchronized with the cut-off of the thermoplastic material and applies the glass beads in a uniform manner on the entire road marking surface with requisite embedment.

4.31.3 The road marking machine should be capable of travelling at uniform speed, both uphill and downhill, to produce a uniform application of striking material and capable of following straight lines and making normal curves in a true arc.

4.32 Hot In Place Recycling (HIPR) Equipment

4.32.1 Hot In Place Recycling (HIPR) Equipment for Remixing (**Figure 63**) should be equipped with suitable features to carry out different functions such as:

i) An indirect heating system (infra-red or hot air or as the case may be) for heating the existing bituminous pavement surface uniformly without burning it.

ii) A milling drum/scarifier to rip the heated bituminous surface to the required depth.

iii) Suitable means (e.g. hopper and conveyor system coupled with feed systems for hot virgin mix and rejuvenator) for transferring the heated milled material along with additional hot virgin mix/rejuvenator to the pug mill mixer.

iv) A pug mill mixer for preparation of homogenised uniform remixed material.

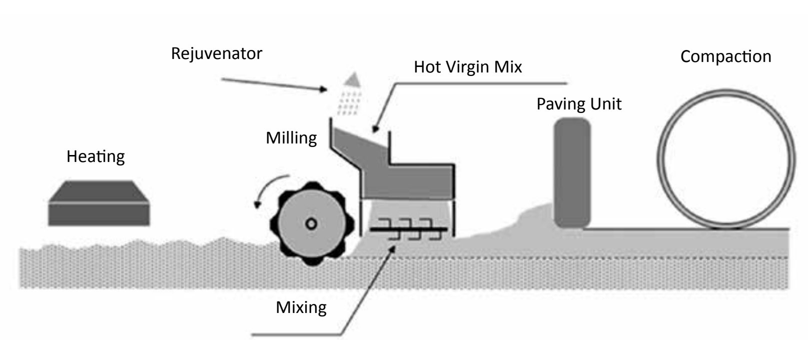


Figure 63: Hot In Place Recycling Equipment for Remixing

v) A paving unit for laying the remixed material on the milled pavement surface.

vi) A compaction unit to compact the mix after paving.

A single machine can have all of the above features or there can be a train of equipment for performing different functions.

The HIPR equipment should have electronic controls to monitor the processes of heating, feeding of materials, mixing and laying. It should be capable of maintaining the mix temperature throughout the recycling process with the final mix conforming to specifications.

4.32.2 The HIPR Equipment should have working width at least equal to a single carriageway with adjustable arrangement. The heated width of surfacing should exceed the scarified width by at least 75 mm on each side.

The HIPR Equipment should be capable of milling up to a depth of 50 mm with a working output of 2 – 5 m/min. It should also be capable of incorporating more than 50% RBP (Reclaimed Bituminous Pavement) in the recycled mix.

4.33 Cold In Place Recycling (CIR) Equipment

4.33.1 Cold In Place Recycling (CIR) of bituminous pavement is in situ process of rehabilitation of damaged bituminous pavement involving 100% reuse of the existing bituminous pavement materials. The process is called cold recycling because the aggregates are not heated and are processed at ambient temperature with addition of fresh aggregates, water and recycling agent. The recycling agent can be bitumen emulsion, foamed bitumen and cementitious materials, either alone or in combination. While bitumen emulsion or foamed bitumen, as the case may be, is usually added in the mixing drum, cement may be added in slurry form in the mixing drum or it may be pre-spread on the damaged pavement by a spreader and consequently picked up by the milling drum of the recycler.

4.33.2 A Cold In Place Recycling Equipment should have suitable features and controls for carrying out and monitoring the following fundamental operations:

i) Reclamation of the existing pavement to the specified depth in one pass

ii) Transformation of the reclaimed pavement into bituminous aggregates of suitable size

iii) Addition of fresh aggregates, water and recycling agent

iv) Uniform mixing of all the components to produce a homogeneous mix

v) Placement of the recycled mix on the pavement

vi) Compaction of the mix

A single machine can perform all of the above operations (except compaction, which is carried out by a separate roller) or there can be a train of equipment for performing different functions.

An example of single unit recycling equipment (**Figures 64** and **65**) would be one which reclaims, sizes and mixes in the additives in the milling cum mixing drum while the placement operation is performed with a hydraulically adjustable scraper blade/screed attached to the back of the unit. The milling cum mixing drum has a hydraulically adjustable milling drum flap front for gradation control of the cut aggregates and microprocessor-controlled injection systems for addition of water and recycling agent.

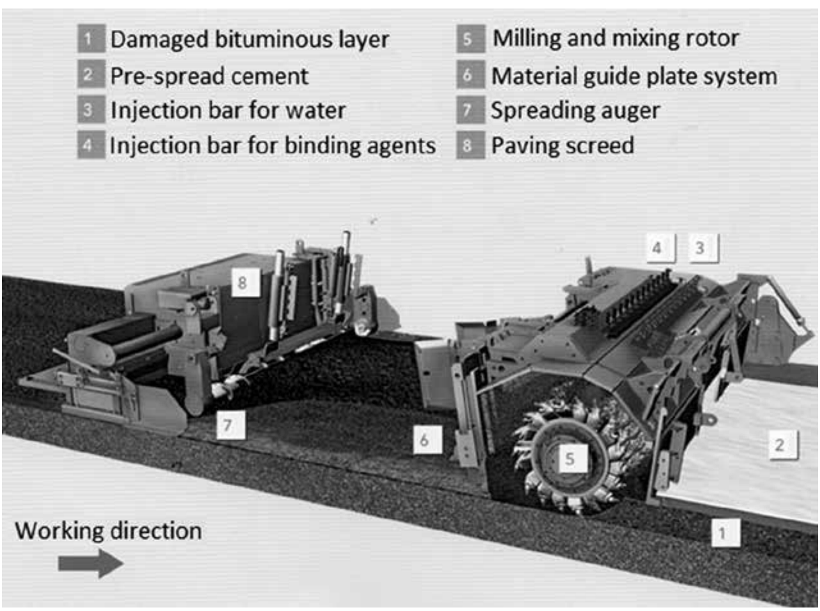


Figure 64: Single Unit Cold In Place Recycling Equipment (with Pre-spread Cement)

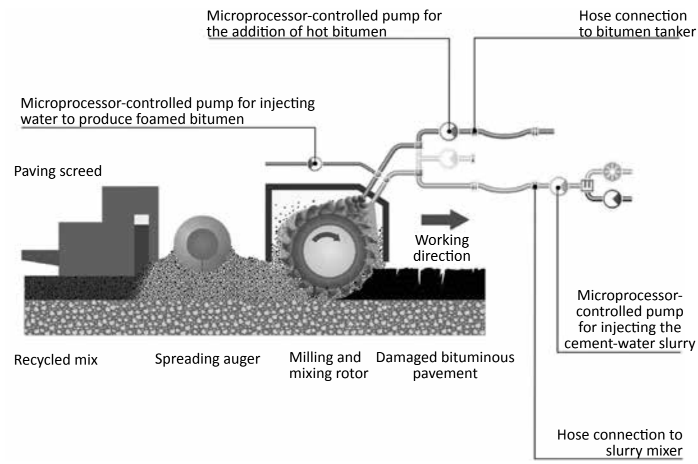


Figure 65: Single Unit Cold In Place Recycling Equipment (with Cement Slurry addition in Mixing Drum)

An example of a multi-unit recycling train would be the case where the reclamation of the pavement is performed by a milling drum, the sizing is accomplished by a mobile screen/crusher unit, the mixing is done with a mobile pug mill and the placement is carried out with a standard paver. **Figure 66** illustrates another configuration of a multi-unit recycling train where a milling cum mixing drum pulverizes the pavement and prepares the recycled mix and then transfers the mix via a conveyor to a bituminous paver finisher for placement.

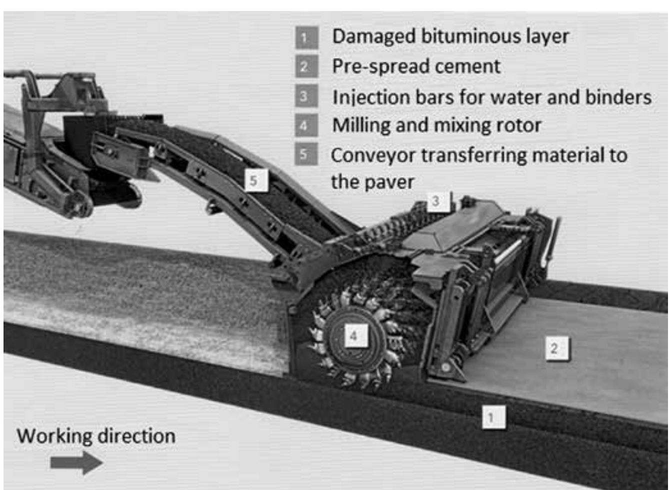


Figure 66: Multi-Unit Cold In Place Recycling Train (with Pre-spread Cement)

4.33.3 Milling can be done either in up-cut or down-cut mode (**Figure 67**). The milling rotor operates against the recycler's direction of travel when using the up-cut process, and in the recycler's direction of travel when using the down-cut process.

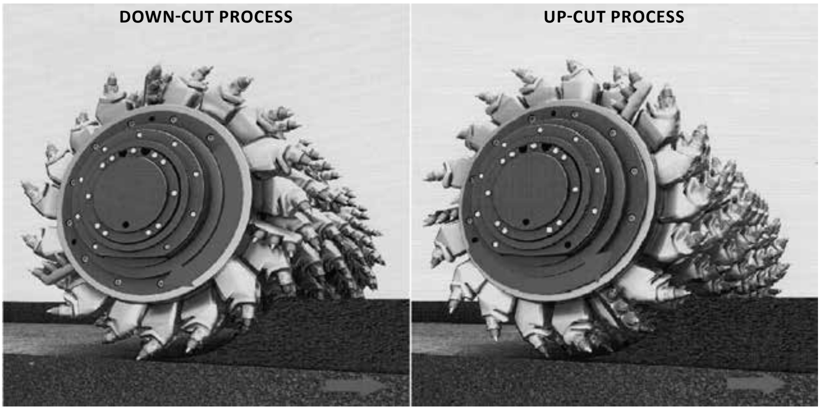


Figure 67: Down-Cut Milling versus Up-Cut Milling

4.33.4 Foamed Bitumen (Figure 68) – Foamed bitumen is produced from hot standard viscosity grade bitumen. In the process, the bitumen is heated electrically and small amounts of water and air are injected

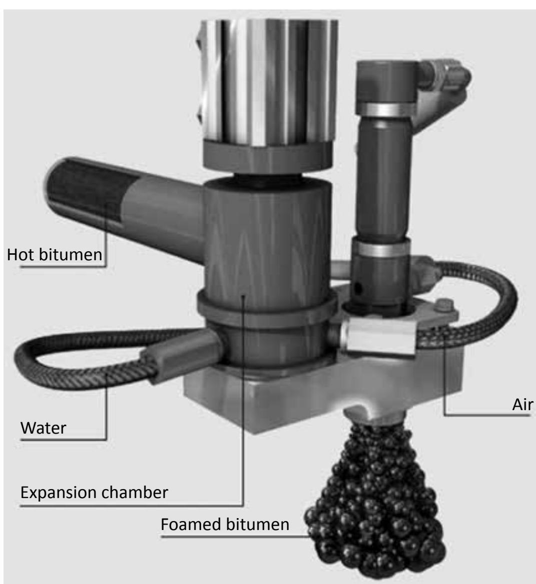


Figure 68: Production of Foamed Bitumen

into the hot bitumen at high pressure in the expansion chamber which results in the bitumen foaming and expanding to around 15-20 times its original volume. The bitumen foam, while still in its unstable foamed state, is then injected into the mixing drum via pneumatic injection nozzles. The greater the volume of the foam, the better will be the distribution of the bitumen in the aggregate.

Separate spraying systems are provided for addition of water and foam bitumen in the mixing drum and are microprocessor-controlled for accurate metering of the requisite quantities.

4.33.5 The machine shall be equipped with levelling/grade controls to ensure longitudinal as well as transverse profile. **Figure 69** illustrates a four-way lifting pendulum arrangement in a four wheel drive crawler unit for height adjustment and to compensate for unevenness in the ground and to match the gradient/slope as per pavement requirements.

Figure 69: Four Way Lifting Pendulum Arrangement for Height Adjustment and Grade Control

4.33.6 The milling drum should have minimum working width of 2400 mm with variable depth control and variable drum speed to meet site requirements. Equipment with working depth up to 510 mm is available in the market.

4.34 Cold Milling Machine

4.34.1 Removal of existing bituminous pavement can be facilitated by either of the following two methods:

i) Cold Milling

ii) Ripping and Crushing

Cold milling is the most widely used method. It involves automatically controlled removal of pavement to a desired depth and restoration of the surface free of ruts, humps and other imperfections to a specific grade or slope with special equipment called Milling Machine. The resulting surface can be used immediately as a driving surface to ensure ease of traffic and RBP (Reclaimed Bituminous Pavement) can be reused as aggregates back in system.

4.34.2 The key benefits/functions of cold milling (**Figures 70** and **71**) are:

i) Scaled and required removal of bituminous pavement layers ensuring end product is granulated for further reuse of RBP.

ii) Improve riding quality and cross slope of the existing pavement.

iii) Lower the finished grade adjacent to existing curb or shoulder prior to resurfacing.

iv) Lower FRL (Finished Road Level) which has abruptly increased due to periodic overlays.

v) Ensure that the distresses in pavement are eliminated and that pavement is crack free and further overlay on milled surface ensures long lasting pavement.

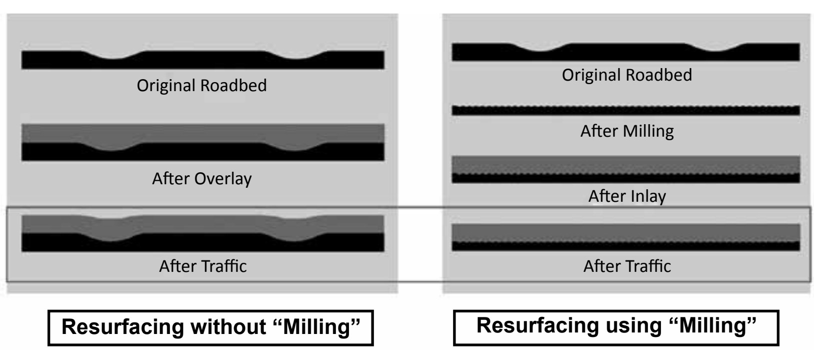


Figure 70: Resurfacing with and without Milling

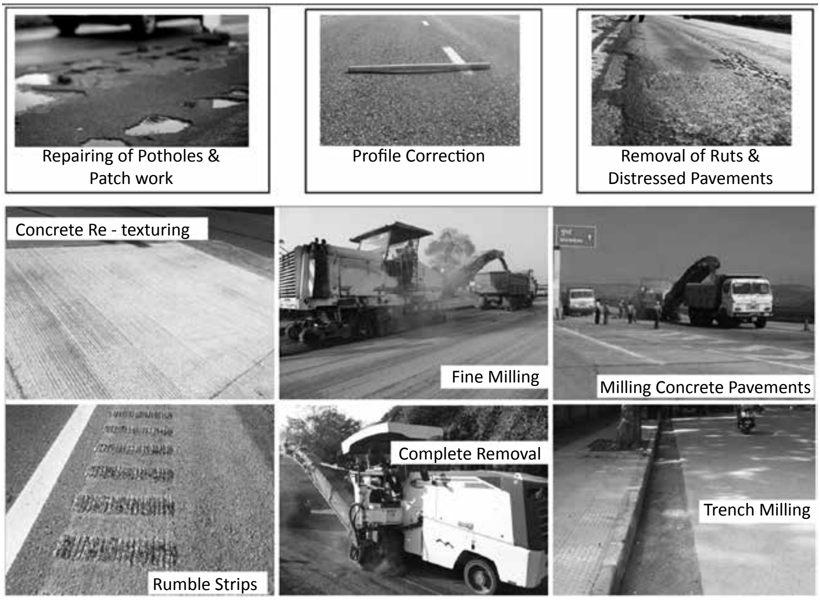


Figure 71: Applications of Cold Milling

vi) Complete or partial removal of the existing bituminous pavement.

vii) Saving of material while doing profile corrective course.

viii) Produce a skid resistant surface texture, if required (e.g. cases where the milled surface is to be the final surface of the pavement).

4.34.3 The cold milling machine may be front loading (**Figure 72**) or rear loading (**Figure 73**) type and consists of the following:

i) A rotating cutting drum (**Figure 74**) equipped with a series of tungsten carbide tipped teeth (with variable tool spacing) for milling the pavement to the required depth. The drum has a number of tools mounted on the drum with uniform spacing ensuring the final cut size meets the gradation requirement for further aggregate reuse. The speed of the machine and milling depth are adjustable quickly at a push of a button. Milling drum (with variable width 0.3 – 2 m) may be of various types depending upon the job requirement – removal of one or several pavement layers, removal of thin layers of surface (ruts and undulations), or removal of entire pavement package (at full depth) etc.

ii) A conveyor system for collecting the granulated bituminous material from the milling drum and discharging it directly onto waiting tipper trucks.

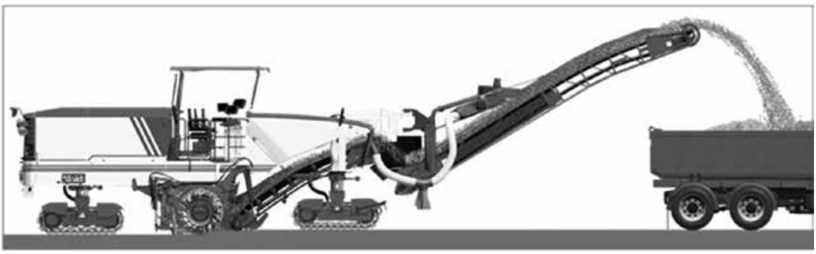


Figure 72: Front Loading Cold Milling Machine

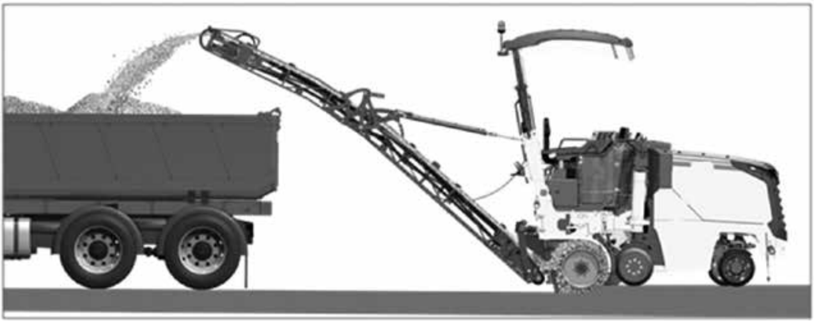


Figure 73: Rear Loading Cold Milling Machine

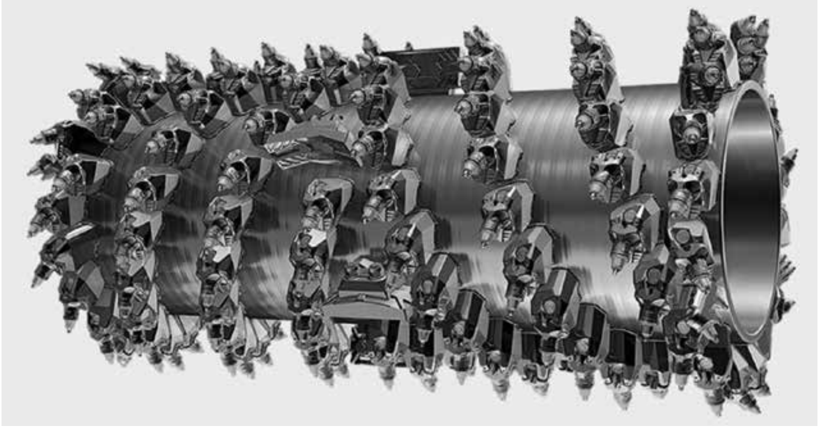


Figure 74: Milling Drum

The milling machine is self-propelled with suitable power drive. It should be equipped with four wheels with "all-wheel" drive or equipped with four independently operated tracks fitted with track pads, thereby eliminating any damage to the bituminous surface.

To ensure proper milling operation, the machine should have complete data displayed on the working panel of the machine. The machine should be capable of maintaining a depth of cut and cross slope as per requirements. The varying depth of cut and variable speed of operation should ensure the desired cut size of the RBP used for recycling.

The machine shall be equipped with sensors for automatic grade controls (**Figure 75**), which ensures longitudinal as well as transverse profile.

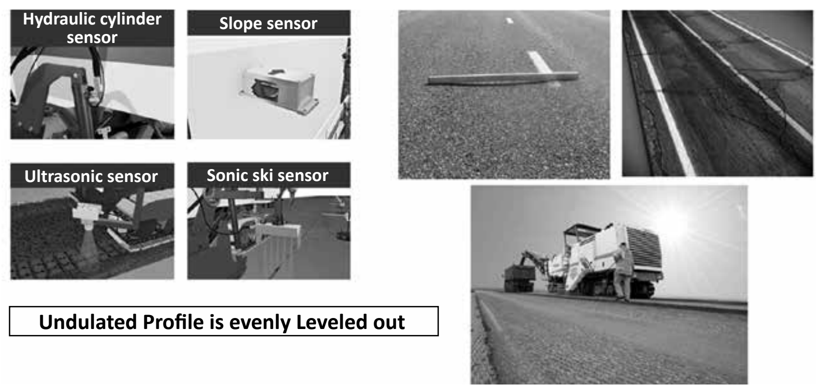


Figure 75: Levelling System in Cold Milling Machine

The milling machine should be equipped with suitable means such as water spray system to effectively limit the amount of dust escaping from the removal operations. It should provide edge to edge milling in order to maintain even profile and reduce error.

A smaller milling machine may be used when milling adjacent to existing curb, around utilities or other areas where it is not practical to use the larger machine.

4.35 Pneumatic Breaker

4.35.1 It is a percussive tool where the piston reciprocates in a cylinder and gives a blow at one end of its stroke. It is used for demolition of rocks, structures and in construction quarrying.

4.35.2 Pneumatic breaker consists of the following:

i) A back head assembly equipped with a 'T'-handle and a throttle lever. The throttle lever shall be located to permit operation of the breaker from either side.

ii) A cylinder assembly equipped with a valve mechanism to control the direction of air required for actuation of the piston, an anvil block sleeve and a reversible piston.

iii) Flanges – All flanges shall have sufficient thickness and strength to prevent failure during operation and to withstand mechanical stress when back head and front head assemblies are installed.

iv) A front head assembly equipped with a chuck for the collar shanked tool and a positive shank retaining device such as latch retainer or swing stirrup type spring retainer. The chuck housing of the breaker shall contain a renewable liner or shall be of solid type.

v) Air inlet connection for supply of fresh air to the breaker. The end of the air inlet connection shall have an extended thread and shall be provided with a nipple for connection to 20 mm air hose. The air inlet connection shall permit operation of the breaker without any obstruction to the normal working or any restraint on the operator.

vi) Exhaust port for directing the exhaust air downward and away from the operator when the breaker is operated from either side.

vii) Suitable air cushions at both ends of the piston in the cylinder.

viii) An internal oil reservoir or an air line oiler for lubrication of the breaker.

4.35.3 Pneumatic breakers may be classified on the basis of weight of the basic unit as:

i) Light (for weight up to 20 kg) – for light demolition work.

ii) Medium (for weight over 20 kg and up to 32 kg) – for breaking light concrete pavements, macadam, frozen ground and gravel.

iii) Heavy (for weight over 32 kg and up to 40 kg) – for breaking concrete pavements, demolition of concrete foundation and walls, cutting pavements and sub-bases, trenching in hard ground and for breaking boulders which cannot be otherwise blasted.

4.35.4 An example of a hand-held pneumatic breaker is jack hammer (**Figure 106**). The tool may be non-rotary or rotary type depending upon the application (e.g. chisel, drill bit, tamping rod, spike or sheeting driver etc.).

4.35.5 For more information on pneumatic breaker, refer to IS:3559.

4.36 Hydraulic Breaker

4.36.1 Hydraulic Breaker is a percussive tool used for demolition works just like pneumatic breaker except that it is hydraulically powered. It is usually used as an attachment in hydraulic excavator or backhoe loader. It (**Figure 76**) comprises of the following:

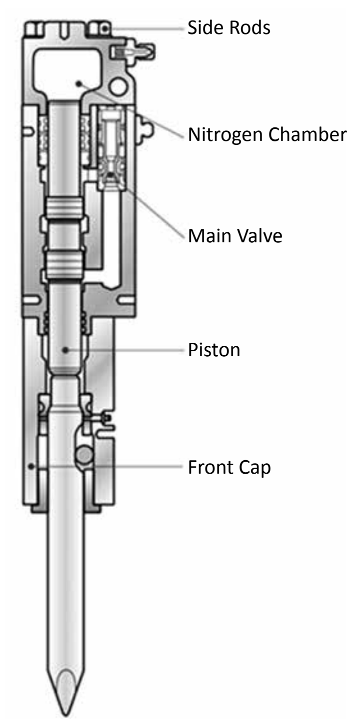


Figure 76: Hydraulic Breaker

i) A directional valve to control the direction of oil flow

ii) An accumulator to store potential energy (most commonly by means of compressed gas) and act as a quick secondary source of fluid power capable of doing useful work as required by the system. It helps to smooth out pulsations in the breaker.

iii) A back head filled with nitrogen gas

iv) Impact piston for delivering the striking energy to the chisel while performing a reciprocal motion

v) A tool (or chisel) that breaks the subject material directly

Blowing operation of the hydraulic breaker involves downward movement of the valve spool in the control valve to allow high pressure oil to act on the impact piston in the cylinder and cause it to move upward, thereby compressing the nitrogen gas in the back head. Subsequently, the direction of oil flow in the directional control valve changes such that it causes the valve spool to rise upward, thereby, reducing the upward oil pressure acting on the impact piston. As a result, the compressed nitrogen gas in the back head now exerts sufficient downward force on the piston, thereby, causing it to move downward and strike the top of the chisel. This sends a compressive stress wave to the working end of the chisel, which causes the rock in touch with it to fracture. Immediately following the initial compressive stress wave, a reflected stress wave is formed, which travels back up the tool, bouncing the piston up off the top of the tool. This cycle of compressive and tensile stresses flowing up and down the tool is repeated with each piston blow.

Anything interfering with the strength of the compressive stress waves during operation such as blank-firing (free-running) or prying with the tool, can lower breaker performance and cause tool fatigue. The breaker must be at a 90° angle to the face of the rock.

Effective measures for controlling dust when using hydraulic breakers include continuous feeding of water to the point of impact through water spray system, provision of a shroud or cowling with a vacuum dust collecting system, etc.

4.36.2 Since a hydraulic breaker is often operated under extreme conditions and has to endure impact vibrations and impact loads, therefore structural stability of the housing is critical to the performance, durability and lifespan of the equipment and hence, one of the most important design factors. Other design factors influencing performance of the breaker include the hydraulic circuit, design of the striking piston, shuttle valve etc.

4.36.3 The performance of the hydraulic breaker (just like a pneumatic breaker) is indicated by blows per minute and overall weight.

4.37 Mobile Slurry Seal Equipment

4.37.1 It consists of a self-propelled assembly of either truck-mounted or continuous run design, which simultaneously manufactures and spreads the mix on the job. In addition to slurry seal, the equipment can be used with slight modification for micro-surfacing. The primary difference between slurry seal and micro-surfacing is that the former uses a bitumen emulsion and the latter a modified bitumen emulsion.

The difference between truck-mounted design and continuous run design (**Figure 77**) of the machine is that the latter is equipped with a self-loading device to replenish its stock of material from specialised feeder truck while continuing to lay slurry seal. Such a machine can run continuously with minimal stops, thereby minimising construction joints.

Continuous Run Unit

Truck-Mounted Unit

Figure 77: Types of Mobile Slurry Seal/Micro-Surfacing Equipment

4.37.2 Mobile slurry seal/ micro-surfacing equipment (**Figure 78**) consists of the following components:

i) Aggregate Bin
ii) Filler Bin
iii) Water and Emulsion Tanks
iv) Conveyors for feeding aggregates and filler to the mixer box
v) Pumps for bitumen emulsion and water
vi) Mixer Box
vii) Spreader Box to place the mixed slurry on the pavement

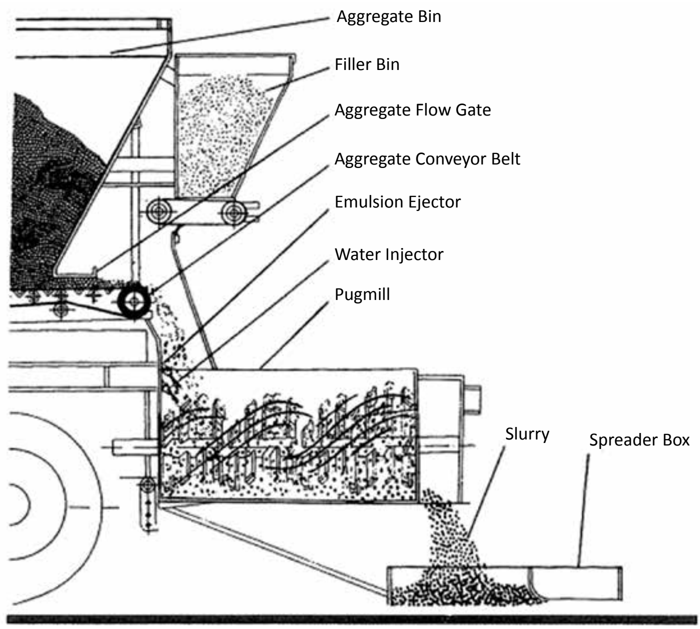


Figure 78: Mobile Slurry Seal/ Micro-Surfacing Equipment

The process consists of feeding the aggregates, filler, water and bitumen emulsion into a hydraulic or mechanical continuous flow mixer at the specified rates. The mixer shall be a multi-blade or spiral continuous flow unit capable of accurately proportioning and mixing the ingredients, thereby producing a homogenised mix. The mix is then discharged onto a spreader box on a continuous basis.

Individual volume or weight controls for proportioning each material to be added to the mix shall be provided and properly marked. The proportioning devices are usually revolution counters or flow meters or totalizer meters or similar devices – a counter to count the revolutions of the aggregate/filler belt head pulley, a metering device capable of measuring the quantity of water and a separate metering device capable of measuring the quantity of bitumen emulsion.

In a hydraulic continuous flow mixer, the drive shaft of the hydraulic motor is connected directly to the emulsion pump and has the same or a parallel shaft connected to the hydraulic motor that drives the aggregate belt head pulley. In a mechanical continuous flow mixer, the emulsion pump and aggregate belt head pulley are driven off the same drive shaft.

The mix shall be spread uniformly by means of a conventional surfacing spreader box attached to the mixer and equipped to agitate and spread the material evenly throughout the box. The agitator consists of paddles mounted on an adjustable shaft and provides sufficient turbulence to prevent the mix from setting in the box or causing excessive side build up or lumps. The spreader box shall be equipped with flexible material (seal) in continuous contact with the existing bituminous pavement and shall be capable of controlling the rate of application. A front seal shall be provided to ensure no loss of the mixture at the road contact point. The rear seal shall act as final strike-off and shall be adjustable to get suitable strike-off height. The spreader box and rear strike-off shall be so designed and operated that a uniform consistency is achieved to produce a free flow of material to the rear strike-off. A secondary strike-off shall have the same adjustment as the spreader box. The spreader box shall have adjustable width and suitable means provided to side shift the box to compensate for variations in the pavement geometry. A burlap drag or other approved screed may be attached to the rear of the spreader box to provide a uniform, smooth and highly textured mat.

Some spreader boxes are equipped with one or more sets of augers to improve the distribution of slurry seal in the spreader box.

For continuous run design of mobile slurry seal equipment, the machine shall be equipped with a self-loading device and forward and reverse speed controls to enable the operator to have full control of the forward and reverse speed during application of the slurry seal.

For more information on mobile slurry seal/ micro-surfacing equipment, refer to IRC:SP:81.

4.38 Mastic Cooker

4.38.1 Mastic cooker (**Figure 79**) is mobile equipment meant for preparation of mastic asphalt. It is suited for small scale works.

4.38.2 It consists of compartments, where each compartment is an insulated tank with provision for heating. Heating is usually done by oil fired burners. The central and main compartment is equipped with a mechanical agitator and is used for heating bitumen and for preparing the mix, while the side pockets or compartments are meant for preheating of coarse and fine aggregates and filler.

4.38.3 Mastic cookers of various capacities ranging from 0.5 tonne to 3 tonne are usually used depending on the amount of work involved.

4.38.4 For large scale works, batch type hot mix plant along with paver finisher and aggregate chip spreader should be used. For more information, refer to IRC:107.

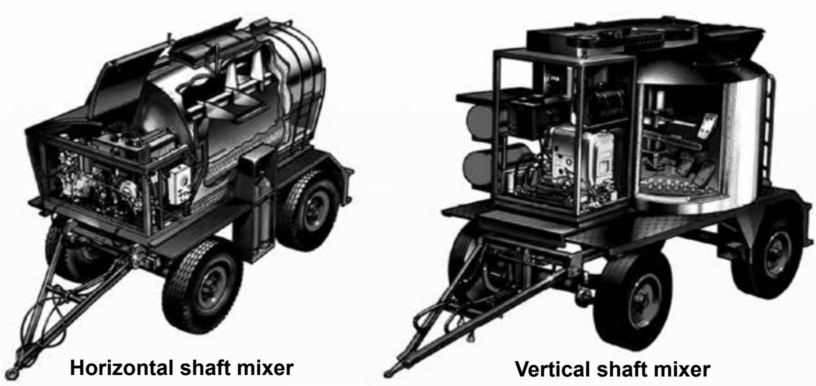


Figure 79: Mastic Cooker

4.39 Snow Blower

4.39.1 Snow Blower (**Figure 80**) is a machine primarily used to cast heavy concentration of snow away from the roadway. It should be self-propelled with four wheel drive (hydrostatic drive for carrying out snow cutting/blowing operation) and equipped with the following:

i) An auger system to cut and disaggregate a snow pack.

ii) An impeller system for casting/blowing the broken snow particles via a chute.

iii) A chute capable of rotating about a vertical axis for casting the snow in the desired direction.

The machine should be capable of operating at high altitudes (up to 5500 m above mean sea level). It should have adequate lighting and heating (for operator cabin as well as fuel line, engine sump and cylinder block assembly) arrangements with all-round visibility from the operator cabin.

Figure 80: Snow Blower

4.39.2 Key Performance Parameters/ Specifications for effective operation of a Snow Blower are indicated in **Table 29**.

Table 29: Specifications for Snow Blower

Sl. No.	Specification	Value
1.	Ground Clearance	300 mm or more
2.	Turning Radius	Max 8.5 m or less
3.	Wheel Base	3000 mm or less
4.	Snow Clearing Width (Width of blower head should be more than axle width)	2400 mm or more
5.	Snow Cutting and Clearing Capacity (maximum capacity depending on snow densities and other parameters)	5000 TPH ± 250 TPH
6.	Casting Distance	10 – 40 m
7.	Snow Clearing Height	1500 mm or more
8.	Snow Clearing Working Speed	0.3 km/hr or more
9.	Travel Speed	40 km/hr or more

4.40 Cold Bituminous Mixing Plant

4.40.1 As the name suggests, this plant is used for preparation of cold bituminous mix by blending bitumen emulsion with pre-wetted aggregates according to a laboratory job mix formula. The cold mix may be used for base, binder, levelling or wearing course or structural overlays, especially during the rainy season. The plant may be mobile or stationary and is powered by a diesel engine or electric motor. A mobile plant is mounted on a chassis with pneumatic tyres of adequate size and with over-run and parking brakes.

4.40.2 A mobile mixing plant is usually preferred and consists of the following components:

i) **Aggregate Feeder** – It shall have not less than two bins or compartments, each of sufficient capacity and provided with accurate mechanical means for feeding the aggregate at a uniform and predetermined rate to the elevator or to some intermediated conveyor delivering the aggregate to the weighing or measuring equipment. The feeder shall provide for adjustment of total and proportional feed. For smaller plants, the cold feed hopper may be directly mounted over the pug mill and discharge door opened or closed manually. The loading of the cold feed hopper may be done manually or by mechanical means.

ii) **Aggregate Elevator (if necessary)** – The aggregate may be elevated to the mixer by a bucket conveyor, a skip hoist or a belt conveyor.

iii) **Bitumen Emulsion Storage Unit** – It should have sufficient capacity for at least one day run.

iv) **Mixer** –The mixer is usually a twin shaft pug mill and can be either of the continuous or batch mixing type. Suitable means shall be provided for accurate weighing and feeding of aggregates and bitumen emulsion into the mixer. However, in case of smaller mixers, volumetric measurement of both aggregates and bitumen emulsion may be permitted.

The mixer can have capacity ranging from 6 TPH to 60 TPH.

4.40.3 For more information on mobile cold bituminous mixing plant, refer to IS:5435.

PART B : EQUIPMENT FOR BRIDGE WORKS

5. ACTIVITY WISE EQUIPMENT FOR BRIDGE WORKS

Table 30 lists out the essential equipment required for each bridge construction activity. Equipment required for excavation for structures and bituminous wearing coat on bridge deck has already been included in **Section 3**.

Table 30: Activity Wise Equipment for Bridge Works

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
Foundation, Substructure and Superstructure				
1.	Plain/Reinforced Cement Concrete (PCC/RCC) in Open Foundation/ Well Foundation/ Pile Cap/ Substructure/ Superstructure	i) Air Compressor	1114, 1200, 1500, 1600, 1700, 2100, 2200, 2300	Required in case of removing water from foundation; Minimum 300 cfm capacity compressor preferred.
		ii) Dewatering Pump		
		iii) Bar Cutting Machine		For preparation of reinforcement cage in case of RCC.
		iv) Bar Bending Machine		
		v) Crane		For transportation/ placement of reinforcement cage.
		vi) Concrete Mixer or Concrete Batching and Mixing Plant + Transit Mixer/ Agitator Truck		
		vii) Electric Genset		

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		viii) Concrete Pump or Crane + Concrete Bucket or Chute or Drop/Tremie Pipe		Crane required for handling tremie pipe.
		ix) Concrete Vibrator		For concrete compaction.
		x) Floater/Trowel		For concrete finishing.
		xi) Formwork		
		xii) Water Tanker		
		xiii) Scaffold		
		xiv) Wire Brush		For scraping top surface of foundation/ well cap/ pile cap prior to concreting for substructure.
2.	Providing and Constructing Temporary Island for Construction of Well Foundation in water	i) Crane with Grab Bucket	1200	Assumed that earth is available within the working space of crane with grab bucket.
3.	Providing and Constructing one span service road to reach island location from one pier location to another pier location	i) Front End Loader or Backhoe Loader	1200	
		ii) Tipper Truck		

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
4.	Sinking of Well (other than pneumatic method of sinking) through Sandy Soil/ Clayey Soil/ Soft Rock/ Hard Rock Strata	i) Crane with Grab Bucket	1208	Bucket capacity usually 0.5 to 2 cum.
		ii) Pneumatic or Hydraulic Breaker (Chisel)		Required in case of hard clay/rock strata.
		iii) Kentledge + Loading Platform or Steep Pipe + Nozzle + Water Pump or Drilling Equipment + Grouting Equipment + Hydraulic Jack or Blasting Accessories		For conventional sinking of well. For sinking of well by water jetting. For sinking of well by Jack Down method; minimum 500 tonne capacity jack to be used.
		iv) Electric Genset		
		v) Light Source		
		vi) Air Compressor		Minimum 300 cfm capacity compressor preferred.
		vii) Dewatering Pump		Dewatering not to be done in case sand blows are expected.
		viii) Boat		Not required in case of dry bed.
		ix) Tipper Truck		

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
5.	Pneumatic Sinking of Well	i) Air Compressor	1208.8	Minimum 300 cfm capacity compressor preferred.
		ii) Dewatering Pump		
		iii) Pneumatic Sinking Equipment		
		iv) Crane		
		v) Motorised Barge		Not required in case of dry bed.
		vi) Boat		Not required in case of dry bed.
		vii) Electric Genset		
		viii) Light Source		
		ix) Tipper Truck		
6.	Bored Cast In Situ Concrete Pile	i) Concrete Mixer + Electric Genset + Tremie Pipe or Concrete Batching and Mixing Plant + Electric Genset + Transit Mixer + Tremie Pipe	1106, 1107, 1700	
		ii) Air Compressor		300 cfm capacity compressor preferred.
		iii) Dewatering Pump		
		iv) Pile Boring Equipment		
		v) Crane		For lowering reinforcement cage in bored hole.

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		vi) Bentonite Pump		For maintaining drilling mud (bentonite suspension) at a level sufficient-ly above surrounding ground water level through-out the boring process as well as bentonite flushing for washing bored hole prior to concreting.
		vii) Front End Loader or Backhoe Loader		For disposal of muck from pile bore hole.
		viii) Tipper Truck		
7.	Driven Precast/ Cast In Situ Concrete Pile	i) Concrete Mixer + Electric Genset + Tremie Pipe or Concrete Batching and Mixing Plant + Electric Genset + Transit Mixer + Tremie Pipe	1106, 1107, 1700	For concreting in case of cast in situ pile.
		ii) Air Compressor		300 cfm capacity compressor preferred.
		iii) Dewatering Pump		

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		iv) Pile Driver		
		v) Crane		For lowering reinforcement cage and handling steel casing in case of cast in situ pile. For precast pile, crane or trailer to be used for its transportation.
		vi) Front End Loader or Backhoe Loader		For disposal of muck.
		vii) Tipper Truck		
8.	Driven Steel Pile	i) Pile Driver	1108, 1900	
		ii) Crane		For transportation of steel pile.
		iii) Air Compressor		300 cfm capacity compressor preferred.
		iv) Dewatering Pump		
		v) Front End Loader or Backhoe Loader		For muck removal.
		vi) Tipper Truck		

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
9.	Backfilling behind abutment, wing wall and return wall (with Granular/ Sandy material)	i) Backhoe Loader	2200	Assumed that backfilling material is available at site location; otherwise Tipper Truck to be considered for haulage of backfilling material from another location.
		ii) Plate Compactor or Rammer		
		iii) Water Tanker		
10.	Providing and laying of Filter Media with granular materials/ stone crushed aggregates provided over the entire surface behind abutment, wing wall and return wall to the full height compacted to a firm condition	i) Backhoe Loader	2200, 2504.2.2	For preparing/ trimming surface to the required slope. Assumed granular/ aggregate material is available at site location; otherwise Tipper Truck to be considered in case of haulage of granular/ aggregate material from another location.

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		ii) Plate Compactor or Rammer		
		iii) Water Tanker		
11.	Prestressed Concrete (PSC)	i) Concrete Mixer or Concrete Batching and Mixing Plant + Transit Mixer/ Agitator Truck	1500, 1700, 1800	
		ii) Electric Genset		
		iii) Concrete Placement Equipment		
		iv) Concrete Vibrator		For concrete compaction.
		v) Floater/Trowel		For concrete finishing.
		vi) Water Tanker		
		vii) Formwork/ Mould		
		viii) Prestressing Equipment		
		ix) Grouting Equipment		Required in case of post-tensioning for grouting the ducts.
12.	Launching and placing in position Precast Concrete Girders/ Beams/ Slabs/ Segments	i) Trailer	2300	For transportation from stockyard to site.
		ii) Crane		For launching/ placing in position.

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
13.	Expansion Joint	i) Diamond Saw	2600	For removing portion of wearing coat over recess prior to joint installation.
		ii) Wire Brush		For preparation of recess.
		iii) Air Compressor		
		iv) Mobile Hot Mix Plant		For Asphaltic Plug Joint.
		v) Rammer or Plate Compactor or Roller		
		vi) Welding Equipment + Hand/ Machine Tools/ Weighted Roller		For Compression Seal Joint. Welding Equipment for welding anchorage to main reinforcement in the deck. Hand/ Machine Tools for compressing and ejecting the seal. Weighted Roller for squeezing the seal in place.

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		vii) Welding Equipment + Crow Bar		For Single/ Modular Strip/ Box Seal Joint. Crow Bar for inserting the seal between the edge/ separation beams.
River Training and Protection Works				
14.	Apron laid directly or in wire crates on river bed or Pitching/ Revetment on Slopes or Rubble Stone/ Cement Concrete Block Flooring over Cement Concrete Bedding (Floor Protection)	i) Tipper Truck or Tractor Trolley	2503, 2504, 2505, 2506, 2507	For transportation of stones/ boulders.
		ii) Backhoe Loader		For preparation of bed.
		iii) Trimming Tools		For preparing side of river bank to the required slope and profile.
		iv) Derrick		For placing of stones/ boulders usually in case of pitching on slopes.
		v) Crane or Tilting Platform/ Pantoon/ Barge		For laying of filled wire crates in underwater conditions in case of apron.

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		vi) Concrete Batching and Mixing Plant/ Concrete Mixer + Electric Genset + Concrete Placement Equipment + Formwork/Mould + Concrete Vibrator		For preparation of cement concrete blocks as well as cement concrete toe wall and bedding (for floor protection).
Repair and Rehabilitation				
15.	Sealing of Cracks by Injection of Epoxy Resin	i) Wire Brush or Air Compressor + Sand Blasting Equipment or Water Pump (for water jetting)	2803	For surface cleaning/ preparation.
		ii) Pump + Nozzle or Epoxy Injection Gun + Air Compressor		For epoxy injection.
16.	Replacement of Spalled Concrete by Epoxy Mortar/ Polymer Mortar	i) Grinder or Scarifier or Air Compressor + Grit Blasting Equipment or Water Pump (for water blasting)	2804	For surface preparation by mechanical means.

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
		ii) Spray Gun or Hard Rubber Roller or Nylon Bristle Brush		For application of epoxy primer coat or polymer bond coat.
		iii) Floater/ Trowel		For application of epoxy mortar.
17.	Cement Grouting	i) Wire Brush	2806	For surface cleaning.
		ii) Air Compressor		
		iii) Drill		
		iv) Grouting Equipment		
18.	Guniting/ Shotcreting	i) Air Compressor + Shotcreting Equipment	2807	
		ii) Water Tanker		
19.	Replacement/ Rectification of bearings	i) Lifting Jack	2810	For lifting of superstructure spans; Preferably minimum 40 tonne lifting capacity.
20.	Removal of existing wearing coat including its disposal	i) Pneumatic Breaker or Hydraulic Breaker	2811	
		ii) Tractor- Trolley or Tipper Truck		

Sl. No.	Description of Work/Activity	Equipment	Ref. to MoRTH Specifications (Fifth Revision) Clause/Section	Remarks
21.	Providing External Prestressing with high tensile steel wires/ strands including drilling for passage of prestressing steel	i) Prestressing Equipment	2812	
		ii) Grouting Equipment		
		iii) Electric Genset		
		iv) Drill		

6. DESCRIPTION OF ESSENTIAL EQUIPMENT FOR BRIDGE WORKS

Bulk of the equipment used for bridge works has already been described in **Section 4**.

Other essential equipment for bridge works are discussed below:

6.1 Concrete Placement Equipment

6.1.1 Concrete is either mixed at the project site itself or transported to the site via a transit mixer or agitator truck. Thereafter, it must be placed to its final position without segregation and before it has achieved an initial set. Depending on the horizontal and vertical distance of the concrete movement and other constraints, the following means are available for placement of concrete:

i) Concrete Buckets

ii) Skip and Hoist

iii) Buggies and Wheel Barrows

iv) Chutes

v) Drop Pipes

vi) Belt Conveyors

vii) Concrete Pumps

6.1.2 Concrete Bucket – Commonly lifted by cranes, concrete buckets should be selected such that they can be lifted safely to the required concrete placing locations by the job site crane. Selection of bucket size is governed by the desired production rate. Larger the bucket size, smaller will be the number of work cycles required to execute a given concrete placement. Accordingly, the crane should be selected such that its lifting capacity is more than the weight of the loaded bucket.

The discharge gate (usually of clamshell type) at the bottom of the bucket may be operated manually or with aid from external power. Since the bucket must be raised and lowered and allowed to swing freely, it is not feasible to have a permanent connecting line to supply power for the discharge gate. An effective technique to operate the gate with external power is by compressed air. A compressed air line can be attached to the bucket by means of a quick-connecting coupling and detached simply by twisting.

6.1.3 Skip and Hoist – This method is used for transporting concrete vertically. At the ground level, the skip is first loaded with concrete and it, then, travels vertically on rails up to the desired level, where it discharges concrete by manual or automatic operation. Lifting of the skip is powered by a hoist of minimum 0.5 ton capacity.

6.1.4 Buggies and Wheel Barrows – Buggies and wheel barrows are suitable for concrete placement over short distances. They are used for small works or as a complementary means on projects utilizing cranes or concrete pumps as the major concrete placing equipment. When considering the use of buggies and wheel barrows, the expense of building ramps, runways and similar setups should be taken into account as they can operate only on smooth and rigid surfaces.

Buggies can be manual (hand buggies) or motor-propelled (power buggies). The power buggy has a single lever controlled hydraulic dumping mechanism.

6.1.5 Chute – Chutes are often used to transfer concrete from a higher elevation to a lower elevation. They should have a round bottom, and the slope should be steep enough for the concrete to flow continuously without segregation. Transit mixers are normally equipped with built-in swing (and often extendable) chutes. These chutes are hydraulically operated for direct placing of the mix when the concreting location is within chute reach.

6.1.6 Drop Pipe – Drop pipes are used to transfer the concrete vertically down. They are used when concrete is placed in a wall or column to avoid segregation caused by allowing the concrete to free fall through the reinforcement. A tremie operation occurs when a drop pipe (which in this case is called a tremie pipe) is used to place concrete under water. The lower end of a tremie pipe is kept continuously immersed in fresh plastic concrete.

6.1.7 Belt Conveyor – Belt conveyors provide for rapid movement of fresh concrete. Selection of proper belt size and speed is required to achieve the desired rate of transportation. Particular attention must be given to points where the concrete leaves one conveyor for continuing on another conveyor or is discharged, and at the points where the belt passes over the rollers, so that segregation does not occur at any of these points.

Belt conveyors can be classified into three types:

i) Portable or Self-contained Conveyors
ii) Feeders or Series Conveyors
iii) Side Discharge or Spreader Conveyors

6.1.8 Concrete Pump – Concrete Pump is covered in **Section 6.2**.

6.2 Concrete Pump

6.2.1 Concrete pumps allow high placing rates and are useful where space for construction equipment is limited.

To work properly, the pump must be fed with concrete of uniform workability and consistency and adequate fluidity and cohesiveness. Concrete pumps are powered either by the engine of the trucks on which they are mounted or by a separate diesel engine or electric motor.

6.2.2 Concrete pumps are typically classified on the basis of the following characteristics:

i) Type of pumping unit
ii) Mode or frequency of transportation
iii) Form of conveying
iv) Concrete-mix delivery with assistance

Table 31 illustrates classification of concrete pumps.

Table 31: Classification of Concrete Pump

Sl. No.	Classification Basis	Type	Examples
1.	Type of pumping unit	Piston	Hydraulic driven
			Mechanical driven
			Single Piston
			Multi Piston
		Rotary	Vacuum
			Elastic
2.	Mode or frequency of transportation	Self-propelled mobile	Truck mounted
		Non self-propelled mobile	Trailer mounted
		Stationary	Skid mounted/ Fixed in place
3.	Form of conveying	With integral distribution boom	Truck mounted (Boom Pump)
		With separate distribution boom	Articulating distribution arm (with support legs)
			Tower mounted boom
		With connected conveying tine	Pipe and/or hose run from pump to placement (Line Pump)
4.	Concrete mix delivery with assistance	With pressurised air	Concrete spraying (Shotcreting)

6.2.3 Piston Pump (Figure 81) – The most common concrete pumps are usually of the piston type and consist of a receiving hopper, two concrete pumping cylinders, and a valving system to alternately direct the flow of concrete into the pumping cylinders and from there to the pipeline. One concrete cylinder receives concrete from the receiving hopper while the other discharges into the pipeline to provide a relatively constant flow of concrete through the pipeline to the placing area. Pistons in the concrete cylinders create a vacuum to draw in concrete on the intake stroke and mechanically push it into the pipeline on the discharge stroke. These pistons are driven by hydraulic cylinders on most pumps, but may also be driven mechanically.

Use of an agitator in the feeding/ receiving hopper helps maintain the flowability of concrete and prevents it from setting.

In case of very large pumping distances, relay pumping using pumps in series may be adopted.

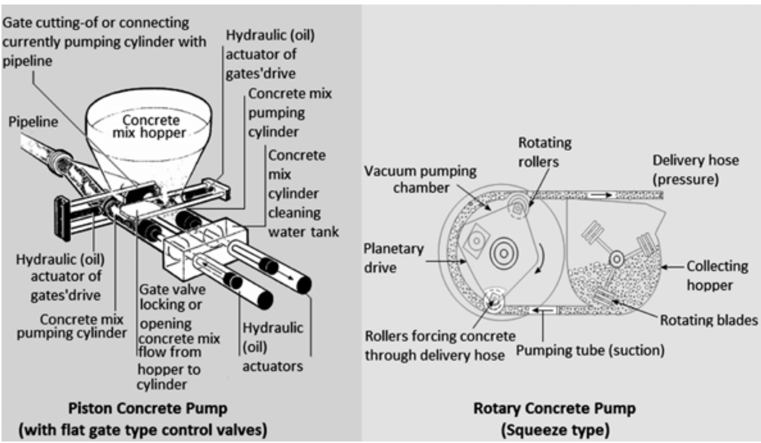


Figure 81: Piston and Rotary Concrete Pumps

6.2.4 Rotary Pump (Figure 81) – In this type of pump (also called squeeze pump), a peristaltic action is used to impart energy to the concrete mix with the intent of transporting the mix to and through the conveying pipe and/or hose. Concrete in the collecting/ intake hopper is fed by rotating blades into a flexible hose which is connected to and fitted inside the pumping chamber. Rollers (two or more in number), which are mounted on planetary gear drives at the external circumference of a hydraulic motor driven rotor assembly, rotate on the flexible hose within the pumping chamber and progressively squeeze the concrete out at the discharge port. Subsequently, as the elastic hose returns to its original shape (i.e. cylindrical) after the passing of the roller, concrete flow from the hopper to the pump is induced. Maintaining the pumping chamber under vacuum can ensure that except when being squeezed by roller, the hose shape remains cylindrical so that a continuous flow of concrete is permitted.

6.2.5 Pump with Pipeline – In this configuration, also termed as a line pump, the pipeline (rigid or flexible) is a separate system that must be assembled by means of quick couplings and connected to the pump before pumping operation begins. The pipeline is laid from the location of the pump to the concrete placing area. The pump is located within good access of the transit mixer or agitator truck. In case of a central concrete batching and mixing plant located at the work site, the pump is placed with the hopper just under the mixer's discharge opening. The free end of the pipeline has a flexible rubber pipe connected to it for better control of the concrete discharge location and for easier handling by the workers who have to direct the spreading of the concrete. However, holding and moving the end of the pipe may be difficult given its weight when filled with concrete. In such cases, it is desirable to use a special light weight distribution (or placing) boom, which connects to the end of the rigid pipe and is supported by a ballasted base. The entire articulated boom assembly is crane lifted for relocation as the concreting progresses.

The pump may be stationary or mobile (mounted on a truck or trailer).

6.2.6 Pump with Integral Distribution Boom (Figure 82) – In this configuration, also termed as a boom pump, the pump is mounted on a truck and is equipped with a revolving (slewing) boom to which a fixed length delivery line is connected. The boom is hydraulically operated and consists of three to six articulating sections. For a given boom length, a greater number of sections provides the boom with greater manoeuvrability. Boom length indicates the boom's maximum vertical reach, measured from the ground. Maximum horizontal reach is measured from the boom's slewing axis. Effective horizontal reach depends upon the truck make and size, and specific boom dimensions and truck dimensions need to be considered when selecting a truck mounted pump for a given concreting operation.

Since the reach of boom pumps is limited, these pumps use ready-mixed concrete with the pump optimally positioned to enable maximum coverage of the concreting area for each concreting operation.

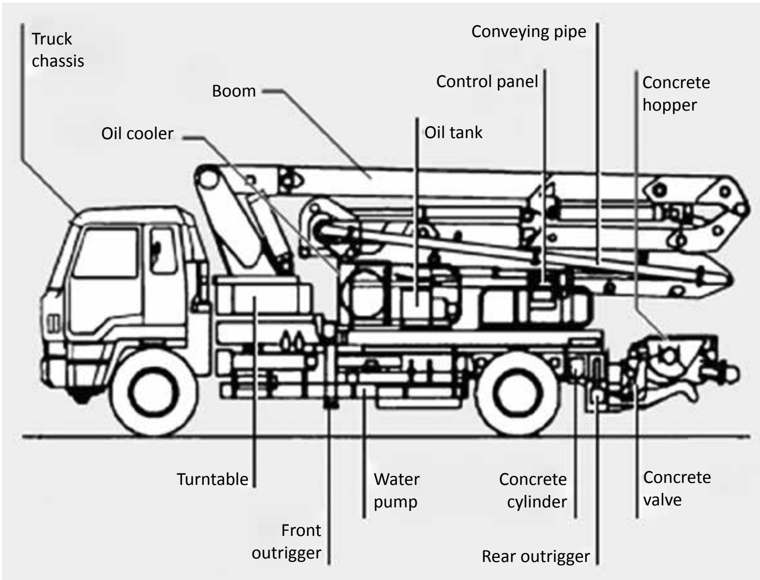


Figure 82: Truck-Mounted Concrete Pump with Integral Distribution Boom

6.2.7 Pump with Separate Distribution Boom – This configuration consists of a stationary or mobile pump at the concrete loading end, a hydraulically articulated separate placing boom at the concrete placing end, and an intermediate pipeline connecting the pump to the boom.

For applications which may be affected by the limited reach of boom pumps on account of large horizontal/ vertical distribution reach (e.g. underwater concreting in case of long span bridge over deep water body with long piers), it is advisable to use a pump with separate distribution boom.

6.2.8 Selection of concrete pump is primarily governed by two important parameters – maximum volumetric output (in cum/hour) and peak pumping pressure. To be able to achieve a targeted output of concrete at site, it is essential to determine, as accurately as possible, the required pumping pressure so that, together with the desired output, a rational basis for selecting a pump can be developed. Pumping pressure will depend upon factors like total lead (including horizontal and/or vertical distance over which the concrete is to be pumped), delivery pipeline diameter, directional changes in the pipeline, concrete consistency and delivery output.

6.2.9 For more information on concrete pumps, refer to IS/ISO:21573 (Part 1).

6.3 Pneumatic Sinking Equipment

6.3.1 Pneumatic Sinking Equipment (**Figure 83**) consists of the following:

i) Working Chamber
ii) Airlocks
iii) Air Compressor
iv) Air Conditioning Plant
v) Exhaust Valves
vi) Lighting System

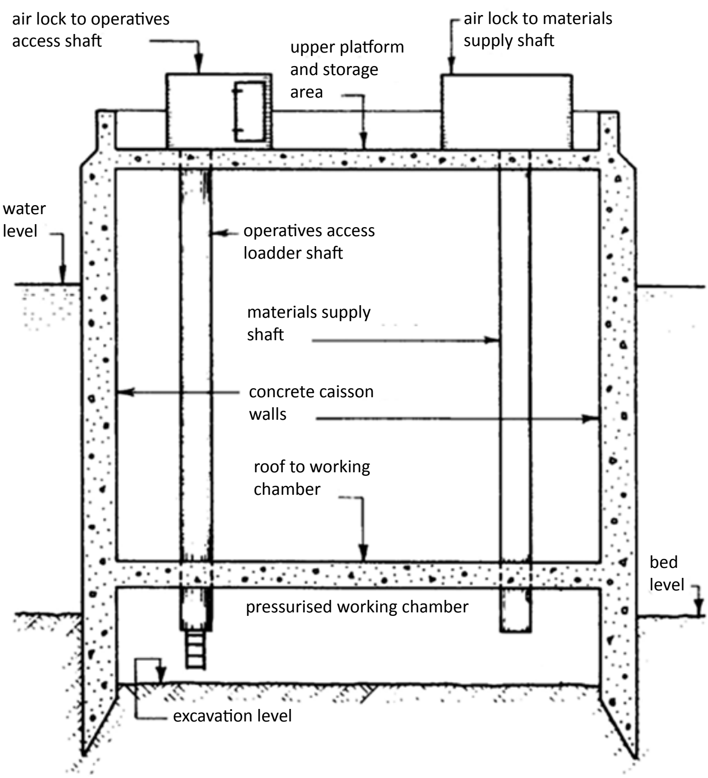


Figure 83: Pneumatic Sinking Equipment

6.3.2 **Working Chamber** – When caissons are designed to be sunk under compressed air, it is usual to provide a single large working chamber instead of having a number of working chambers separated by cross walls. The single chamber is a convenient arrangement for minimising resistance to sinking since the resistance is only given by the outer walls. Control of sinking by differential excavation from a number of cells is not necessary since control of position and verticality can readily be achieved by other means, for example, by the use of shores and wedges beneath the cutting edge, or by differential excavation beneath the cutting edge.

The roof of the working chamber (called corbel) must be strongly built as it may have to resist high air pressures over a wide span.

Access to the working chamber is through shafts. Since all excavated material must be lifted through the shafts, the shafts must have adequate capacity in size and numbers to pass the required quantity of spoil in buckets through the air locks to meet the desired rate of sinking. The air shaft is usually oval in plan and is divided into two compartments by a vertical ladder. One compartment is used for hoisting and lowering spoil buckets and the other is for the workmen. In case of larger caissons (where 15 or more workmen are involved), separate air shafts are provided for excavated muck and workmen.

6.3.3 Air Locks – The air lock is a steel pressure vessel made in the form of a chamber with two doors. One door opens to the outside and the other to the air shaft. This arrangement makes it possible to maintain a constant air pressure in the working chamber during the passage of men and material. One of the doors must always be kept closed to prevent the compressed air pressure in the working chamber from becoming lower. In small caissons, an airlock serves several functions – it is used by men as an entry to the working chamber; for the transport of excavated muck; and for delivering concrete to fill the working chamber at the end of sinking. In larger caissons, separate locks for men and muck are provided.

The air lock is mounted on top of the air shaft and it is essential for the safety of the workmen to ensure that the lock is always above the highest tidal or river flood levels, with sufficient safety margin to allow for unexpected rapidity in sinking of the caisson. Alternatively, the air locks can be protected against flooding by building up the skin plating or by providing a cofferdam around the top of the caisson to the required height.

The size of the air locks and air shafts is governed largely by the quantity of material to be excavated, that is, by the size of the muck bucket.

6.3.4 Air Compressor – Compressed air for the working chamber is delivered from a compressor plant via air locks and air shafts and a pipe distribution system. According to the location of the caisson, the compressor plant is land-based or barge mounted.

Compressors for air supply are usually of stationary type. Ideally, they should be driven by variable speed motors to enable the supply to be progressively increased as the caisson sinks deeper.

6.3.5 Air Conditioning Plant – Improved working conditions and greater immunity to caisson sickness can be ensured by using an air conditioning plant. The plant should aim to remove moisture and oil, and to warm the air for working under cold weather condition or cool the air for working under hot weather condition.

6.3.6 Exhaust Valves – Exhaust valves shall be provided, having risers extending to the upper part of the chamber. These shall be operated whenever necessary, especially after a blast. Precautions shall be taken that men are not allowed to resume work after a blast until the gas and smoke have cleared.

6.3.7 Lighting System – All lighting in compressed air chambers shall be operated only by electricity. Two independent electric lighting systems with independent sources of supply shall be used. These shall be so arranged that the emergency source shall become automatically operative in case of failure of the regularly used source.

The minimum intensity of light on any walkway ladder, stairway or lower working level shall be 0.25 candlepower. In all work places, the lighting shall always be such as to enable workmen to see their way about clearly. All external parts of lighting features and electrical equipment lying within 2.5 m above the floor shall be constructed of non-combustible, non-absorbing insulating materials. If metal is used, it must be effectively earthed. Portable lamp shall have non-combustible, non-absorbing insulating sockets, approved handles, basket guards and approved cables.

6.3.8 Safety provisions as contained in IS:4138 and **Section 1208.8** of MoRTH's Specifications for Road and Bridge Works shall be strictly followed.

6.4 Pile Driver

6.4.1 Driven piles are usually installed to established criteria – minimum blow count per unit penetration or minimum penetration.

The function of a pile driving hammer (or pile driver) is to provide the energy required to drive a pile. The pile driver is usually mounted on a piling rig (**Figure 84**).

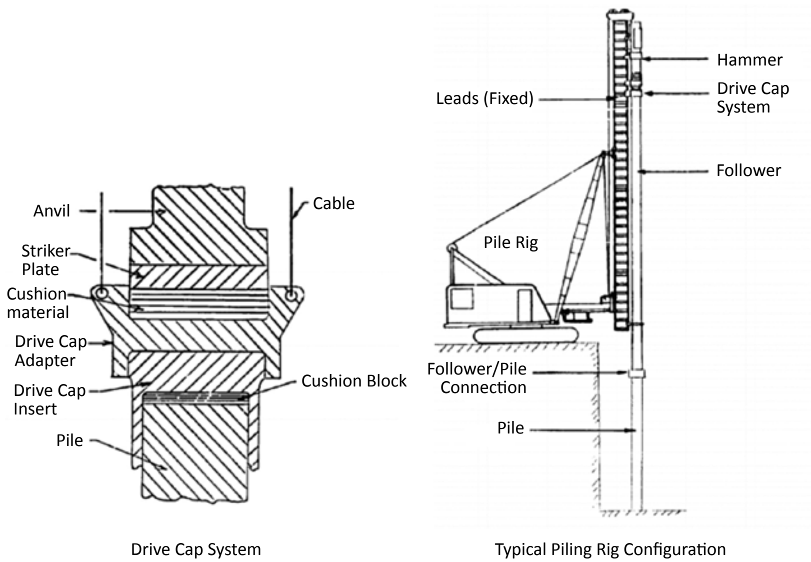


Figure 84: Piling Rig

6.4.2 Pile drivers are designated by type and size. Different types of pile drivers are available for catering to various subsurface conditions and are discussed below:

- i) Drop type
- ii) Single Acting (steam or compressed air) type
- iii) Double Acting (steam or compressed air) type
- iv) Differential Acting (steam or compressed air) type
- v) Diesel type
- vi) Hydraulic type
- vii) Vibratory type

Drop Hammer (Figure 85) – A drop hammer is a heavy metal weight that is lifted by a hoist line, then released and allowed to fall onto the top of the pile. A pile cap is positioned between the hammer and the pile head because of the high dynamic forces and serves to uniformly distribute the blow to the pile head and, therefore, acts as a shock absorber.

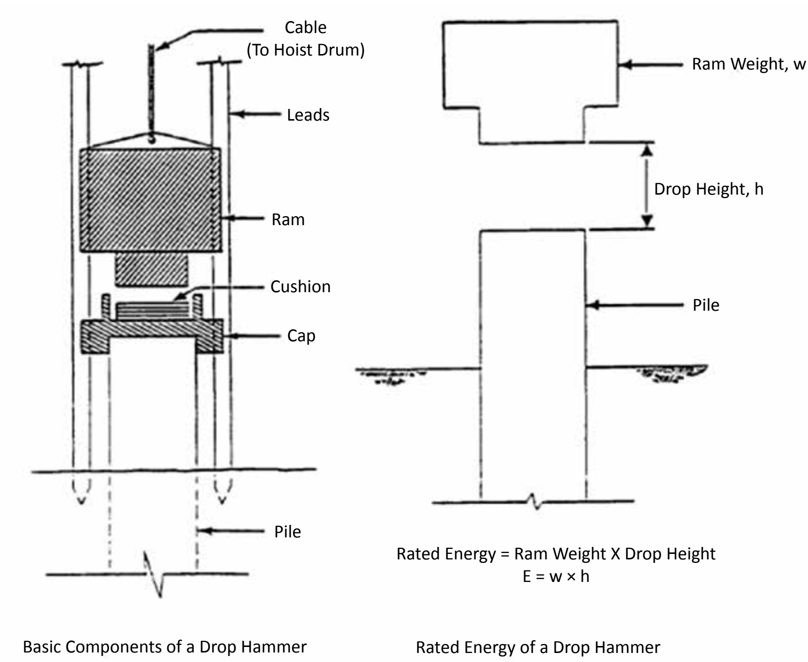


Figure 85: Drop Hammer

The hammer may be released by a trip and fall freely, or it may be released by loosening the friction band on the hoisting drum and permitting the weight of the hammer to unwind the rope from the drum. The latter type of release reduces the effective energy of the hammer due to friction loss in the drum and rope. Leads are used to hold the pile in position and to guide the movement of the hammer so that it will strike the pile axially.

A drop hammer is suitable for driving piles on remote projects that require only a few piles and for which the time of completion is not an important factor.

Single Acting Hammer (Figure 86) – A single acting steam or air hammer consists of a freely falling weight (called ram), that is lifted by steam or compressed air, whose pressure is applied to the underside of a piston that is connected to the ram through a piston rod. When the piston reaches the top of the stroke, the steam or air pressure is released and the ram falls freely by its own weight to strike the top of a pile. These hammers rely solely on gravity acting on the striking weight through a distance to achieve their striking energy.

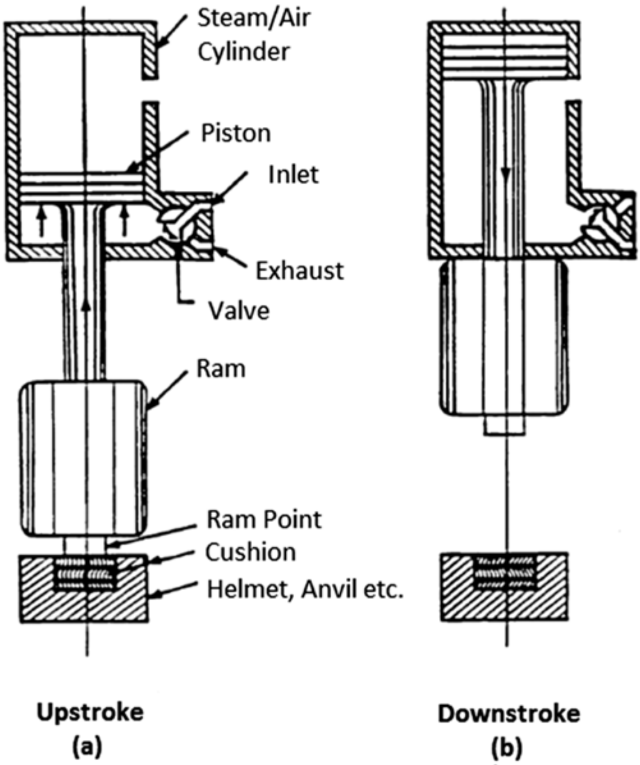


Figure 86: Single Acting Hammer

A driving cap (or anvil or helmet) is positioned between the hammer and the pile head to uniformly distribute the blow to the pile head.

A single acting hammer is usually used in a pile lead, though it can be fitted to operate free hung.

A single acting hammer can strike higher blows per minute than a drop hammer.

Double Acting Hammer (Figure 87) – Here, the striking ram (piston) is driven by compressed air or steam when rising as well as when falling. The air or steam enters a valve box containing a slide valve that sends it alternately to each side of the piston, while the opposite side is connected to the exhaust ports. Thus, with a given weight of ram, it is possible to attain a desired amount of energy per blow with a shorter stroke than with a longer single-acting hammer.

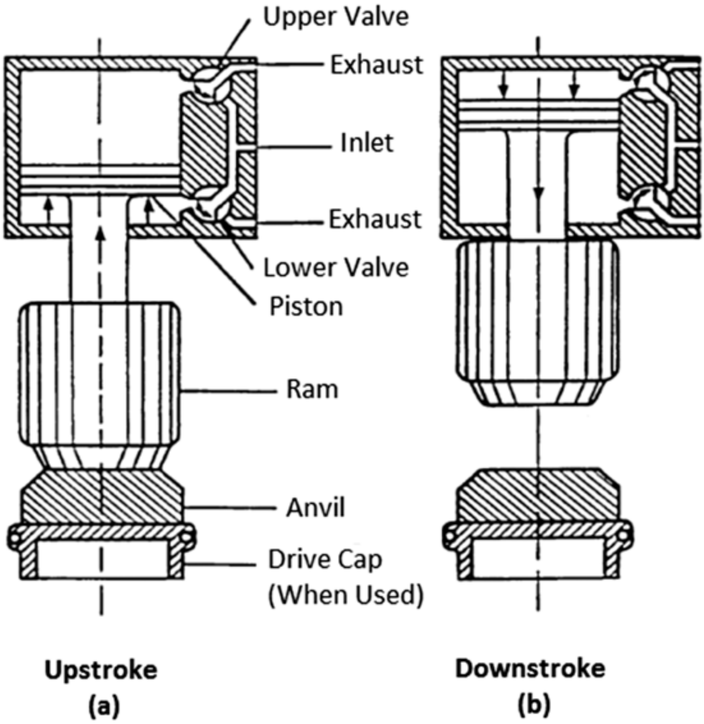


Figure 87: Double Acting Hammer

A double acting hammer can strike higher blows per minute than a single acting hammer.

The lighter ram and higher striking velocity of the double acting hammer may be advantageous when driving light to medium weight piles into soils having normal frictional resistance. The high frequency of blows will keep a pile moving downward continuously, thereby preventing static skin friction from developing between blows. However, when heavy piles are driven, especially into soils having high frictional resistance, the heavier weight and slower velocity of a single acting hammer will transmit a greater portion of the rated energy into driving the piles.

Differential Acting Hammer (Figure 88) – Here, the air or steam pressure used to lift the ram is not exhausted at the end of the upward stroke but is valved over the piston to accelerate the ram on the down stroke.

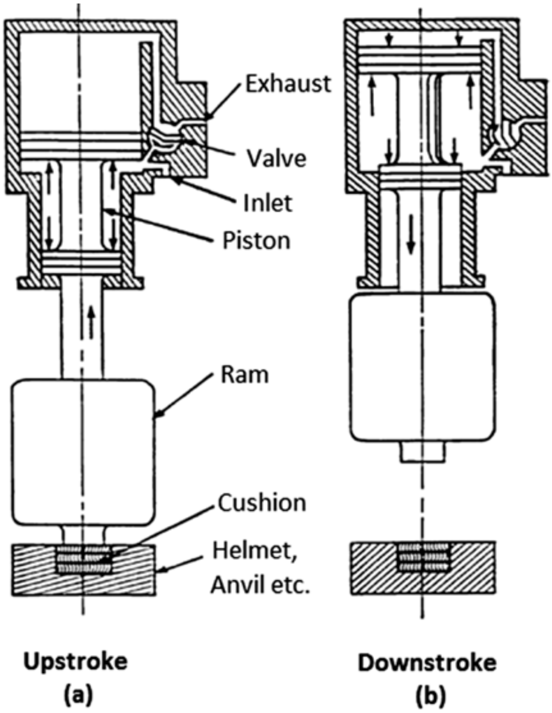


Figure 88: Differential Acting Hammer

The number of blows per minute is comparable with that for a double acting hammer, whereas the weight and equivalent free fall of the ram are comparable with those of a single acting hammer.

These hammers require the use of a pile cap with cushioning material and a set of leads.

Diesel Hammer (Figure 89) – It is a self-contained driving unit that does not require an external source of energy like an air compressor or steam boiler. It is, therefore, simpler and easily movable from one location to another than a steam hammer.

A diesel hammer unit consists of a vertical cylinder, a piston or ram, an anvil, fuel and lubricating oil tanks, a fuel pump, injectors and a mechanical lubricator.

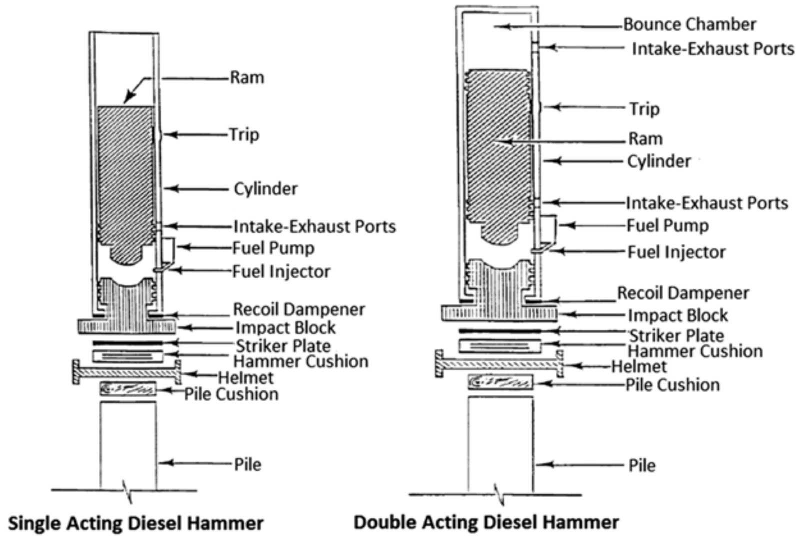


Figure 89: Diesel Hammer

Figure 90 illustrates the operation cycle of a single acting diesel hammer. After the hammer is placed on top of the pile, the combined piston and ram are lifted by a lifting attachment (e.g. cable from crane) to the upper end of the stroke and released to start the unit operating. As the free-falling ram nears the end of the down stroke, it activates a fuel pump that injects the fuel into the combustion chamber between the ram and the anvil. As soon as the ram passes the exhaust ports, air is trapped in the combustion chamber. The continued down stroke of the ram compresses the air and fuel to ignition heat. The resulting explosion drives the pile downward and the ram upward to repeat its stroke. The energy per blow can be controlled by the operator (through manually operated variable fuel injector) as per requirement.

Operation of a double acting diesel hammer differs from that of a single acting diesel hammer in the sense that the top of the cylinder is capped and has a “bounce chamber”, which compresses the air as the ram reaches near the top of its upward stroke and halts the ram’s upward flight when sufficient pressure builds up. The ram then begins its downward stroke under the effect of both gravity as well as the internal pressure generated in the “bounce chamber”. The rest of the operation cycle is similar to that of a single acting diesel hammer.

Diesel hammers require a pile cap with cushioning material to protect the pile heads during driving.

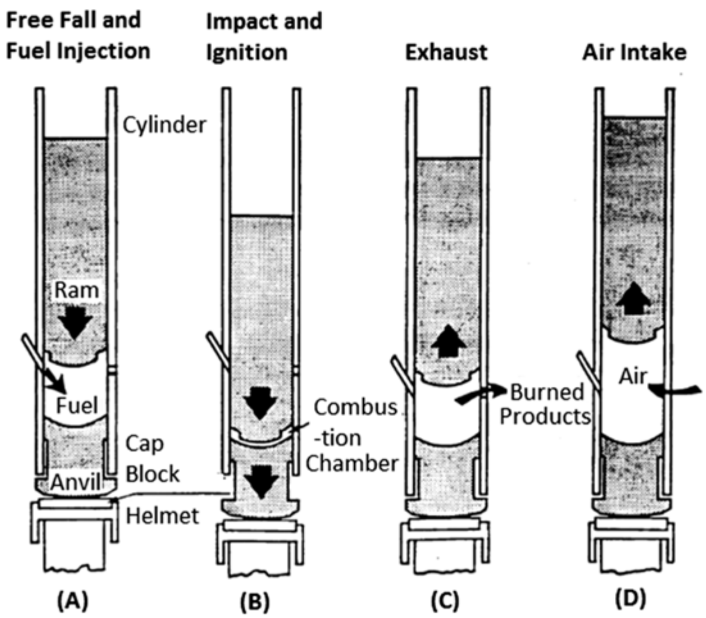


Figure 90: Operation Cycle of Single Acting Diesel Hammer

Hydraulic Hammer – It is more efficient than steam, air or diesel hammers. It operates on the differential pressure of hydraulic fluid instead of compressed air or steam.

It can be of two types: hydraulic drop (or single acting) hammer and double acting hydraulic hammer.

In a hydraulic drop hammer, the ram is lifted by hydraulic pressure to a preset height and then allowed to free-fall onto the anvil on account of gravity. With these hammers, the height of the drop can be varied to match the pile and ground conditions.

In a double acting hydraulic hammer, movement of the ram in both upward stroke and downward stroke is facilitated by hydraulic pressure. The net energy applied to the pile by the accelerated ram is measured during every blow on a control panel and can be continuously regulated.

Vibratory Hammer (Figure 91) – The hammer is equipped with two horizontal shafts to which eccentric weights are attached. As the shafts rotate in opposing directions, vibrations are produced in the vertical direction and then, transmitted to the pile as the pile is rigidly connected to the hammer by hydraulic clamps. From the pile, the vibrations are transmitted into the adjacent soil. The agitation of the soil materially reduces the skin friction between the soil and the pile.

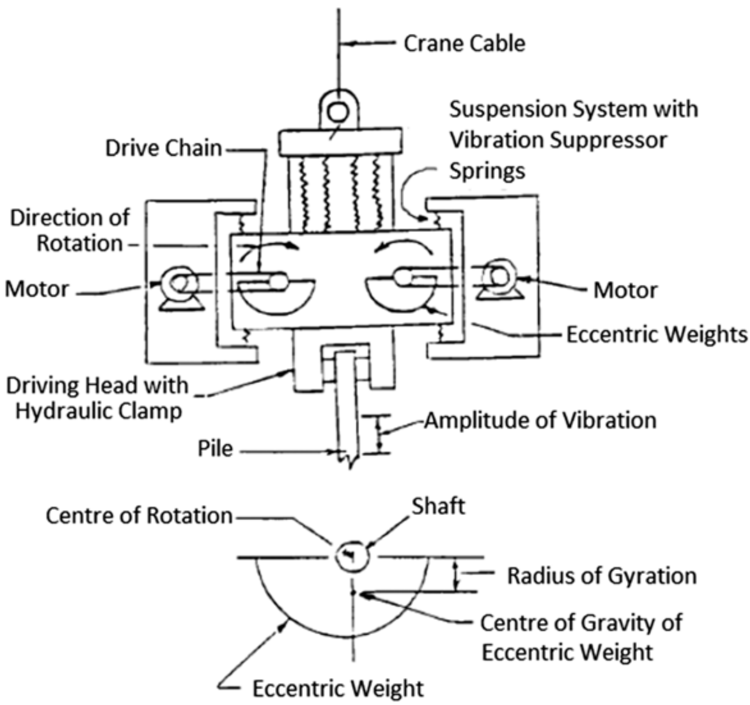


Figure 91: Vibratory Hammer

Leads are rarely employed with vibratory hammers. The hammer is powered either electrically (electric genset) or hydraulically (hydraulic power pack).

The performance of a vibratory hammer depends upon its amplitude, frequency, eccentric moment, vibrating weight and non-vibrating weight.

Vibratory hammer should not be used for driving permanent piles unless specified in the Contract or approved by the Engineer because there is no way to determine the amount of energy delivered to the pile. If approved, it should be used in combination with pile load testing and re-tapping with an impact hammer, ensuring that acceptable load capacity is achieved.

However, vibratory hammer can be used to install temporary works (e.g. sheet piles for shoring) as well as for pile extraction.

6.4.3 Pile drivers may be classified on the basis of weight of ram (or striking part) as:

i) Light (for weight up to 500 kg)

ii) Medium (for weight over 500 kg and up to 2500 kg)

iii) Heavy (for weight over 2500 kg)

Driven Pile Foundations (Permanent Works) – The weight or power of the hammer should be sufficient to ensure a penetration of at least 5 mm per blow unless rock has been reached. It is always preferable to employ the heaviest hammer practicable and to limit the stroke, so as not to damage the pile. The minimum weight of the hammer shall be 2500 kg. In the case of precast concrete piles, the mass of the hammer shall not be less than 30 times the mass of 300 mm length of pile.

6.4.4 The performance of the hammer is indicated by its weight, rated energy and blows per minute.

6.4.5 Selection of the hammer type and size depends upon a variety of factors like:

i) Size, type and number of piles

ii) Soil characteristics and site topography

iii) Type of rig/crane available

iv) Project location – whether driving is to be done on land or over water

6.4.6 Use of a water jet to assist in driving piles into sand or fine gravel can speed up the driving operation. Water discharged through a nozzle at the lower end of a jet pipe loosens and keeps the soil around the pile in agitation (thereby reducing the resistance due to skin friction), and removes the soil particles from the hole ahead of the penetration of the pipe.

When water jetting is used, at least two jets shall be attached to the pile symmetrically.

If large quantities of water are used for jetting, provision shall be made for collecting and draining away of water when it comes to the surface of the ground, so that the stability of the piling plant is not endangered by the softening of the ground.

6.5 Pile Boring Equipment

6.5.1 Construction of bored piles requires careful selection of the boring equipment. The choice of the appropriate piling equipment will depend upon the subsoil strata, groundwater condition, type of founding material, pile diameter, pile depth etc.

6.5.2 The following methods are usually adopted for advancing boreholes:

i) **Rotary or rotary-percussion rigs using Continuous Mud Circulation (CMC) method** – This method (**Figure 92**) uses drilling mud to bring the drill cuttings out as well as to stabilise the borehole. A mud pump of sufficient capacity (depending upon the diameter and depth of the borehole) is used to ensure that drilling fluid (bentonite) of sufficient viscosity and velocity is maintained in continuous circulation so that the drill cuttings are suspended in the mud and brought to the surface by the flow of bentonite. The level of the bentonite suspension is kept constant.

   A minimum of 2 m length of top of the borehole shall invariably be provided with casing to ensure that the loose soil does not fall into the bore.

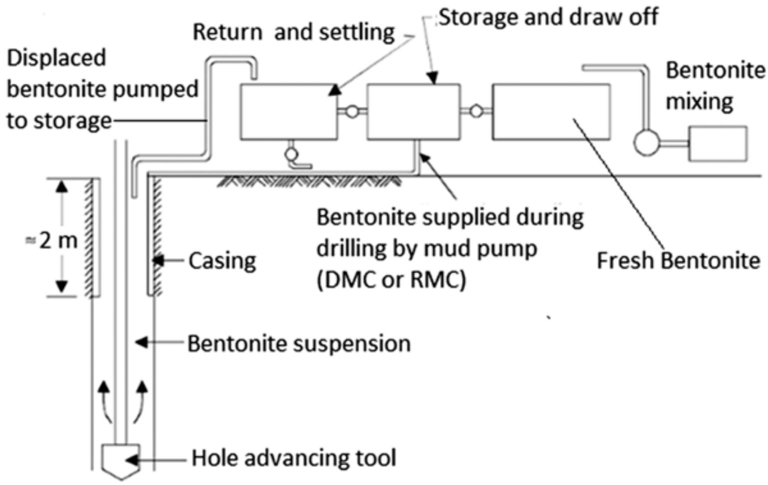


Figure 92: Rotary or Rotary-Percussion Boring using Bentonite Suspension

The various Continuous Mud Circulation (CMC) methods are listed below:

a) **Direct Mud Circulation (DMC)** – Here, the bentonite suspension is pumped into the hole bottom through drill rod and it overflows at the top of the casing.

An improved version of the DMC method is the Rapid Direct Mud Circulation (R-DMC) method, where a tube carrying compressed air is sent to the hole bottom. The air improves mixing of the drill cuttings with the bentonite slurry so that even heavy particles can be forced out of the hole suspended in the bentonite.

b) **Reverse Mud Circulation (RMC)** – Here, the bentonite suspension is pumped directly at the top of the hole and is pumped out from the hole bottom through the drill rod. While the borehole size in DMC method is limited by the mud pump capacity, in RMC method even a pump of medium capacity can create enough bailing velocity to bring the cuttings up and the inner diameter of the drill rod need not be large.

An improved version of the RMC method is the Air Lift Reverse Mud Circulation (A-RMC) method, which uses compressed air to circulate the drilling fluid and drill cuttings to the surface.

Both the RMC and A-RMC methods are suited for large diameter holes.

Principle of operation of rotary and rotary-percussion drills is explained in **Section 6.9**.

For rotary and rotary-percussion drills using flushing medium (eg: water), that aids in cutting process but not suitable for bore stabilisation, temporary casing should be provided for the entire length of the borehole.

ii) **Cable Percussion Rig (Bailer and Chisel Method)** – The rig consists of a tripod derrick and winch which are used to lift and drop heavy cutting tools down on to the base of the borehole. The selection of cutting tool depends upon the soil conditions. Heavy hammer weights can be added onto the top of the cutting tool to increase the momentum of the dropping tool.

In this method, the borehole is stabilised by steel casing instead of drilling mud. A temporary casing has a collar at its top to take blows during casing driving and a cutting edge at its bottom to facilitate driving. The casing is driven open ended with a pile driving hammer using a casing drive bar. Materials inside the casing are removed progressively as the percussion equipment drills the hole. After concreting is over, the casing is extracted using a casing extractor bar.

iii) **Winch (Figure 93)** – A typical piling winch consists of a winch drum powered by a prime mover. The standard capacities (drum rope pull) of the winch drum shall be 1.5 tonne, 2.5 tonne and 5 tonne; and the drum diameter shall be not less than 20 times the diameter of the wire rope used.

The prime mover is usually a diesel engine of the air cooled type or an electric motor. A suitable reduction gear shall also be provided.

The transmission system shall be geared, chained or belt (flat belt or V-belt) drive and provided with suitable guard cover.

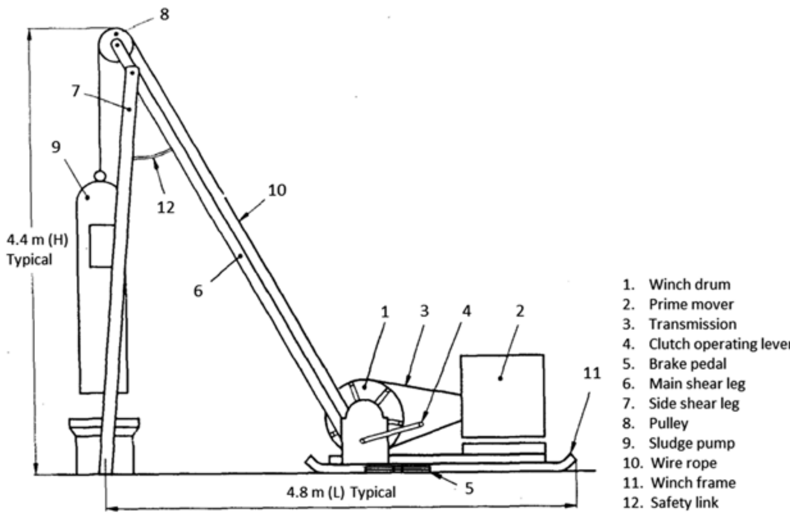


Figure 93: Winch and Derrick

The clutch system consists of a clutch wheel and friction plate(s) or a friction cone operated by a lever.

The brake system consists of a brake band connected with the foot brake pedal or brake handle for hand operation.

The winch frame is truck-mounted, crawler-mounted or skid-mounted. A proper stabiliser shall be provided to transmit the load to the ground smoothly.

iv) **Derrick (Figure 93)** – The hoisting capacity of the derrick shall be at least equal to the maximum drum rope pull and preferably more by 25%. The standard derrick consists of a main shear leg and two side shear legs, and has a pulley at the top of the main shear leg. The pulley shall have a diameter at least 20 times the diameter of the wire rope used. It shall have a suitable guard and shall be properly lubricated. A safety link is provided near the top of the derrick so as to preclude any accidental increase in the distance between the legs.

Boring/Cutting Tools – The following types of boring/cutting tools are available for selection:

a) **Sludge Pump (Figure 94)** – Boring is usually advanced by using a sludge pump (also called shell). Sludge pump is a hollow cylindrical steel body with a cutting shoe at the bottom and a lifting hook at its top. It has hinged trap door immediately above the bottom cutting edge and it has an opening (window) near the top for muck removal. Above this window, lead or steel or concrete may be added to increase the weight of the sludge pump for effective boring.

Weight of the sludge pump shall vary with the diameter but normally minimum weight shall be 7.5 kN.

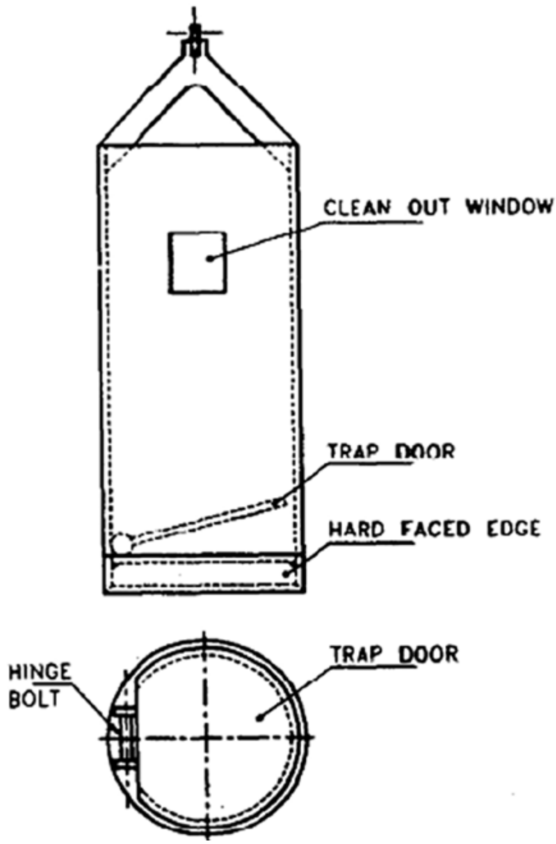


Figure 94: Sludge Pump

b) **Bailer (Figure 95)** – The bailer is used for removal of water or slush from the bore hole. It is made up of a hollow steel cylinder with a lifting hook at the top and a truncated base plate with perforation at the bottom. There is a plunger passing through a central hole of the base plate which acts as a plug valve. This plunger is about 20 cm long and has about 15 cm diameter steel-plates welded at its top and bottom. This closes the central hole in the base plate of the plunger and thus retains the slush material for removal.

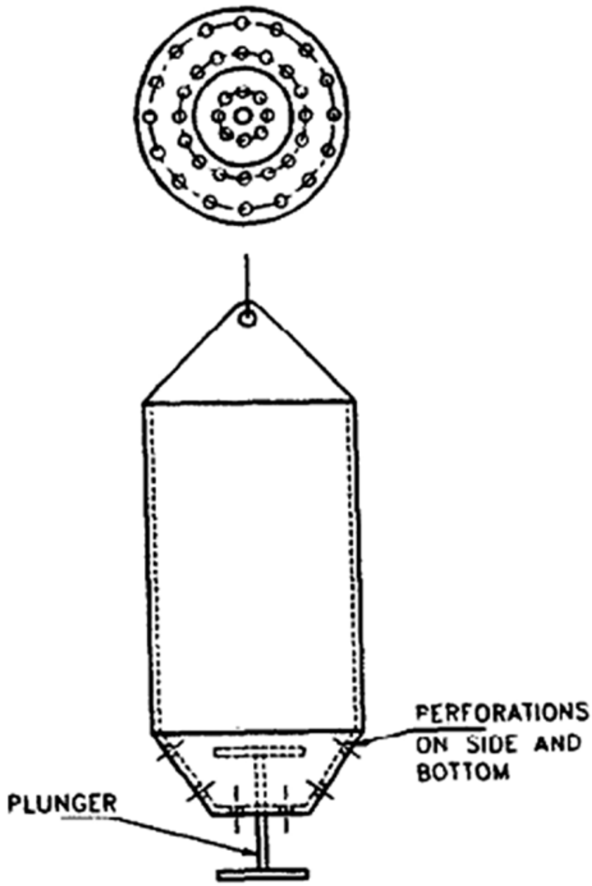


Figure 95: Bailer

c) **Chisel (Figure 96)** – Hard strata during boring is broken by chisels. The chisel is made of solid round bar with a hard faced edge at the bottom. It shall weigh at least

7.5 kN for 450 mm piles and 12.5 kN for 500 and 600 mm piles.

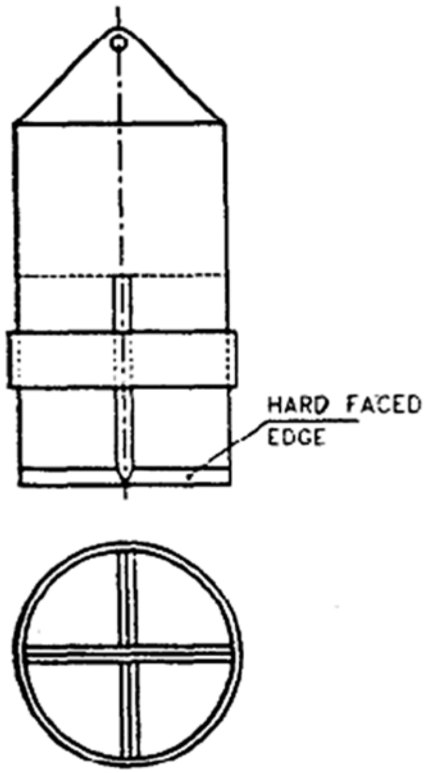


Figure 96: Chisel

6.5.3 After the boring operation is complete, the bore bottom is cleaned to remove rock debris, pile bore soil etc. using a special cleaning tool (e.g. rope operated grab or kelly mounted hydraulically operated grab or other suitable means) and/or washed by bentonite flushing. Washing the hole by bentonite flushing shall be done in two stages – after completion of boring and prior to concreting after placement of reinforcement cage. Flushing of bentonite shall be done continuously with fresh bentonite slurry till the consistency of inflowing and out flowing slurry is similar.

6.5.4 Temporary casing has been considered in this Section for the purpose of bored pile construction. However, permanent steel liner shall be provided for the full depth of the pile in the following situations:

i) The surrounding soil is marine clay

ii) Soft soil is present

iii) Surrounding soil has sulphate content equal to or more than 1%

iv) Surrounding water has sulphate content equal to or more than 2500 ppm

v) Leakage of sewage is expected

6.5.5 **Figures 97** and **98** illustrate construction of bored pile using drilling mud and temporary casing respectively for bore stabilisation.

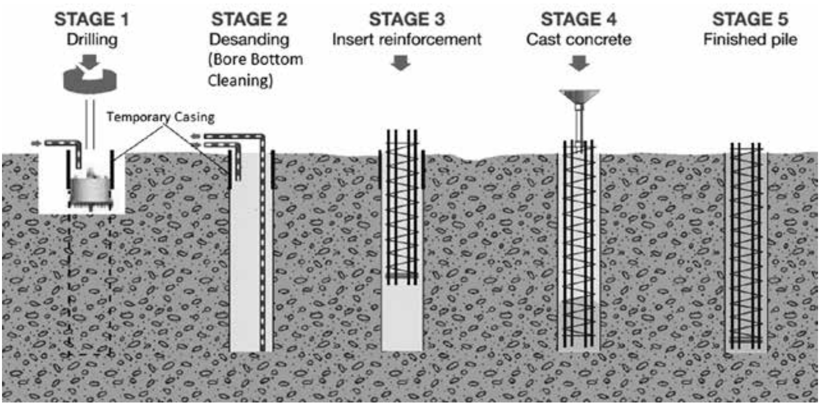


Figure 97: Bored Pile Construction using Drilling Mud for Bore Stabilisation

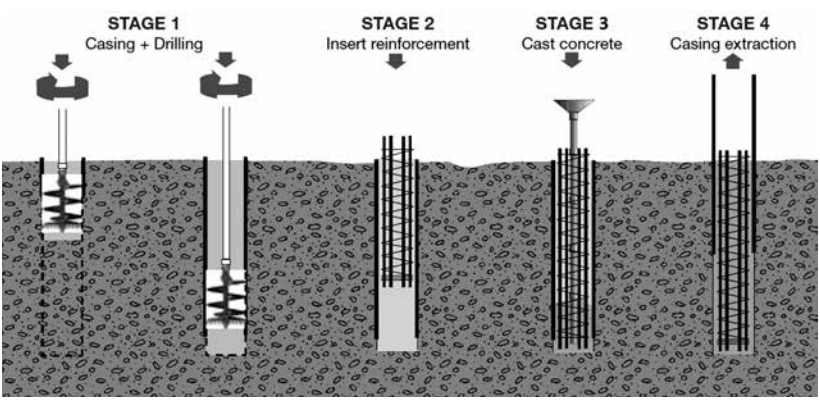


Figure 98: Bored Pile Construction using Temporary Casing for Bore Stabilisation

6.6 Prestressing Equipment

6.6.1 Prestressing Equipment (**Figure 99**) consists of the following:

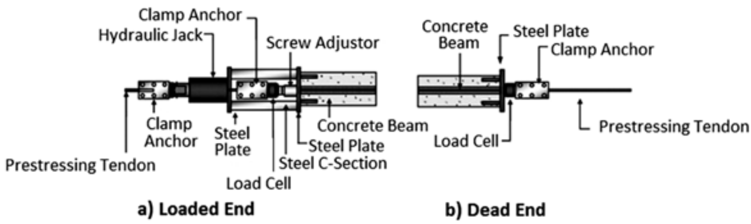


Figure 99: Prestressing Equipment

i) **Tensioning Apparatus** – Prestressing steel may be tensioned by means of hydraulic or mechanical jacks, attached to one or both ends of the tendon. When two or more wires/strands constitute a tendon, a single multi-pull stressing jack shall be used, which is capable of tensioning simultaneously all the wires/strands of the tendon.

The tensioning apparatus shall be such that it facilitates measurement and control of application of force. The tensioning apparatus should be independently supported so that it does not induce any undesirable secondary stresses. The anchorage provided for the temporary gripping of tendons on the tensioning apparatus shall be secured and such as not to damage the tendon. Devices such as dynamometers or pressure gauges are attached to the tensioning apparatus for measuring the applied force. Suitable safety devices shall be fitted to protect pressure gauges against sudden release of pressure. Facilities shall also be provided for linear measurement of the extension of prestressing steel to the nearest mm and of any slip of the gripping devices at transfer.

The following types of prestressing jacks are usually available:

a) **Mono-Strand Jack** – Jacks for stressing single (mono) strands generally have two cylinders, one on each side of the strand, with a wedge device for gripping and pulling the strand.

b) **Multi-Strand Jack (Figure 100)** – Jacks for stressing multi-strand tendons as an entire group are generally of the centre-hole type, i.e., tendons pass through a hole in the middle and are attached at the rear of the jack. It is important that all strands are orientated properly to the holes in the jack. A 'star plate' or 'recessed plate' is used to ensure proper alignment.

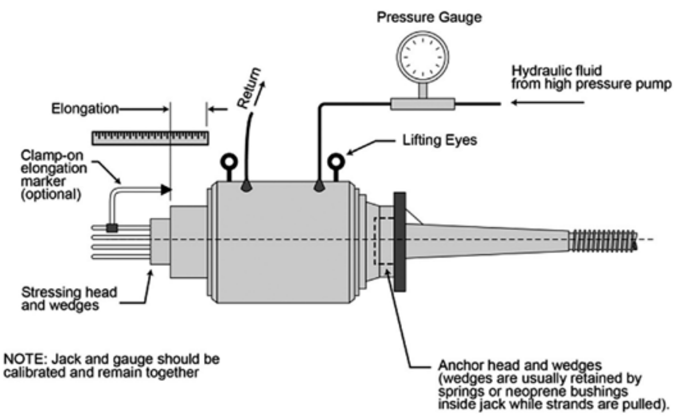


Figure 100: Multi-Strand, Centre-Hole Stressing Jack

c) **Bar Jack (Figure 101)** – Bar Jacks have a central hole through which the bar tendon passes and is secured by a nut at the rear of the jack. Most jacks have an enlarged nose to accommodate a bar-coupler. Many bar jacks have a hand or mechanical ratchet to rotate and tighten the anchor nut against the anchor plate as the bar elongates under load. A chair and open-end wrench may be used in lieu of nose and ratchet for bar jacks. By carefully tightening the anchor nut, anchor set or seating loss can be minimized or eliminated.

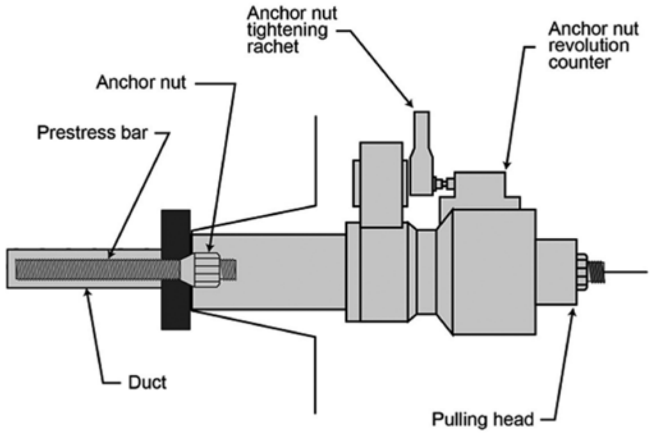


Figure 101: Prestressing Bar Jack

ii) **Temporary Gripping Device** – Prestressing tendons may be gripped by wedges, yokes, double cones or any other approved type of gripping devices. The prestressing wires may be gripped singularly or in groups. Gripping devices shall be such that in a tensile test, the wire or wires fixed by them would break before failure of the grip itself.

iii) **Releasing Device** – The releasing device shall be such that during the period between the tensioning and release, the tension in the prestressing elements is fully maintained by positive means, such as external anchorages. The device shall enable the transfer of prestress to be carried out gradually so as to avoid large difference of tension between wires in a tendon, severe eccentricities of prestress or the sudden application of stress to the concrete.

iv) **Anchorage Device** – The anchoring device shall fulfill the following requirements:

a) It shall be strong enough to resist in all respects a force equal to at least the breaking strength of the prestressing tendon it anchors.

b) It shall transfer effectively and distribute, as evenly as possible, the entire force from the prestressing tendon to the concrete without inducing undesirable secondary or local stresses.

c) It shall be safe and secure against both dynamic and static loads as well as against impact.

d) It shall have provision for the introduction of a suitable protective medium, such as cement grout, for the protection of the prestressing steel unless alternative arrangements are made.

6.6.2 In case of pre-tensioning of tendons, the stressing bed or mould along with abutments shall be rigid enough to sustain the reaction of the prestressing force without distortion. In the long line method of prestressing, sufficient locator plates should be distributed throughout the length of the bed to ensure that the wires are maintained in their proper position during concreting. The moulds shall be free to slide in the direction of their length and thus permit the transfer of the prestressing force to all the concrete elements along the whole line. Sufficient space shall be left in between the ends of concrete elements to permit access for cutting the strands/wires after transfer. Hold-downs or deflectors shall be used for holding or deflecting the tendons in required position firmly.

6.6.3 Cutting and trimming of wires or strands after prestressing operation shall be done by suitable mechanical or flame cutters. When a flame cutter is used, care shall be taken to ensure that the flame does not come in contact with other stressed steel. The flame cutting of wire or strand shall be carried out at least 75 mm beyond the point where the tendon will be gripped by the anchorage or jacks. In post-tensioned members, the ends of prestressing steel projecting beyond the anchorages shall be cut after the grout has set.

6.7 Grouting Equipment

6.7.1 Grouting is required for filling up the voids or cavities in rock or soil mass in order to increase its strength and/or impermeability.

Grouting also finds application in filling up the ducts in case of post-tensioned tendons of prestressed concrete members of bridges. Grouting protects the post-tensioned steel against corrosion and develops bond between the prestressing steel and the surrounding structural concrete.

6.7.2 The following equipment (**Figure 102**) is required for grouting:

i) **Grout Mixer and Agitator**

It is essential that the grout is maintained in a homogenous state and of uniform consistency so that there is no separation of cement during entire grouting process.

Grout should be mixed in a mixer operating at 1500 rpm or more. The high speed of mixing serves the purpose of violently separating each cement grain from its neighbour thus permitting thorough wetting of each grain. This proves to be advantageous by chemically activating each grain to thorough hydration before reaching its final resting place. Further, individual grains penetrate finer cracks more readily than flocs.

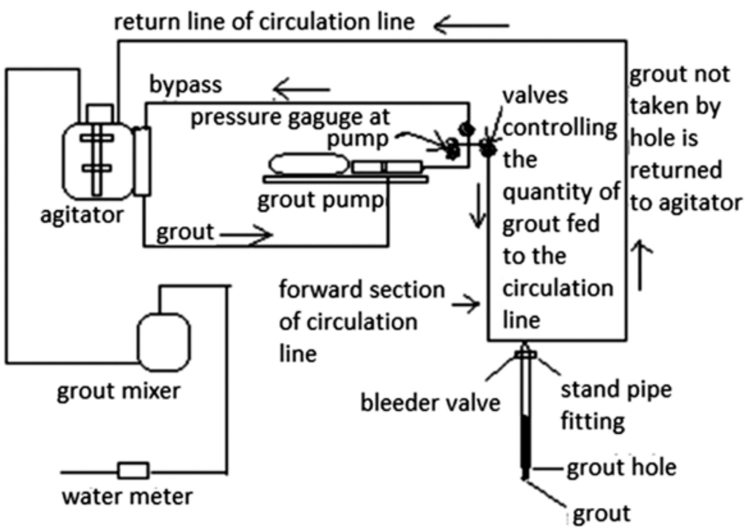


Figure 102: Grouting Equipment

Mixers (**Figure 103**) are usually of two types – paddle mixer and colloidal mixer. Paddle mixers are generally cylindrical in shape with the axis either horizontal or vertical and equipped with a system of power driven paddles for mixing by agitation. Vertical barrel type mixers have proved satisfactory when small mixers are required for use in confined or limited working spaces. This type of mixer consists of a vertical barrel having a shaft with blades for mixing, driven by a motor mounted on top of the mixer above the barrel.

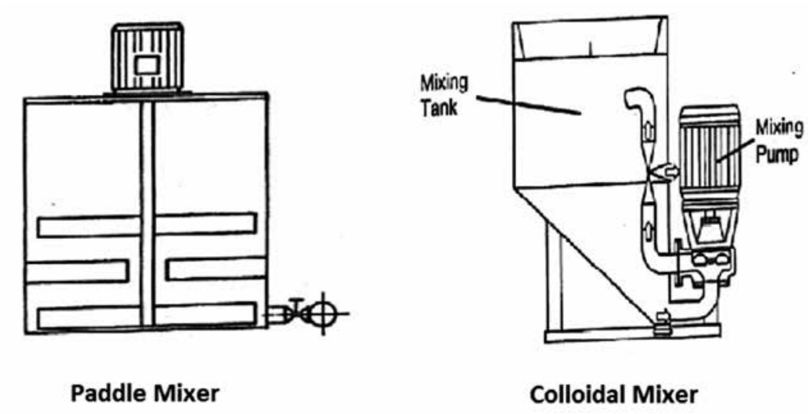


Figure 103: Grout Mixer

Centrifugal pump mixers, also called colloidal mixers, are also available, which consist of a mixing tank and a high speed mixing or recirculating pump (centrifugal type). The pump circulates water from the bottom to the top of the tank while the other mix components are added and pre-wetted. The cement particles are then individually mixed by the high shearing action of the pump, thereby preventing coagulations or lumps and ensuring homogeneity of the grout.

The mixer, whether paddle or colloidal, is usually a batch mixer, which means that a full mixing cycle has to be completed before the mix can be used. Therefore, a separate storage device is essential for continuous grouting operation. The storage device is equipped with an agitator to keep the grout moving continuously before it is pumped into the hole.

ii) **Grout Pump**

The pump should be of positive displacement type and capable of injecting the grout in a continuous operation and not by way of pulses. The grout pump shall be fitted with a pressure gauge to enable pressure of injection to be controlled. It shall also have a relief arrangement for bypass of the grout in case pressure builds up. It should be designed to minimize clogging of valves and ports and allow a flexible rate of injection.

Use of hand pumps for grouting is not recommended. Compressed air operated equipment for injection should not be used as it is likely that there will be some air entrapped in grout.

iii) **Grout Screen**

The grouting equipment should contain a screen having a suitable mesh size. Prior to introduction into the grout pump, the grout should be passed through such screen. This screen should be easily accessible for inspection and cleaning.

In case the mixer and pump are combined in one unit, the dry material should be screened before mixing.

iv) **Grout Manifold and Grouting System Arrangement**

A grout manifold or header is a 'T' arrangement of pipe and various fittings such as couplings, nipples, unions, tees, valves and a pressure gauge, all attached to the collar of the grout hole.

The functions of the manifold are:

a) Permit regulation of the flow of grout into the hole or duct.

b) Maintain the desired allowable grout pressure.

c) Allow any excess grout to be drained from the system or returned to the agitator tank for recirculation.

d) Close off the hole when washing the supply lines.

Manifold designs vary and depend on the type of grouting system.

Grouting system arrangement may be either of the following two types:

a) **Single Line System** – It consists of one grout supply line from the pump to the grouting manifold at the hole. The pressure gauge should be constantly monitored so that the pressure on the grout is regulated as long as grouting is in progress. Any desired increase or decrease in the grouting pressure is obtained by changing the speed of the grout pump. When the grout in the supply line becomes sluggish, the grout hole valve should be closed and the blow-off valve opened so that the supply line can be flushed or washed. The grout hole valve should also be checked to ensure against a false refusal. Joints in hoses and pipes should be tight.

b) **Circulation System** – It requires two separate pipe lines, one to act as a supply line from the grout pump to the grout hole and the other to act as a return line from the grout hole to the agitator/ pump. By opening the supply and grout hole valves, grout is forced into the hole as required. Pressure is maintained by adjusting either the supply valve or the return valve, or both, so that complete control of pressure is maintained at the hole. There should be a pressure gauge at the delivery end of the pump. No grout is wasted when washing out the grout lines and close control of the grouting operation is maintained. When direct electric or diesel drive pumps are employed, use of a return line is necessary.

v) **Water Pump**

Before commencement of grouting, a stand-by direct feed high pressure water pump should be available at site for an emergency. For example, in case of any problem in grouting the ducts (in case of post-tensioned tendons of prestressed concrete members of bridges), such pump shall immediately be connected to the duct and all grout flushed by use of high pressure water flushing. It is, therefore, necessary to have adequate storage of clean potable water for operation of the water pump for such emergencies.

6.8 Shotcreting Equipment

6.8.1 Shotcrete is mortar or concrete conveyed through a hose and pneumatically projected at high velocity on to a surface. The force of the jet impinging on the surface compacts the material. Generally a relatively dry mixture is used, and so the material is capable of supporting itself without sagging or sloughing, even for vertical and overhead applications.

Shotcrete may be of two types:

i) **Dry Mix Shotcrete (or Gunite)** – Pneumatically conveyed shotcrete in which most of the mixing water is added at the nozzle.

ii) **Wet Mix Shotcrete** – Shotcrete wherein all ingredients, including mixing water, are mixed in the equipment before introduction into the delivery hose. It may be pneumatically conveyed or moved by displacement.

In general, dry mix shotcrete shall be used. The gunite shall comprise 100 parts by weight of cement, 300 parts by weight of quartz sand, 35-50 parts by weight of water and 2 parts by weight approved quick setting compound.

6.8.2 Equipment (**Figure 104**) for dry mix shotcrete includes:

i) Batching and Mixing Equipment

ii) Delivery or Guniting Equipment

iii) Air Compressor

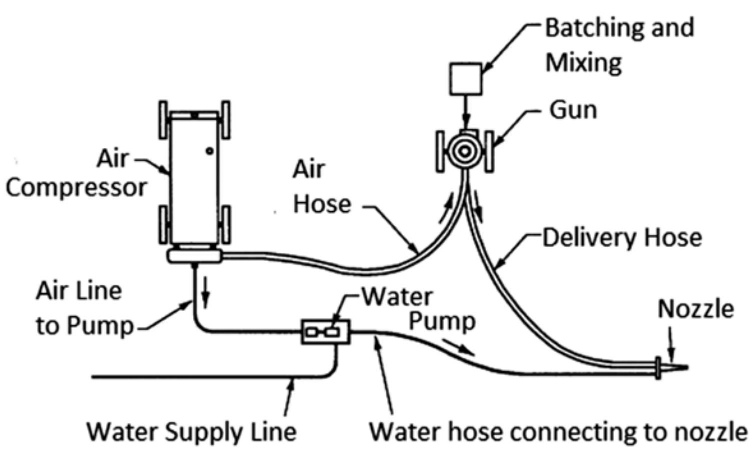


Figure 104: Shotcreting Equipment

6.8.3 Batching and Mixing Equipment – Batching by mass is to be preferred and is strongly recommended. Sand may be batched by volume if periodic checks are made to ensure that the masses are maintained within the required tolerance.

The moisture content of the sand shall be such that the sand-cement mixture will flow at a uniform rate, without slugs, through the delivery hose. The optimum moisture content will depend upon the delivery equipment being used, but it is generally within the range of 3-6%. The sand shall be moistened or dried as required to bring the moisture content to a satisfactory level. Fluctuations in moisture content shall be avoided or appropriately managed.

The mixing equipment shall be capable of thoroughly mixing the sand and cement in sufficient quantity to maintain continuity of placing. The mixing time shall be not less than one minute in a drum-type mixer; where other mixers are proposed, satisfactory evidence shall be presented that they are capable of thorough mixing. The mixer shall be self-cleaning, capable of discharging all mixed material without any carryover from one batch to the next. It shall be inspected and thoroughly cleaned at least once a day (and more often if necessary) to prevent accumulation of batched material.

6.8.4 Guniting Equipment – The delivery or guniting equipment consists of the following:

i) Cement gun
ii) Water tank
iii) Hose pipes (Material hose, Air hose, Water hose)
iv) Nozzle

Cement Gun (Figure 105) – A double chamber cement gun is usually used. It consists of two interconnecting circular vessels fixed one above the other and having airlock valves operated by hand. The whole equipment when assembled shall be airtight and is mounted on wheels to make it mobile. The top vessel is suitable for feeding of sand-cement mix (via a hopper and lever operated valve) and works as tank storage. The bottom vessel has a lever operated valve at the top and feeder at the bottom rotated by means of a worm and worm wheel drive attached to the lower part of the bottom vessel. The bottom vessel is fitted with a material (or delivery) hose of sand blasting quality conforming to IS:5894 for carrying the mix material in suspension by compressed air. At the discharge end of the delivery hose, a nozzle made of gunmetal is provided. The nozzle is filled inside with a perforated manifold through which water is introduced under pressure via a manually operated injection system and intimately mixed with the cement-sand mix. The nozzle shall be capable of delivering a conical discharge stream of uniform appearance throughout.

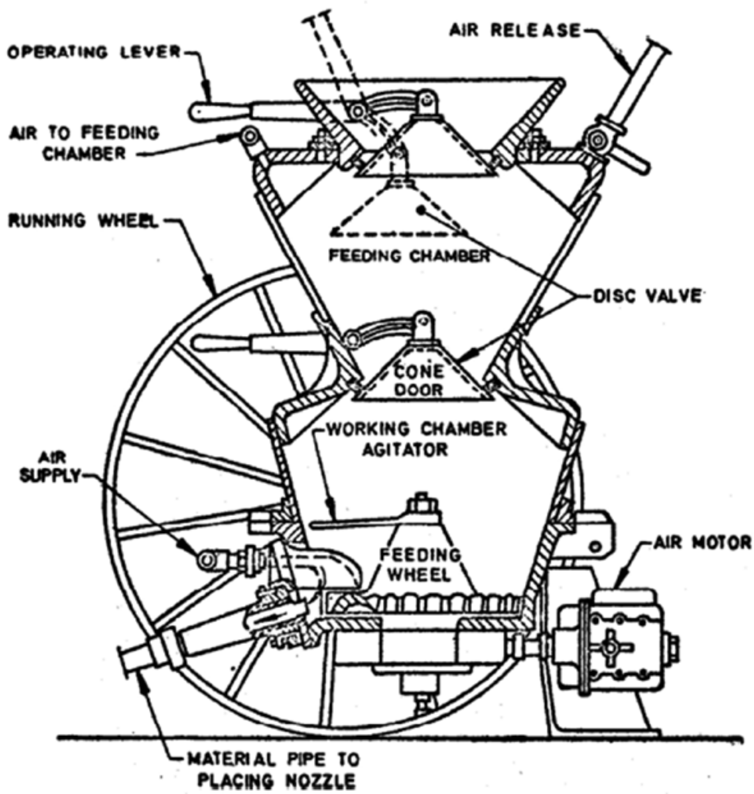


Figure 105: Cement Gun for Guniting

The top vessel shall be provided with the following:

i) Pressure gauge to indicate the pressure of the air in the vessel

ii) Safety valve

iii) Blow off valve

iv) Cleaning valve

v) Air inlet valve

vi) Air connection to the air motor

vii) Moisture and oil separator

The bottom vessel shall be provided with the following:

i) An inlet valve for the air.

ii) An outlet valve for the delivery hose which should have an airtight coupling on it.

iii) A fan mounted at the bottom of the inside of the vessel which shall be operated through a reduction gear. The fitting between the reduction gear and the fan shall also be made tight against leakage of air and sand. The fan and the reduction gear shall be operated by means of an air motor so that the speed of the fan is about 10-15 rev/mm.

iv) Hand hole for cleaning of the inside of the gun.

v) Air inlet point or the outlet point to put the material into the delivery hose.

Water Tank – Twin cylindrical water tanks connected in parallel with arrangement for feeding water to the material hose pipe of one tank at a time shall be provided. Each water tank shall have an inlet water pipe at the top and a cleaning mouth at the bottom both made water tight by stoppers.

Hose Pipe – Three separate hose pipes shall be provided – one for material delivery from cement gun to nozzle, another for supply of air from air compressor to the cement gun, and a third hose for supply of water to the nozzle.

6.8.5 Air Compressor – Properly operating air compressor of ample capacity is essential for a satisfactory shotcreting operation. The compressor shall be fitted with a moisture extractor to keep up supply of clean, dry air adequate for maintaining sufficient nozzle velocity for all parts of the work while simultaneously operating a blow pipe for clearing away rebound.

6.8.6 For more information on shotcreting equipment, refer to IS:6433 and IS:9012.

6.9 Drill

6.9.1 Drilling may be performed to explore the types of materials to be encountered in a project (exploratory drilling), or it may involve production work such as drilling holes for pile boring, blasting, grouting or rock bolt stabilisation work.

Selection of equipment depends upon the following factors:

i) Purpose of the hole
ii) Nature of terrain
iii) Required depth of hole
iv) Rock Properties – hardness, texture, tenacity, formation
v) Project Size (i.e. Total linear amount of drilling)
vi) Availability of water (dry or wet drilling)
vii) Core Size, in case of exploration (diamond drill for small core and shot drill for large core)

6.9.2 Drills use three methods to cause fragmentation of rocks:

i) Percussion
ii) Rotary Grinding
iii) Abrasion

Percussion and rotary drills are the primary production tools of construction work. Abrasion is used for special drilling applications.

6.9.3 Percussion Drill – Here rock disintegration is facilitated by hammer impacts to the drill bit as well as simultaneous rotary motion applied to the bit. This type of drill may vary in size from handheld units (e.g. jackhammer) to drifters and crawler-mounted rigs.

Jackhammers (**Figure 106**) are hand-held, air-operated percussion drills used primarily for drilling in a downward direction. It consists of a hammer, drill steel and bit. As the compressed air flows through a hammer, it causes a piston to reciprocate and produce the hammer effect. The energy of this piston is transmitted to the bit through the drill steel. Air flows through a hole in the drill steel and the bit to remove the cuttings from the hole and to cool the bit. The drill steel is rotated slightly following each blow so that the cutting edges of the bit will not strike at the same place each time.

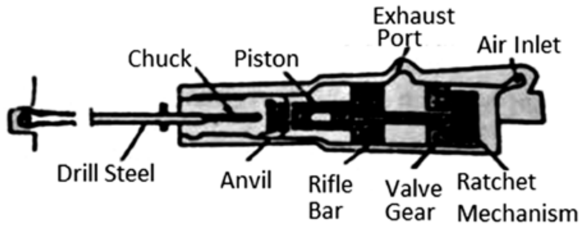


Figure 106: Jackhammer

A Drifter Drill is similar to jackhammer in operation but it is larger and heavier and mounted on a travelling carriage (tractor) or a frame. A drifter can drill in downward, horizontal or upward direction and is used extensively in rock excavation and tunnelling. Either air or water can be used to remove the cuttings. The drifter's weight is usually sufficient to supply the necessary feed pressure for downward drilling. But when used for horizontal or upward drilling, a hand-operated screw or a pneumatic or hydraulic piston supplies the feed pressure.

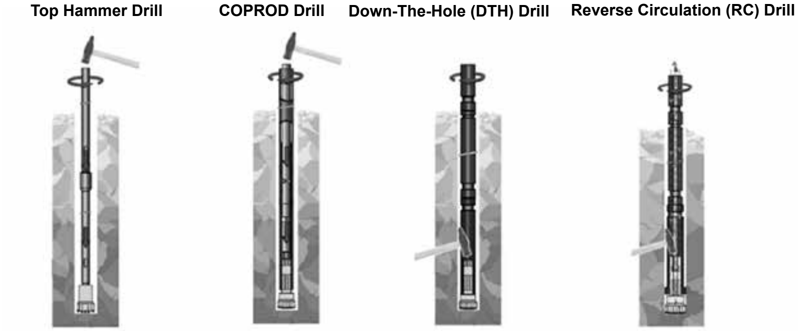
Percussion drills may also be mounted on track carriages to provide mobility. These are usually hydraulically powered. Hydraulic motors tram the machine and power the hammer, the rotation, and the feed of the drill. There is also a hydraulic motor driven air compressor onboard for blowing the hole. Hydraulic drill can normally achieve better penetration rate than an air-driven drill.

6.9.4 Rotary Drill (Figure 107) – In this type of drilling (pressure drilling), the rock is disintegrated by applying a down pressure on the drill steel and bit and at the same time continuously rotating the bit in the hole. The pull down pressure and drill rotation is facilitated by a hydraulic or electric variable speed motor. To remove the rock cuttings and cool the bit, compressed air is constantly forced down the drill steel and through the bit during this process. The bit pressure and quantity of air are controlled as per requirement.

Continuous Mud Circulation (CMC) method (**Section 6.5.2**) may also be used to remove drill cuttings.

Figure 107: Rotary Drilling Mechanism

6.9.5 Rotary-Percussion Drill (Figure 108) – It combines the hard-hitting reciprocal action of the percussion drill with the turning-under-pressure action of the rotary drill. While the percussion drill only has a rotary action to reposition the bit's cutting edges, the rotation of this combination drill, with the bit under constant pressure, can result in faster drilling than the regular percussion drill.



Top Hammer Drill	COPROD Drill	Down-The-Hole (DTH) Drill	Reverse Circulation (RC) Drill
It involves manually hitting the end of the drill rod with the hammer. As recoil makes the rod jump back, it is rotated to ensure that the hole is round. The impact energy of the drill piston is transmitted to the drill bit in the form of shock waves. Drill cuttings are removed from the hole bottom by air or water flushing.	it consists of a threadless drill rod stacked inside a threaded drill tube. The rod transmits impact energy and feed force to the drill bit while the tube transmits rotation. COPROD Drill combines the high speed and penetration rate of top Hammer Drill with the large hole dimensions and hole straightness of DTH Hammer Drill	The hammer is situated down the hole in direct contact with the drill bit. The drill piston strikes the drill bit resulting in efficient transmission of impact energy and insignificant power losses with the hole depth. This drill is suitable for drilling long holes.	The hammer is situated down the hole in direct contact with the drill bit just like DTH Hammer Drill. The difference compared to DTH drilling is that drill cuttings are removed from the hole bottom through an inner centre tube of the hammer by flushing with air, water or drilling fluid. The drilling fluid is continuously circulated out of the drilled hole, where the drill cuttings are removed or disposed, and then recirculated back into the drilled hole to repeat the process.

Figure 108: Rotary-Percussion Drill

Rotary-percussion drill can be of four types:

i) Top Hammer Method

ii) Down-The-Hole (DTH) Method

iii) COPROD Method

iv) Reverse Circulation Method

Rotary-percussion drill by any of the above methods is based upon combination of the following four actions:

i) **Percussion** – The piston inside the drill strikes the tail end of the rod or bit itself and generates shock waves that are transmitted to the bit through the rod (in top hammer) or directly upon it (in DTH hammer).

ii) **Rotation** – The rotary mechanism rotates the rod (in top hammer) or tube (in COPROD) or DTH hammer. With this movement, the bit is turned so that the impacts are produced on the rock at different positions.

iii) **Feed/Thrust Load** – Feed force is required to keep the shank in contact with the drill and the drill bit in contact with the rock. This ensures maximum impact energy is transferred from the piston to the rock.

iv) **Flushing** – It is required to remove rock cuttings from the drill hole and to cool the bit. Flushing medium (air, water, mist, foam or drilling fluid) is forced to the bottom of the drill hole through the rod's flushing hole and the hole in the drill bit.

6.9.6 Abrasion Drill – Rock can be drilled by the mechanical wearing away of its surface by way of frictional contact with a harder material. Shot Drill and Diamond Drill are two common types of abrasion drills and used primarily for exploration drilling (core drilling).

6.9.6.1 In a diamond drill (**Figure 109**), the drilling equipment consists of a diamond bit, a core barrel (single tube type or double tube type) (**Figure 1110**), a jointed driving tube and a rotary head to supply the driving torque. Water or mud is pumped through the driving tube to remove the cuttings. The pressure on the bit is regulated through a screw or hydraulic feed swivel head (or drilling head). When the bit advances to a depth equal to the length of the core barrel, the core is broken off and the drill is removed from the hole.

Two types of diamond core drilling machines are available – conventional (with wire line winch) and hydrostatic.

Diamond drills can drill in any direction from vertically downward to upward.

For more information on diamond drill, refer to IS:11710 (Part 1), IS:11710 (Part 2), IS:10208, IS:15481 (Part 1) and IS:6926.

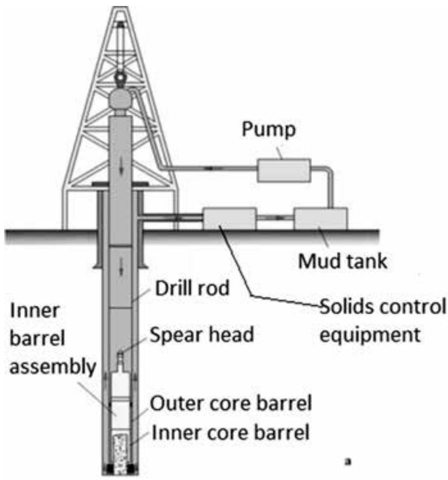


Figure 109: Diamond Drill

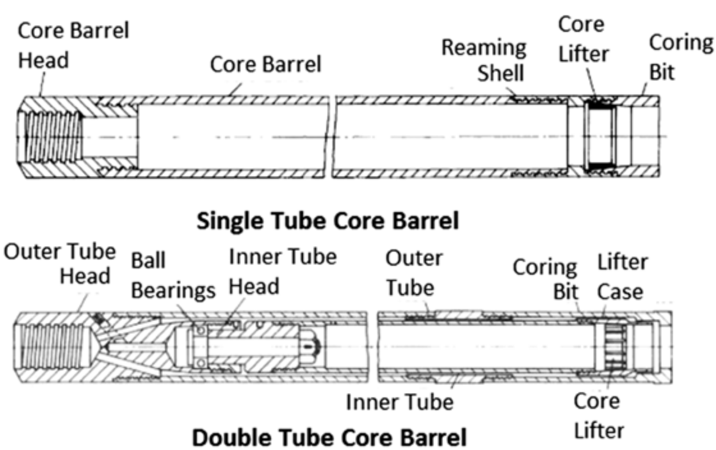


Figure 110: Core Barrel for Diamond Drill

6.9.6.2 Shot (or Calyx Core) Drill (**Figure 111**) depends on the abrasive effect of chilled steel shot to penetrate the rock. It consists of a shot bit, core barrel, sludge barrel, drill rod, water pump and power-driven rotation unit. The cutting action is provided by a slotted bit of mild steel and by very hard steel shot which is fed into the drill hole with the wash water and reaches the bit via the annular space between the core and wall of the barrel. To be effective, the shot must be crushed during the coring. Pre-crushed shot (under the trade name Calyxite) is often used in coring relatively soft rock. Water that is supplied through the drill rod forces the rock cuttings up around the outside of the drill, where they settle in a sludge barrel, to be removed when the entire unit is pulled from the hole. The flow of water must be carefully regulated so that it removes the cuttings but not the chilled shot. Periodically, it is necessary to break the core off and remove it from the hole so that drilling may proceed.

Shot Drill can only be used for downward boring and is a slow process. It is suited for large diameter drilling.

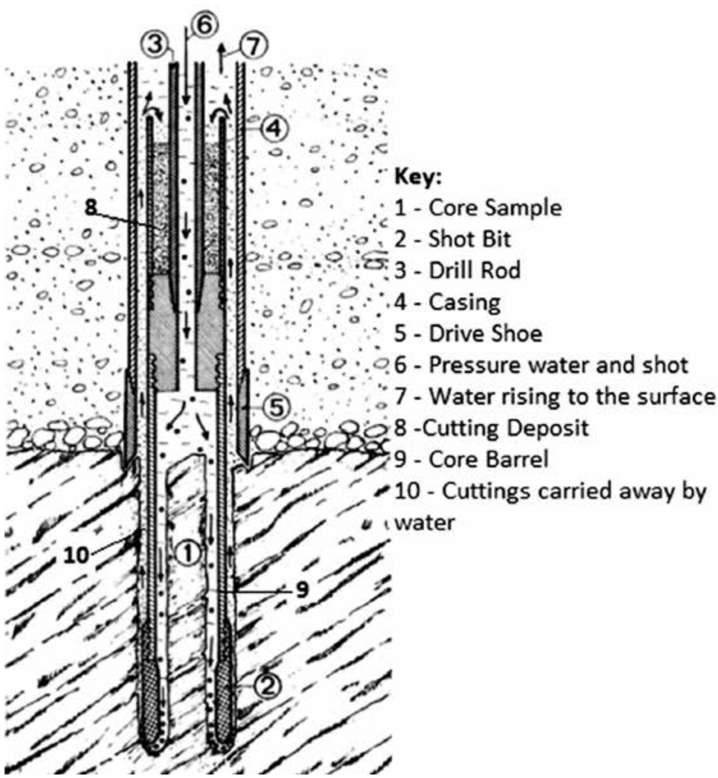


Figure 111: Shot Drill

7. MOBILE ELEVATING WORK PLATFORM (MEWP)

It is mobile equipment that facilitates "hands-on" inspection of bridge members as well as light maintenance works. It is also known as Aerial Platform.

Common types of MEWPs are indicated below:

i) **Manlift (Figure 112)** – It consists of a platform or bucket, capable of holding one or more persons, which is attached to a telescopic boom mounted on the carriage of the vehicle. The boom can be raised, lowered and slewed relative to the vertical axis. Manlifts are limited to use on fairly level terrain.

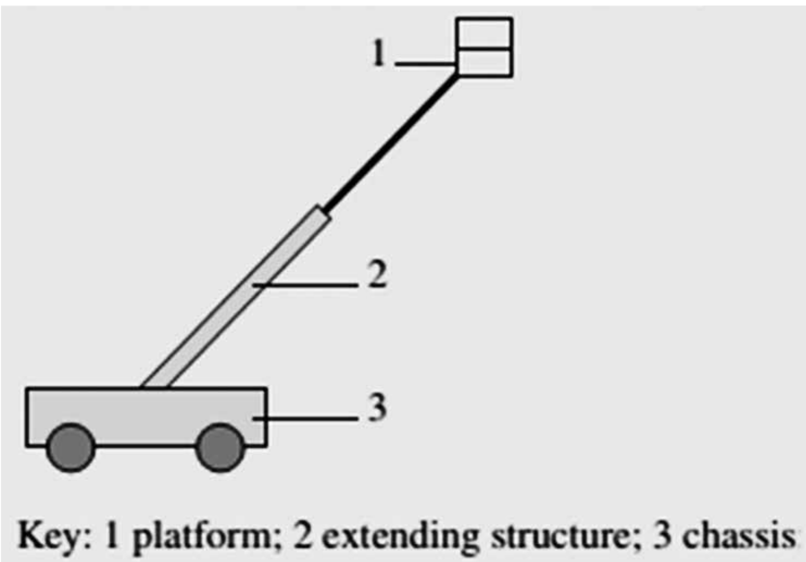


Figure 112:Manlift

ii) **Scissors Lift (Figure 113)** – It is equipped with a scissors extending structure to lift or lower the platform. It is designed for use on relatively level ground. Since its maximum vertical reach is relatively low, it is suitable for bridge inspections with low clearance between the bridge and underpassing roadway.

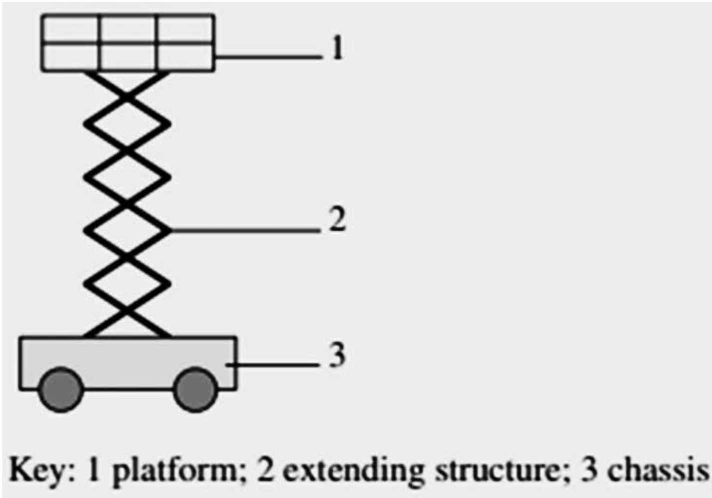


Figure 113: Scissors Lift

iii) **Truck-Mounted MEWP (Figure 114)** – It consists of the following:

a) A Supporting Frame, to which protractible struts (outriggers), a hydraulic feeder and a slewing gear are fixed. The supporting frame is secured to a truck chassis. Struts help in maintaining stability of the vehicle.

b) A Slewing Column attached to the supporting frame through a crown bearing. The column is a slewing welded-construction frame with a transmission gear and brake mounted on it. The lower boom stage and the cylinder are attached to the column by articulated joints.

c) A Two-Stage Boom with the two stages connected by an articulated joint and responsible for raising and lowering of the work platform.

d) A Work Platform or Bucket for accommodating one or more persons.

e) A Straight Line System for keeping the work platform in a horizontal position regardless of the angles at which the boom's stages are positioned.

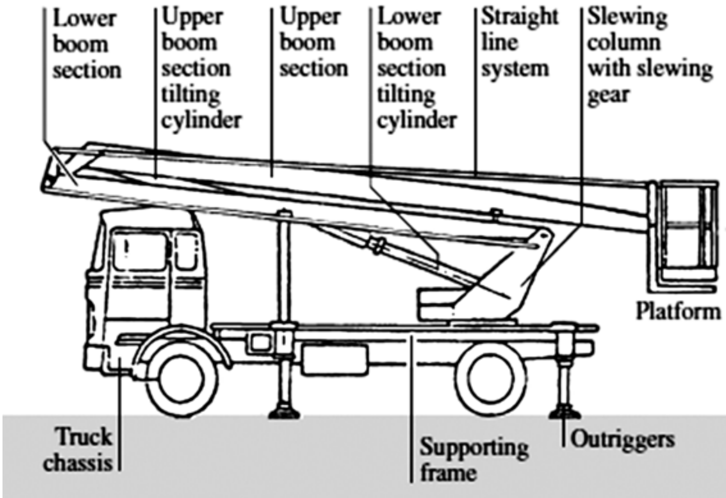


Figure 114:Truck-Mounted MEWP

The work platform positioning system consists of a pump, filters, distributors, valves, steel pipes, hoses and hydraulic cylinders. The hydraulic pump is powered from the truck's gearbox via a lay shaft. Oil is supplied to the working cylinders through a rotary joint. The struts are controlled through distributors mounted on the supporting frame. The boom cylinders and slewing can be controlled through a distributor mounted near the slewing column or on the work platform. The system is protected against the eventuality of simultaneous steering of the struts and the boom's cylinders. The boom's cylinders and those of the struts are equipped with valves to prevent a pressure failure and the resulting uncontrolled shift of the piston rod.

Truck-mounted MEWPs have the following safety measures:

a) Limit switches for preventing the boom's upper section from being excessively raised and the boom's lower stage from being lowered while the boom's upper stage is maximally raised.

b) A hydraulic system lock for preventing the working circuit and the struts from being simultaneously fed.

c) Overload protection in the form of overflow valves, which protect the hydraulic circuits against excessive pressure rise.

d) Emergency lowering of the cradle while the pump drive is switched off.

Basic operating parameters indicating the performance of a truck-mounted MEWP are:

a) Lifting Capacity

b) Maximum Elevation

c) Maximum Radius

d) Work Area (specifying the allowable position of the MEWP in the vertical plane) (**Figure 115**)

e) Angle of rotation of the body

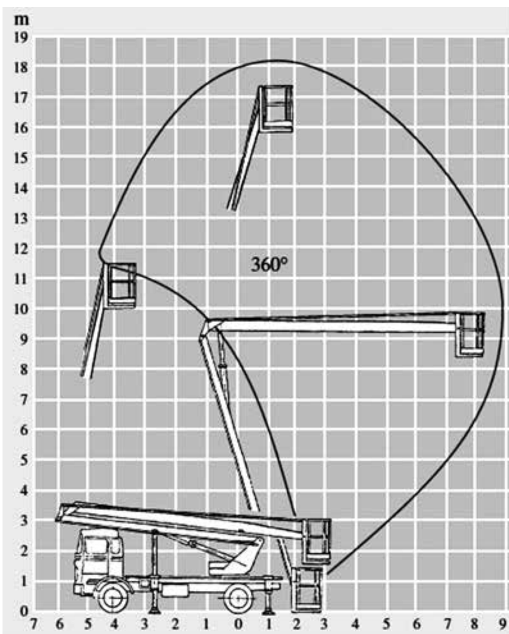


Figure 115: Typical Work Area of Truck-Mounted MEWP with Elevation of 18 m and Radius of 8.7 m

8. MOBILE BRIDGE INSPECTION UNIT (MBIU)

8.1 The Mobile Bridge Inspection Unit (MBIU) is an under bridge inspection vehicle with a cage or platform designed to reach under the superstructure with the vehicle parked on the bridge deck. It can be used for bridge inspection as well as light maintenance works (like cleaning, painting etc.) on bridges.

8.2 Mobile Bridge Inspection Unit is broadly classified into two categories:

i) Cage or Basket Type

ii) Platform Type

8.3 Cage Type Mobile Bridge Inspection Unit (MBIU)

8.3.1 Cage Type Mobile Bridge Inspection Unit (MBIU) (**Figure 116**) consists of the following:

i) A supporting frame, to which a rotating turn table and outriggers are fixed. The supporting frame is secured to a truck chassis. Outriggers help in maintaining stability of the vehicle.

ii) A three-stage or four-stage articulated telescopic boom mounted on the turn table by means of hydraulic system and responsible for raising, lowering and positioning (rotation in a horizontal plane) of the cage under the bridge structure.

iii) A Cage attached to one end of the articulated telescopic boom and capable of accommodating one or more persons.

Figure 116: Cage Type MBIU

8.3.2 Salient Features of Cage Type MBIU:

i) All movements are operated hydraulically and controlled through the control panel provided in the cage and on ground (i.e. bridge deck).

ii) Inter communication system is provided between cage, ground control panel and cabin.

iii) Automatic safety devices are incorporated in the machine to ensure safe operation.

8.4 Platform Type Mobile Bridge Inspection Unit (MBIU)

8.4.1 Platform Type Mobile Bridge Inspection Unit (MBIU) (**Figures 117** and **118**) consists of a lattice frame mounted over the truck. It is provided with a working platform, heavier in weight than cage, and therefore the truck chassis and stabilisation system should be selected carefully to keep ground pressure exerted by the tyres/ stabilisers within permissible limit during translating and stabilisation operation of the machine.

Figure 117: Platform Type MBIU

KEY:
1 - Chassis
2 - Basic Frame
3 - Stabilizer Axle
4 - Hydraulic Drive
5 - Control console chassis
6 - Rotation track connection chassis - rotation frame
7 - Rotation frame
8 - Counter weight
9 - Vertical frame cylinder
10 - Vertical frame
11 - Parallelogram cylinder
12 - Parallelogram
13 - Lifting cylinder
14 - Guide block
15 - Lifting tower upper part
16 - Rotation track connection
17 - Lifting tower lower part
18 - Lifting cylinder basic platform
19 - Overload device
20 - Basic platform
21 - Guide rollers top
22 - Guide rollers bottom
23 - Hydraulic drive for telescopic platform
24 - Telescopic platform
25 - Scaffold

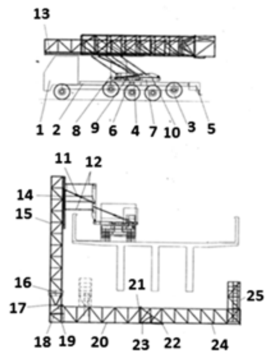


Figure 118: Components of Platform Type MBIU

8.4.2 Salient Features of Platform Type MBIU:

i) The mounted support at the truck consists of a lowering/ lifting mechanism for the lattice frame to put in position around the bridge deck.

ii) Unfolding and folding of the unit is automatic with proper controls.

iii) The following mechanisms facilitate the movement of the working platform in a particular direction or plane:

   a) The launching mechanism along with the support system which is fixed on the truck,

   b) Vertical and translatory motion of the vertical frame (or tower),

   c) A mechanism facilitating the lower arm (working platform) to rotate in a horizontal plane for wider coverage of inspection area underneath the bridge,

   d) The variable length of the working platform by means of extension or retraction.

iv) The working platform is the horizontal platform on which the inspection team stands to carry out the inspection. Payload comprising weight of the persons inspecting the bridge and equipment weight has to be taken into account for designing the unit.

v) The working platform has suitable arrangement for provision of water, compressed air, electricity connections from external source to facilitate use of repair tools and equipment for minor repair of bridge.

vi) The following types of stabilisers are used:

a) Pneumatic tyre stabilisers

b) Rubber bonded solid steel wheel stabilisers

c) Stabilisers fitted with track chain

vii) Various safety devices are incorporated in the machine to ensure safe operation:

a) Overload Device – It is provided on the working platform. In case of overloading on the working platform, horn will give alarm sound and the machine will switch over to emergency cut off position.

b) Emergency Push Button – These are provided in operator's cabin, main control panel, platform control panel and launching panel. In case of emergency, it cuts off electrical circuit instantaneously and stops further operation of unit.

c) Emergency Pump – It is used for retrieval of the unit in case of emergency due to engine failure, power take off or interruption in control system/ hydraulic pump.

d) Emergency Cut Off System – These are fitted at working platform, lifting tower and main control panel and are used to maintain appropriate load in the structure.

e) Limit Switches – These are provided on the working platform to extend or retract its working length.

f) PLC (Programmable Logic Controller) controlled electric drives

g) Special electrical geared drive to manoeuvre the vehicle forward/backward for continuous inspection between pillars without unfolding the unit.

h) Dedicated power supply system to power MBIU for remote area inspection.

i) Online chassis load sensors for sensing structural load distribution during structure folding/unfolding and inspection.

j) Online wind speed monitor.

k) Twin control units for MBIU structure folding/ unfolding.

l) Integrated parking assistant system for parking along the bridge railing.

8.5 Basic operating parameters affecting the performance of an MBIU are:

i) Maximum Load on cage/ platform (including equipment)

ii) Maximum Lowering Depth

iii) Maximum Horizontal Outreach (below construction)

iv) Angle of rotation of the cage/platform

v) Size (Dimensions) of the cage/platform

PART C : EQUIPMENT FOR TUNNEL WORKS

9. ESSENTIAL EQUIPMENT FOR TUNNELLING WORKS

Table 32 lists out the essential equipment required for various tunnelling activities.

Table 32: Activity Wise Equipment for Tunnelling Works

Sl. No.	Activity/Operation	Equipment	Remarks
1.	Excavation (including scaling)	i) Tunnel Boring Machine or Drill Jumbo + Pneumatic/ Hydraulic Drill or Tunnel Shield or Roadheader or Hydraulic Excavator/ Backhoe Loader + Hydraulic Breaker/ Ripper or Hand Excavation Tools or Rock Splitter	
		ii) Light Source	
		iii) Air Compressor	
		iv) Dewatering Pump	Refer Sl. No. 3 of this Table.
2.	Muck Disposal	i) Muck Haulage Equipment on Rail (Locomotive pulled Wagons or Haulage Winches) or	Limited flexibility in movement due to fixed rail system; haulage winch for steep grade and locomotives for fairly level grade.
		Muck Haulage Equipment on Pneumatic Tyres (Dumper or Tipper Truck) or Belt Conveyor	Dumpers suited for large diameter tunnels.

Sl. No.	Activity/Operation	Equipment	Remarks
		ii) Front End Loader or Backhoe Loader or Overhead Rocker Shovel or Short Boom Shovel	Loading Equipment
		iii) Light Source	
		iv) Air Compressor	
		v) Dewatering Pump	Refer Sl. No. 3 of this Table.
3.	Dewatering	i) Centrifugal Pump with Open Impeller (Suction type or Submersible type) or Pneumatic Sludge Pump	Non-clogging type pump to be used as the water pumped is heavily charged with dust particles.
4.	Defuming/ Ventilation (for work personnel)	i) Ventilation Fan + Dust Scrubber (Wet or Dry) + Ventilation Duct + Ventilation Shaft	
5.	Steel Lining	i) Welding Equipment	
		ii) Rail Track + Winch	For erection of steel liner.
6.	Concrete Lining	i) Concrete Batching and Mixing Plant or Concrete Mixer	
		ii) Electric Genset	
		iii) Transit Mixer/ Agitator Truck	For transportation to site.
		iv) Concrete Pump or Pneumatic Placer	For concrete placement.
7.	Shotcreting/ Guniting	i) Air Compressor + Shotcreting Equipment	

Sl. No.	Activity/Operation	Equipment	Remarks
8.	Grouting	i) Drilling Equipment (Percussion Drilling or Rotary Drilling)	Percussion drilling for pack grouting and consolidation grouting; rotary drill for consolidation grouting.
		ii) Grouting Equipment	
9.	Lifting Application	i) Crane or Fork Lift or Hoist Machinery or Winch or Lifting Jack or Grapple or Gin Pole Derrick	

10. TUNNELLING METHODS

Common tunnelling methods are listed below:

i) Cut and Cover Method
ii) Shield Tunnelling Method
iii) Bored Tunnelling Method
iv) Tunnel Jacking Method
v) Immersed Tube Method
vi) Drill and Blast Method
vii) Conventional Excavation by Road Header or Hand Tools
viii) Rock Splitting Techniques
ix) Sequential Excavation Method (SEM)

10.1 Cut and Cover Method

Cut-and-cover tunnel construction typically involves digging a trench, constructing the tunnel structure within the trench, and covering it up with an engineered backfill material. Since these tunnels are dug from the ground surface, they are more economical when located at shallow depths. This method is usually not feasible for crossing streams, mountains, or major transportation corridors. Digging from the surface also presents challenges when buried utilities are present.

Two basic forms of cut-and-cover tunnelling are available:

i) **Bottom-up Method** – A trench is excavated with the help of ground support in the form of diaphragm walls, sheet piles or intersecting piles etc. and the tunnel is constructed within. Once the tunnel is complete, the trench is then backfilled with compacted fill material and the surface is reinstated.

   The tunnel may be of in situ concrete, precast concrete, precast arches, corrugated steel arches etc.

ii) **Top-down Method** – A trench is excavated with the help of ground support in the form of diaphragm walls, sheet piles or intersecting piles etc. A shallow excavation is made to enable the tunnel roof to be constructed using precast beams or in situ concrete. The surface is then reinstated except for access openings. This allows early reinstatement of roadways, services and other service features. Excavation machinery is then lowered into the access openings, and the main excavation is carried out under the permanent tunnel roof, followed by construction of the base slab.

10.2 Shield Tunnelling Method

The Shield Tunnelling method is used in case of excavation through ground that is soft, marshy, or otherwise unstable, and therefore needs to be controlled or otherwise supported during the excavation process. A tunnelling shield acts as a temporary support structure and is in place for the usually short time from when the tunnel section is excavated until it can be lined with a permanent support structure.

The front end of the shield is in the form of a cutting edge and fitted with excavation facilities and the rear end has facilities for removal of excavation spoils and for installation of supports inside the tail of the shield. With this method, a shield is advanced one cycle at a time typically while removing the muck and placing the ground support concurrent to the face. This process is then repeated as often as necessary to complete the tunnel. As the excavation at the face progresses, the shield is pushed forward with the help of hydraulic jacks which takes thrust from the supports at the rear end of the shield. During forward movement of the shield, the tail end slides past the supports already erected inside the tail transferring the load of the excavated periphery from the shield to the supports. Closed shields are used when groundwater control is necessary.

Specialised applications of the shield driven tunnel include use of tunnel boring machines and jacked tunnels.

10.3 Bored Tunnelling Method

A Tunnel Boring Machine (TBM) is a shield with bits mounted on a rotating cutter head that excavates a circular opening. Selection of tools and configuration of the machine depends mainly on the geotechnical characteristics of the ground, level of water table, rock abrasivity and maximum settlement allowed at the surface. Since ground conditions vary (sometimes dramatically) along the tunnel alignment, the final selection of the machine should be an optimal choice taking into consideration key performance parameters, particularly the speed of excavation.

Some TBMs allow for limited interventions at the cutting face to replace the cutting tools. These interventions may involve compressed air, termed hyperbaric interventions, to stabilise the ground at the excavated face. In general, most interventions are planned to take place at geologically favourable locations along the alignment to minimize the risks to work personnel and to manage production costs. Some of the modern TBMs allow the cutting tools to be replaced from within the safety of the machine; however, this has trade-offs because the cutting tools are very difficult to handle within these tight spaces. TBMs are considered to be more cost effective on longer tunnels where economics of scale allows the cost of the machine to be recovered.

TBM can be steered in vertical and horizontal direction along smooth curves. TBM has advantage of not disturbing the surrounding strata which makes it suitable for use in built up area.

Tunnel Boring Machines are covered in **Section 11**.

10.4 Tunnel Jacking Method

Tunnel Jacking or Jacked Box Tunnelling is considered to be a relatively non-intrusive method of constructing shallow tunnels, large oversized culverts or under-bridges. It involves pushing large concrete box sections through the soil typically crossing under existing structures, infrastructure or transportation routes where settlement is of primary concern using specialised jacking equipment and hydraulic jacks.

Soil around the tunnel opening is stabilised using suitable technique (e.g. grouting). Large hydraulic jacks push the precast tunnel sections into place from a launching pit while the ground at the face is simultaneously excavated. At the end of the cycle, the jacks are retracted; a new segment is added at the launching pit; and the string of segments is gradually pushed into place to advance another cycle. This process is repeated as often as necessary to complete the tunnel from the launching pit to the receiving pit.

The main benefit of Tunnel Jacking is that it allows the infrastructure above the proposed tunnel structure to remain live and active during the construction work.

10.5 Immersed Tube Method

An immersed/ sunken tube tunnel is a tunnel constructed directly under a waterway. Immersed tube tunnels are often used in conjunction with other forms of tunnels at their end, such as a cut and cover or bored tunnel, which is usually necessary to continue the tunnel from near the water’s edge to the entrance (portal) at the land surface.

Construction of an immersed tube tunnel involves three distinct stages:

i) **Trench Dredging** – A trench is dredged at the bottom of the waterway by removing underwater material, using a dredger, without causing significant damage to the marine environment. The dredged material is then carried off by a barge for disposal at suitable location. The bed foundation, readied using a screed barge, prepares the tunnel alignment under the water surface where the tunnel elements/segments will rest.

ii) **Tunnel Element Construction** – Hollow box sectioned elements of steel or concrete used for the actual shell of the tunnel are constructed on dry land, usually a dry dock, casting basin, fabrication yard or ship-like platform or factory. Each segment is individually designed to fit into the tunnel alignment, which usually slopes from each end towards the middle where the drainage is collected.

iii) **Tunnel Installation** – The prefabricated tunnel elements are then floated to the tunnel site by barge. With the assistance of a cable and crane/ winch system, the tunnel element is towed from the holding area to the exact place it needs to be in the tunnel trench. The tunnel element is held and guided by two advanced immersion pontoons. Their position is controlled by mooring cables that are connected to anchors on the sea/river bed. The actual immersion begins by filling the tunnel element's ballast tanks with water. This makes the element heavy enough to sink to the bottom under its own weight. Using cables, winches and ballast tanks, the element is guided to the bottom under full control. For guiding the tunnel elements down to their exact position in the trench, suitable technology (GPS, echo sounding) is used. Each element is sunken into place and lined up next to the element already placed under the water. Water is pumped out of the space between the bulkheads. Water pressure on the free end of the new element lined to an existing section compresses a rubber seal between the two elements engaging the sealing membranes to lock together. Use of robust rubber seals is highly effective in ensuring a high degree of water tightness within the tunnel. Engineered, erosion resistant backfill is then placed over the trench to permanently bury the tunnel and protect it from ships, scour and to resist positive buoyancy.

10.6 Drill and Blast Method

Controlled Drill and Blast Method is a conventional excavation technique and can provide a cost effective solution especially for shorter applications in hard rock tunnelling or when the rock mass is subject to variable conditions such as faulting and shear zones. Drill and blast method may be used in conjunction with sequential excavation method when developing large span openings in rock.

A series of holes of requisite diameter, length and direction are drilled into the tunnel face. The drills used for tunnelling are either pneumatically or hydraulically powered and having either air pusher legs and/or mounted on drilling jumbos (**Figure 119**). With air pusher legs, it is always advisable to use templates for guiding the direction of drilling. Drilling jumbos can have a simple mounting arrangement on truck or rail. In advanced machines, the three dimensional drilling pattern can be fed into the program of the drilling jumbo and, hence, there is no need for profile marking on tunnel face prior to drilling unlike the conventional drilling jumbo. The choice of drilling system will depend upon the size, shape and length of tunnelling work at hand. Water pressure for flushing the drill holes must be controlled so as to avoid weakening of surrounding rock mass in case of tunnelling in jointed and weak rock mass.

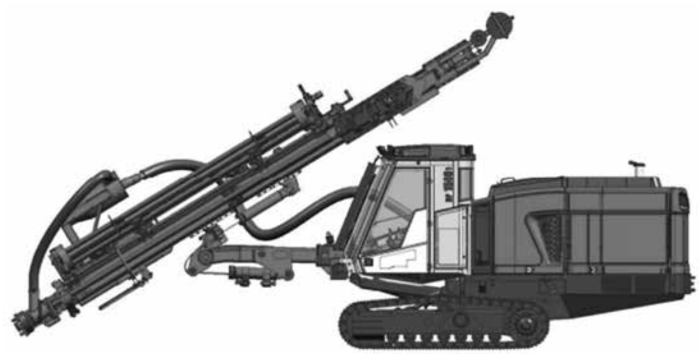


Figure 119: Drilling Jumbo

Under carefully controlled and monitored conditions, the explosives are loaded into the drilled holes and detonated sequentially, thereby breaking the rock while spreading the release of energy from the explosives over several seconds. The blasted rock fragments are removed from the tunnel using conveyor belt or tipper trucks (dumpers). Initial support consisting of some combination of rock bolts, dowels and shotcrete is needed to stabilise the opening in the rock mass. This process is repeated in cycles as necessary to complete the length of the tunnel. After the tunnel is completed, a cast-in-place final liner is placed.

10.7 Conventional Excavation by Road Header or Hand Tools

Other than controlled drill and blasting, conventional tunnel excavation involves use of two types of tools/ equipment:

i) **Roadheader (Figure 120)** – It is electro-hydraulically powered excavation equipment consisting of a rotary cutting head mounted on a hydraulic boom, a loading device usually involving a conveyor, and a crawler travelling on track to move the entire machine forward into the rock face. The boom can be moved up or down and right or left to cover the whole face. The boom presses the rotating cutting head into the rock face, cuts the rock into small fragments which drop down to the invert of the tunnel. Collector arms of the machine pull the muck onto an apron which transfers the muck onto a trailing conveyor for depositing the muck into muck disposal vehicles. In case of soft soil tunnels, the Roadheaders operate under the protection of and inside the shields.

Rotary cutting head can be of two types – transverse (rotates parallel to cutter boom axis) or longitudinal (rotates perpendicular to cutter boom axis). Apart from rotating cutter head, various types of special function heads are also available.

Roadheader can cut variable or odd shapes and is suited for short tunnels. For tunnels having height more than about 5 m, excavation using Roadheader may have to be carried out in multiple stages in view of boom limitations, even in competent rocks.

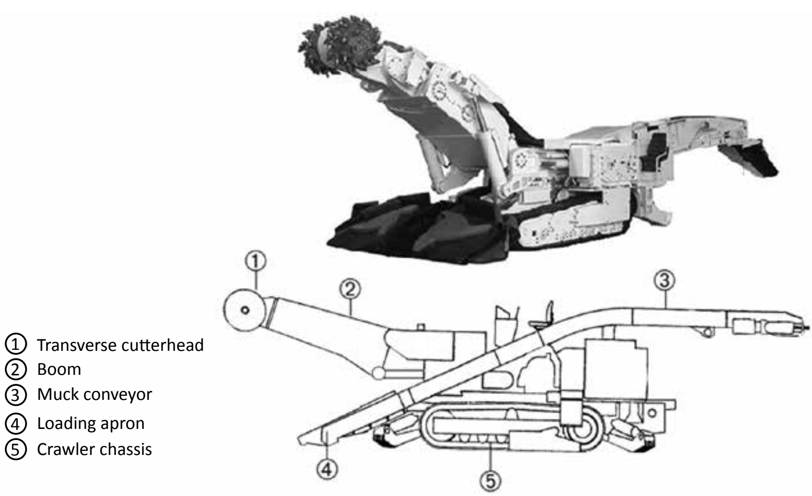


Figure 120: Roadheader

ii) **Hand Tools** – Excavation is done manually by the labour using small mechanical tools.

10.8 Rock Splitting Techniques

Where rock cannot be blasted for various reasons such as avoiding noise, vibrations and surface subsidence, the rock can be split along planes of weaknesses and fissures. Then the pieces can be separately picked up and removed. Various rock splitting techniques are described below:

i) **Conventional Wedging and Splitting** – Wedges and feathers are inserted into natural fissures or predrilled holes and the rock induced to split along the line of wedges, for subsequent removal.

ii) **Hydraulic Splitters** – They are inserted into holes predrilled in a pattern and the rock induced to split along the line of holes quickly and noiselessly, for subsequent removal.

iii) **Chemical Splitters** – After they are poured into holes/ fissures, they expand and split the rock in predetermined patterns, for subsequent removal.

iv) **Other Splitting Agents such as Cardox, Nonex and Penetrating Cone Fracture (PCF)** – The Cardox system is based on liquid carbon dioxide being converted to high pressure carbon dioxide gas with ignition. The gas spreads through fissures and micro-cracks in the rock and breaks it in tension rather than compression as with explosives.

The Nonex system consists of a cartridge containing a propellant, which on ignition produces gases. The gas pressure increases as the cartridge is sealed in a drillhole and, hence, causes the rock to split.

The PCF tube is a hollow plastic tube, open at one end which can then be filled with the powdered smokeless propellant and then closed with a small cap. The other end is machined into a wedge to lock into the stemming, and to seal the hole when inserted for ignition. In the cap, there is an entry port for insertion of an electric match, which is the means for detonation. The gases produced under pressure break the rock by tension effect.

Since, the rock requires less energy to break in tension than compression, lower energy input is required for chemical splitters compared to blasting by explosives.

10.9 Sequential Excavation Method (SEM)

When the ground lacks the strength for full-face excavation, removal can be done in phases. Sequential Excavation Method (SEM), also known as New Austrian Tunnelling Method (NATM) or Norwegian Method of Tunnelling (NMT), is a technique in which a tunnel is sequentially excavated in stages; the intermediate stages are supported, as necessary, in a controlled manner; and the next portion is incrementally excavated until the full cross-section is completed. Although SEM is commonly used in soft ground and weak rock, it can also be combined with drill and blast methods and used in hard rock applications. SEM is generally carried out in shorter tunnels and allows a tunnel of any shape or size to be excavated.

In SEM, excavation is carried out using common mining methods and equipment (like road header, hydraulic excavator, backhoe loader etc.), chosen according to the soil conditions. The ground for excavation must be fully dry for applying SEM and, hence, ground dewatering is essential prior to excavation. Suitable ground improvement techniques like grouting, ground freezing etc. may be done to increase the soil strength and reduce its permeability and, therefore, stabilise the soil for tunnelling. Excavation of ground is followed by provision of temporary support through shotcreting in combination with fibre or welded-wire fabric reinforcement, steel arches (usually lattice girders), and sometimes ground reinforcement (e.g. soil nailing) to line the tunnel or support the face and, thus, control settlement. After the tunnel is completed, a cast-in-place final liner (concrete) is placed to accommodate the permanent loads.

11. TUNNEL BORING MACHINE (TBM)

11.1 Tunnel Boring Machine (**Figure 121**) is a complete single mobile unit facilitating operation of various tunnelling activities and made up of mechanisms for cutting, shoving, steering, gripping, shielding, exploratory drilling, ground control and support, lining erection, muck removal, ventilation and power supply.

11.2 TBM typically consists of one or two shields (large metal cylinders) and trailing support mechanisms. The main features of a TBM are listed below:

i) At the front end of the shield, a rotating cutter wheel is located.

ii) Behind the cutting wheel there is a chamber, where depending on the type of the TBM, the excavated soil is either mixed with slurry (Slurry-Face TBM) or left as it is. The chamber may be under pressure (closed machine) or open to external pressure (open machine).

iii) Behind the chamber there is a set of hydraulic jacks supported by the finished part of the tunnel which push the TBM forward. The rear section of the TBM is braced against the tunnel walls and used to push the TBM head forward. At maximum extension, the TBM head is then braced against the tunnel walls and the TBM rear is dragged forward.

iv) Behind the shield, inside the finished part of the tunnel, several support mechanisms which are part of the TBM can be found: muck (soil/rock) removal, slurry pipelines if applicable, control rooms, rails for transport of the precast segments, etc.

v) The cutting wheel will typically rotate at 1 to 10 rpm (depending on size and stratum), cutting the rock face into chips or excavating soil (muck). Depending on the type of TBM, the muck will fall onto a conveyor belt system and be carried out of the tunnel, or be mixed with slurry and pumped back to the tunnel entrance.

vi) Depending on rock strata and tunnel requirements, the tunnel may be cased, lined, or left unlined. This may be done by bringing in precast concrete sections that are jacked into place as the TBM moves forward, by assembling concrete forms, or in some hard rock strata, leaving the tunnel unlined and relying on the surrounding rock to handle and distribute the load.

vii) A caisson system is sometimes formed at the cutting head (in case the pressure at the tunnel face is greater than that behind the chamber), which allows workers to go to the front of the TBM for inspection, maintenance and repair. If this needs to be done, safety features for working under pressure should be ensured and workers trained in the operation of the locks. Safety requirements for working under compressed air condition should be as per IS:4138.

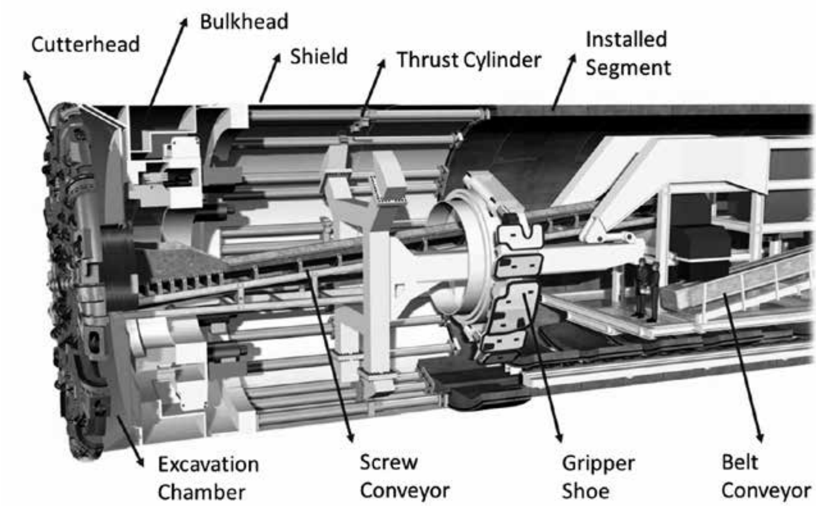


Figure 121: Tunnel Boring Machine (TBM)

11.3 Two different types of TBMs are used according to the expected ground conditions – open shield type and closed shield type.

Open type TBM refers to those providing lateral support only. It can be used in conditions where the face of the excavation is self-standing. TBMs falling under this category include Gripper or Main Beam TBM, Single Shield TBM, Double Shield TBM.

Closed type TBM refers to those providing lateral as well as frontal support. It is meant for application under the water table with water inflow being prevented by compressed air or by supporting the cutting face according to the slurry or EPB principle. TBMs falling under this category include Compressed Air TBM, Slurry Shield TBM, Earth Pressure Balance (EPB) TBM.

11.4 Common types of TBM are discussed below:

11.4.1 *Gripper (or Main Beam) TBM*

Gripper TBM (**Figure 122**) is the classic form of tunnel boring machine. It is used for boring tunnels in hard rock with medium to high stand-up time. To move forward, the machine uses a hydraulic gripper reaction system (clamping shoes) that pushes radially against the tunnel walls and produces thrust behind the cutter head. This TBM is normally used with temporary non-concrete lining, whereas most other types of TBMs are used with segmental lining. In Main Beam TBM, the rock is held up using ground support methods such as steel ribs, rock anchors, ring beams meshes and shotcrete. The advance rate of a Gripper TBM depends essentially on the time required to install the rock support devices. The Gripper TBM can be most economically used if the rock does not need constant support.

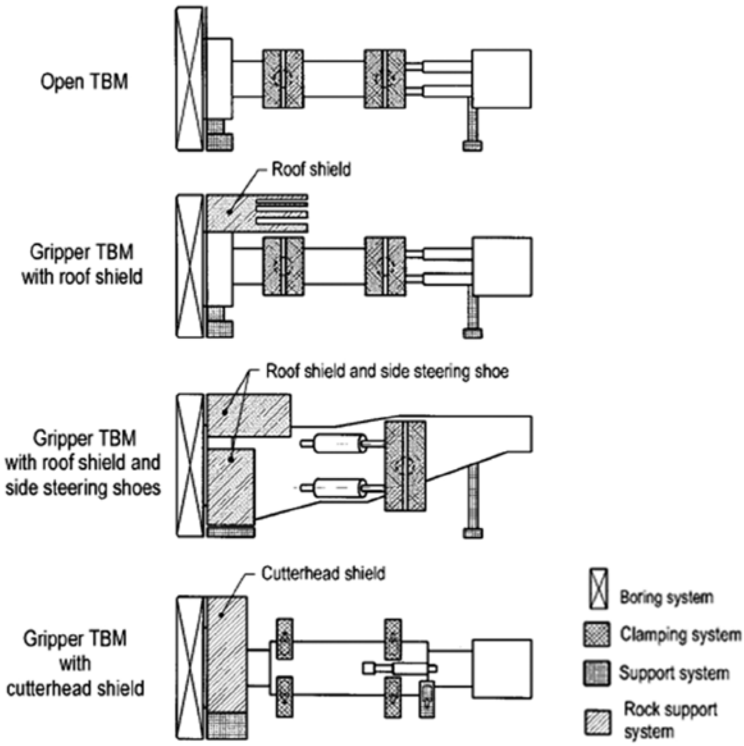


Figure 122: Gripper TBM

Gripper TBM may be provided with static protection roof (roof shield), installed behind the cutter head, to protect work personnel in case of isolated rock falls. Side steering shoes, if provided in addition to roof shield, act as a partial shield with protection function as well as provide support at the front when moving the machine and steering through boring. The side surfaces can be driven radially against the tunnel walls.

In a Gripper TBM with cutter head shield, the cutter head protects the work personnel in the area of the cutter head. When moving such a machine, the short shield liner forms the forward support.

11.4.2 *Single Shield TBM*

Single Shield TBM (**Figure 123**) is primarily meant for application in hard rock with short stand-up time, soft rock and brittle or fractured rock. The cutter head is not essentially different from that of a Gripper TBM in relation to excavation tools and muck transport. This type of TBM is equipped with a shield to support the tunnel temporarily as well as to protect the machine and work personnel. The shield extends from the cutter head over the entire machine. The tunnel lining is installed under the protection of the shield tail. Support with reinforced concrete segments is the commonly used technique. According to the geology and application of the tunnel, the segments are either installed directly as final lining (single shell construction) or as temporary lining with the later addition of an in situ concrete inner skin (double shell lining). In contrast to Gripper TBM, the machine is thrust forward with thrust jacks directly against the existing tunnel support.

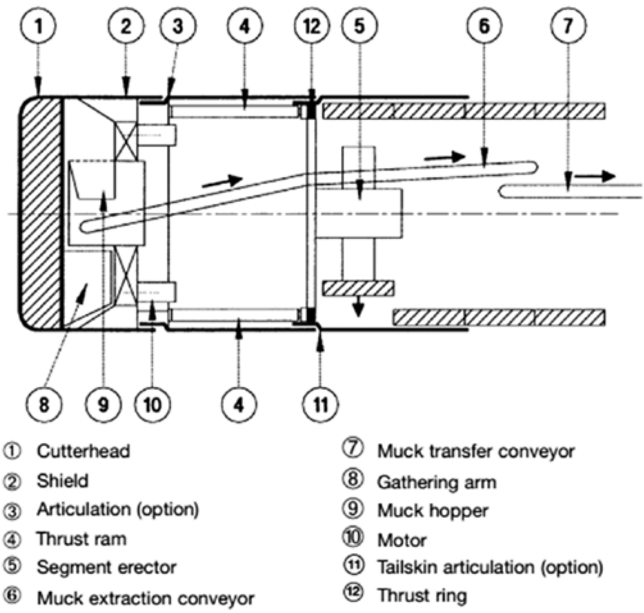


Figure 123: Single Shield TBM

Since this type of TBM relies solely on thrusting off the segments for advance, therefore larger segments are often required. The operation is cyclic – while segments are being placed, boring is discontinued. Another disadvantage is that there is no reverse force reaction to manipulate the shield when it starts to get trapped.

11.4.3 *Double Shield TBM*

Double Shield (or Telescopic Shield) TBM (**Figure 124**) is meant for application in fractured rock with low stand-up time, unstable rock strata (with geological fault zones) or where a high rate of advancement is required. It has two main components – the front shield and the gripper or main shield. Both shield parts are connected with each other with telescopic jacks. The machine can either adequately clamp itself radially in the tunnel using the clamping units of the gripper shield; or where the geology is bad, can push off the existing lining in the direction of the drive. The front shield can thus be thrust forward without influencing the gripper shield, so that in general continuous operation is possible, nearly independent of the installation of the lining.

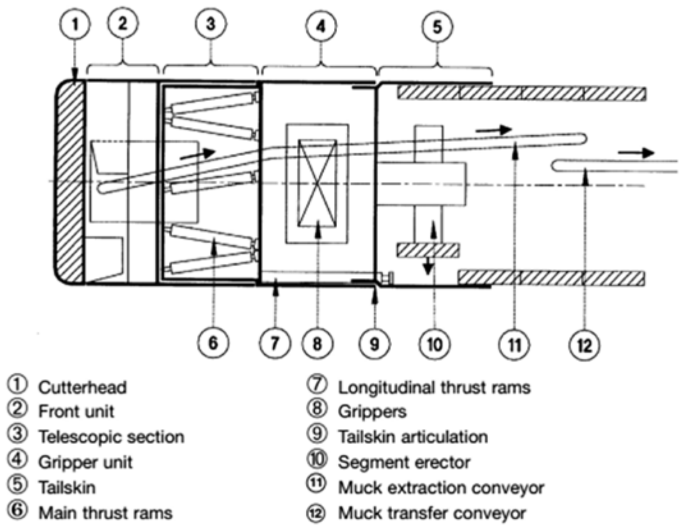


Figure 124: Double Shield TBM

The apparent advantages of the rapid advance of a Double Shield TBM only apply with a single shell segmental lining. The machine body is fully shielded to hold rock in place until the lining is set. Boring and segment erection happen concurrently.

The Double Shield TBM has, however, essential disadvantages compared to the Single Shield TBM. When used in fractured rock with high strength, the rear shield can block due to the material getting into the telescopic joint. The machine is long and therefore prone to getting trapped.

11.4.4 *Earth Pressure Balance (EPB) TBM*

Earth Pressure Balance (EPB) TBM (**Figure 125**) is a closed type of machine and relies on balancing the thrust pressure of the machine against the soil and water pressures from the ground being excavated. It is meant for application in unstable, saturated rock, loose rock, soft rock or fairly cohesive soils. It is, however, not recommended for very abrasive and hard ground.

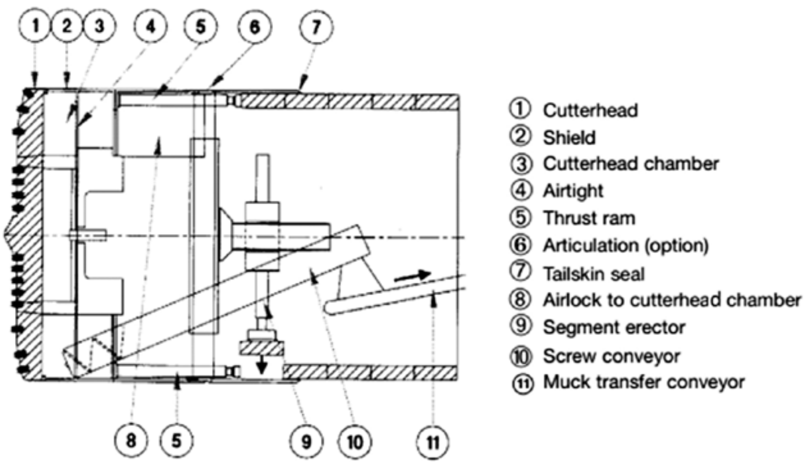


Figure 125: Earth Pressure Balance (EPB) TBM

In this type of TBM, the soil is loosened at the tunnel face by tools mounted on the rotating cutter head. The excavated spoil is pressed through openings in the cutter head into the excavation chamber, where it mixes into the earth slurry and is pressurised under confinement to ensure tunnel face support (positive face pressure). Muck is extracted from the excavation chamber either continuously or intermittently by a pressure relief discharge system that takes it from the confinement pressure to the ambient pressure in the tunnel. Muck removal is mechanically controlled and is facilitated through the rotation of the screw conveyor and, subsequently, by a conveyor belt and/or skips.

11.4.5 *Slurry-Face TBM*

Slurry-Face TBM (**Figure 126**) is a closed type of machine and is meant for application in problematic geological and hydrological conditions like faulted rock, soils of varying hardness, soft ground, tunnelling under waterways, areas where high water penetration (high permeability) is expected or gaseous zones, requiring a complete sealing of the cutter head area while excavating for protection against gas/water intrusion into the tunnel environment. Unlike EPB TBM where the excavated soil acts as a supporting medium to provide supporting pressure at the tunnel face, in Slurry-Face TBM, a secondary support medium in the form of bentonite (clay) slurry ensures tunnel face support.

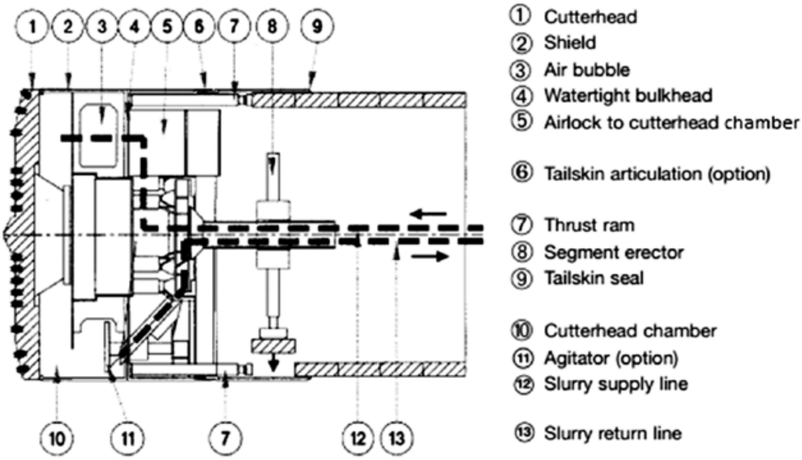


Figure 126: Slurry-Face TBM

In this type of TBM, the soil is loosened at the tunnel face by tools mounted on the rotating cutter head. The excavated spoil is pressed into the excavation chamber through openings in the cutter head and mixes into the bentonite slurry there. The slurry mix in the excavation chamber is pressurised to balance soil and water pressure on working face. Depending on the ground characteristics, conditioners may be added to the slurry.

Face pressure in Slurry TBM is hydraulically controlled by adopting one of the following two methods:

i) The first method uses differential pumping – variable speed pumps meant for supply and discharge of slurry from the machine are precisely controlled to ensure that the pressure between them is maintained at the face pressure. Variable speed of the discharge pump is regulated to control the desired flow while variable speed of the supply pump is regulated to determine face pressure in the machine.

ii) The second method uses a pocket of air trapped in a chamber behind the bulkhead to pressurise the slurry in the excavation chamber. The second method of pressure control is preferred over the first method because pressure regulation of gases is easier and more accurate (with tighter tolerances) than that of liquids. The second method is independent of the slurry flow and allows a larger flow around the circuit without affecting the accuracy of face pressure control. An active face pressure can be maintained, controlled and adjusted even when the pumping system is switched off.

Slurry mix from the excavation chamber is pumped out of the tunnel to an above-ground slurry treatment plant via a hydraulic transport system (long pipelines with in-line booster pumps). The excavated material is treated and separated from the slurry mix in the slurry treatment plant. This also allows safe dispersion of hazardous gaseous components, if any, without endangering work personnel in the tunnel.

11.4.6 *Mix Shield TBM*

Mix Shield TBM is equipped with a full-face cutter head which has combined features for hard rock and soil excavation. It is meant for application in areas characterized by mixed geological conditions like rock-soil mixed face or unstable tunnel face. The machine can work in closed or open mode and with different confinement techniques depending on the geological conditions of the ground to be excavated. Changeover from one work mode to another requires mechanical intervention to change the machine configuration. Different means of muck extraction are used for each work mode.

There are three main categories of Mix Shield TBM:

i) Machine capable of working in open mode, with a belt conveyor extracting the muck, and, after a change in configuration, in closed mode, with earth pressure balance confinement provided by a screw conveyor

ii) Machine capable of working in open mode, with a belt conveyor extracting the muck, and, after a change in configuration, in closed mode, with slurry confinement provided by means of a hydraulic mucking out system (after isolation of the belt conveyor)

iii) Machine capable of providing earth pressure balance and slurry confinement. TBM of this type is generally restricted to large diameter bores because of the space required for the special equipment for each confinement method.

Mix Shield TBM provides flexibility in excavation of rock, soil and mixed ground. However, cutter wear and damage is generally high and muck discharge may be difficult due to mixing of rock and soil.

12. TUNNEL VENTILATION SYSTEM (TVS)

Tunnel Ventilation Systems (for vehicular traffic) operate in two modes:

i) **Normal Mode** – to dilute toxic gases and pollutants produced by motor vehicles to ensure safe operation.

ii) **Emergency Mode** – to remove smoke and excessive heat from the tunnel in case of emergency (e.g. fire).

Quantum of fresh air required to be introduced into a tunnel depends upon the following factors:

i) Traffic characteristics – traffic volume, traffic density, traffic composition, direction of traffic flow (unidirectional or bidirectional)

ii) Effect of elevation

iii) Effect of gradient and vehicle speed

iv) Meteorological conditions

Basic types of tunnel ventilation systems as described in **Table 33** are used separately or in combination to expel stagnant air and introduce fresh air into the enclosed tunnel space.

Table 33: Types of Tunnel Ventilation System

Sl. No.	Type of System	Features
1.	Natural Ventilation (**Figure 127**)	i) Movement of air is controlled only by meteorological conditions and the piston effect from vehicular traffic where stale air is pushed out of the tunnel by vehicles travelling through the tunnel in the same direction. ii) Piston effect is reduced in case of bi-directional traffic. iii) The meteorological conditions arise from elevation and ambient temperature differences between the two portals of the tunnel and from prevailing winds that channel through the tunnel. iv) Normally for tunnels shorter than 500 m, natural ventilation is enough. Exception would be urban tunnels with heavy traffic volume having possibility of congestion during peak hours where provision of mechanical ventilation becomes necessary. Another exception is tunnels longer than 500 m, with very low traffic volume, where natural ventilation is sufficient . v) Where technically feasible, provision of a vertical shaft near about the centre of the tunnel would effectively improve natural ventilation due to additional chimney effect (i.e. elevation difference). If such a shaft is fitted with an exhaust fan, the chimney stack effect will not be affected by change in atmospheric conditions. vi) Axial fans often installed in naturally ventilated tunnels for fire and smoke emergencies.

Sl. No.	Type of System	Features
2.	Longitudinal/Linear Ventilation (**Figure 128**)	i) Similar to natural ventilation with the addition of mechanical fans to improve ventilation characteristics. ii) Fresh air introduced at one end mixes with the air inside the tunnel and travels through the tunnel bore to the other end on account of its own pressure duly aided by the piston effect created by vehicular traffic. Here, the tunnel bore acts as the ductwork for the fans. iii) Fans can be reversible to push air into the tunnel or to pull air from the tunnel. iv) Where a central shaft is provided, fresh air introduced at both the ends travels up to the shaft and is exhausted through the shaft. v) This system is most effective for tunnels with unidirectional traffic. vi) In case of long tunnels, the linear flow is aided by jet (booster) fans at intermittent locations located near and hanging from the arch of the tunnel.
3.	Semi Transverse Ventilation (**Figure 129**)	i) Use of mechanical fans for movement of air. ii) Ductwork is added with flues that allow the air to be uniformly distributed throughout the tunnel. iii) This plenum or ductwork is typically located above a suspended ceiling or below a structural slab within a tunnel. iv) Air either leaves or enters through the portals while the tunnel bore acts as either the exhaust or intake duct respectively. v) Reversing the direction of fans can impact the efficiency of the system. vi) This system is suitable for tunnels with bidirectional traffic.

Sl. No.	Type of System	Features
4.	Fully Transverse Ventilation (**Figure 130**)	i) Primarily used for long tunnels with heavy or bidirectional traffic. ii) Use of two air ducts – one for supply air and the other for exhaust air. iii) Tunnel bore not used as part of the ductwork. iv) Pressure difference is created between the supply and exhaust ducts to control air flow. v) Ducts are commonly located in the ceiling (Exhaust Air) and invert (Fresh Air) but may also be located along the sides of the tunnel.
5.	Single Point Extraction	i) Used in conjunction with semi and fully transverse ventilation systems to increase airflow during emergency (e.g. fire). ii) Remote controlled mechanism to increase the opening size of exhaust flues during emergency.

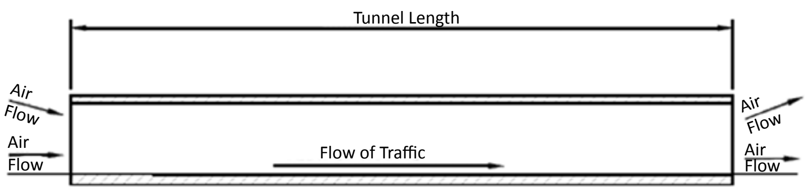


Figure 127: Natural Ventilation

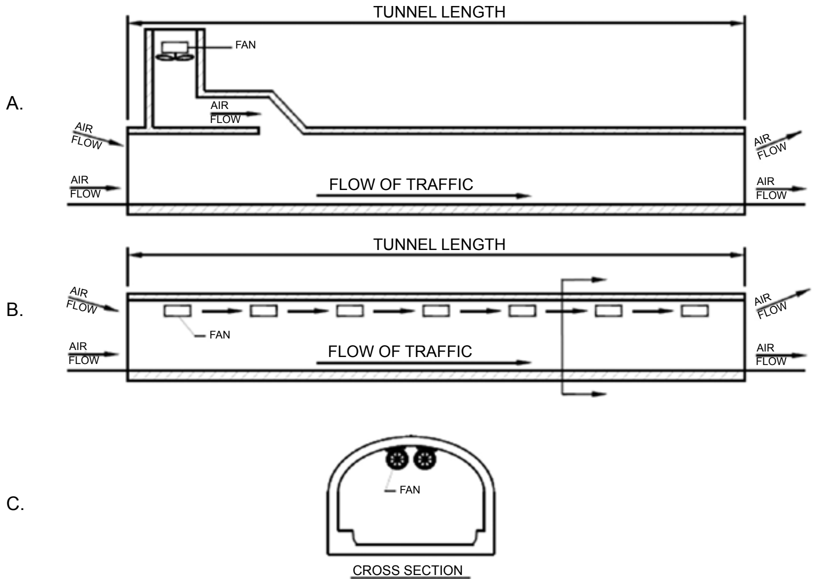


Figure 128: Longitudinal Ventilation A) Saccardo Nozzle B) Jet Fans C) Cross Section

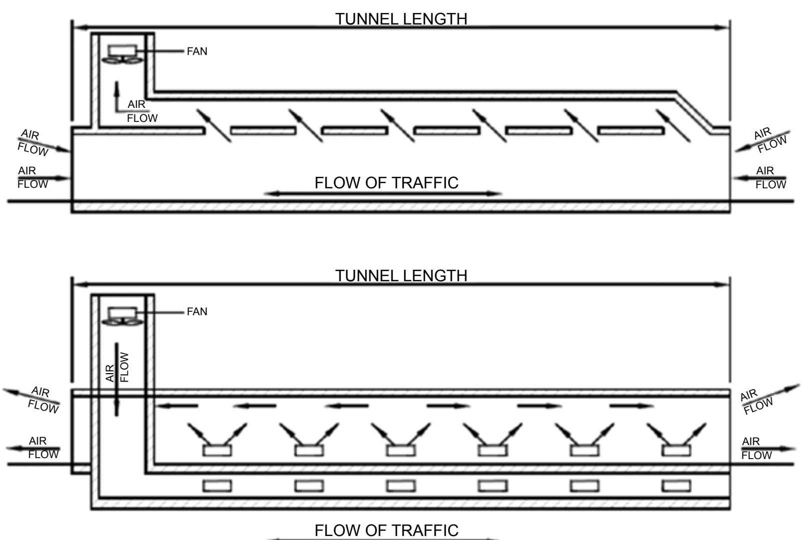


Figure 129: Semi Transverse Ventilation

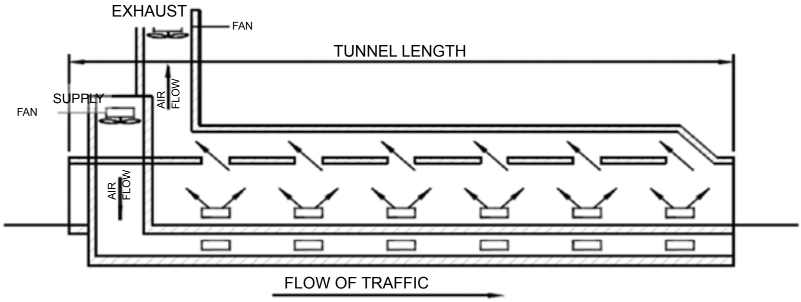


Figure 130: Fully Transverse Ventilation

Equipment used in Tunnel Ventilation Systems is listed in **Table 34.**

Table 34: Tunnel Ventilation Equipment

Sl. No.	Equipment	Features
1.	Fan (**Figure 131**)	i) Usually of two types – axial and centrifugal. ii) Axial Fan a) Discharges air parallel to the axis of the impeller rotation. b) Common for longitudinal ventilation systems. c) Two types of axial fans – tube type and vane type. d) The difference between the two is the addition of guide vanes on one or both sides of the fan impeller in case of vane axial fan, which allows for delivering higher pressure than tube axial fan. e) Axial fans commonly mounted horizontally on the tunnel ceiling at various intervals. iii) Centrifugal Fan a) Discharges air at 90° to the axis of the impeller rotation. b) Common for semi and fully transverse ventilation systems as well as Saccardo nozzle type systems with longitudinal ventilation. c) Can be either backward-curved or airfoil-bladed, for tunnel applications. d) Predominantly located within ventilation or portal buildings where they are connected to supply or exhaust ductwork.

2.	Motor	i) Electric motors commonly used to drive the fans. ii) Constant speed or variable speed type motors used, depending on the design requirements.
3.	Fan Drive	i) Motor to be connected to the fan either directly or indirectly. ii) In direct drive, motor is connected to the impeller shaft directly. iii) In indirect drive, motor is connected to the impeller shaft using belts, chains or gears. iv) Indirect drive allows for more flexibility in the location of the motor.
4.	Sound Attenuator	i) For mitigation of noise level generated by tunnel exhaust system near residential location. ii) Noise attenuators mounted either directly to the fan or within ductwork along the system.
5.	Damper	i) To control air flow within the ductwork. ii) Usually positioned in fully open or fully closed mode; however some dampers can be operated in an intermediate position.

Tube Axial Fan **Vane Axial Fan** **Centrifugal Fan**

Figure 131: Types of Ventilation Fans

13. OTHER TUNNEL SYSTEMS

Other common tunnel systems are described in **Table 35**.

Table 35: Other Tunnel Systems

Sl. No.	System	Features
1.	Lighting System	i) Various lighting systems used in tunnels – fluorescent, high pressure sodium, low pressure sodium, metal halide, LED lighting. ii) Selection of lighting system is determined by its life cycle cost and the amount of light required. iii) Provision of highly reflective surfaces on the walls and ceiling, such as tile or metal panels, can improve the tunnel luminescence for a given set of luminaries. iv) Since requirement of light intensity in different zones of the tunnel during day time is different from that during night time, required intensity can be achieved by putting the luminaries in two different circuits. Alternatively, luminaries that can give variable output by use of dimmers can also be used. v) Gradual increase or decrease in the intensity of lighting within different zones of the tunnel can be achieved by installing different types of luminaries or by using one or two types of luminaries at a closer or wider spacing as required. For easier adjustment in spacing, the luminaries can be mounted on sets of ladders arranged in longitudinal direction and hung from the crown of the tunnel. vi) Since tunnel lighting is required round the clock, it is necessary to install and maintain a 100% backup system.
2.	Fire and Life Safety Systems	i) These systems include – control panels, initiating devices (e.g. heat and smoke detectors, pull-stations, cameras), notification appliances (e.g. strobes, horns, radios, variable message signs), wiring, conduit and cables, emergency egress signs, fire hydrants, extinguishers, water reservoir, fire-hose coil with supply, sprinklers and fire engines.

Sl. No.	System	Features
		ii) These systems are used to detect a fire during an emergency, to initiate an emergency response, and to inform the tunnel users of appropriate emergency actions to take.
3.	Power Distribution System	i) Includes electrical equipment, wiring, conduit and cable used for distributing electrical energy from the utility supply (i.e. service entrance) to the line terminals of equipment. ii) The electrical equipment includes transformers, switchgear, switchboards, panel boards, motor control centres, starters, switches and receptacles.
4.	Signs and Messaging System	i) For controlling tunnel traffic; can provide directions and warnings to tunnel users and help in tunnel evacuation in case of emergency. ii) Can be mounted on the tunnel walls, overhead ceiling or on the barriers at the portals. iii) Includes reflective signs and illuminated displays that use light bulbs or LEDs to convey messages.
5.	Security Systems	i) Includes surveillance systems, communication systems, stopped traffic detection system, wrong way detection systems, CCTV (Closed Circuit Television), SCADA (Supervisory Control and Data Acquisition) systems, chemical/ biological/ radiological monitoring systems, detection systems for explosions, traffic management systems, systems that control access to the tunnel, equipment rooms, command and control centres.

PART D : EQUIPMENT FOR QUALITY CONTROL

14. TESTS FOR SOILS

Table 36 indicates the various tests for soils along with the requisite apparatus and applicable BIS Codes.

Table 36: Tests for Soils

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
1.	Determination of Water Content **(IS: 2720 Part II)**	i) **Oven Drying Method:** Container, Balance, Oven, Desiccator ii) **Sand Bath method:** Container, Heat Resistant Tray, Balance, Sand Bath, Heating Equipment, Palette Knife/ Steel Spatula, Scoop iii) **Alcohol Method:** Evaporating Dish, Palette Knife/ Steel Spatula, Balance, Methylated Spirit iv) **Rapid Determination using Infra-red Lamp Torsion Balance Moisture Meter:** Infra-red Lamp, Torsion Balance Moisture Meter, Palette Knife/ Steel Spatula v) **Rapid Determination from Gas Pressure developed by reaction of Calcium Carbide with the Free Water of Soil:** Metallic Pressure Vessel, Counterpoised Balance, Scoop, Calcium Carbide Storage Bottle, Cleaning Brush, Steel Balls
2.	Determination of Specific Gravity for Fine Grained Soils **(IS: 2720 Part III/ Section 1)**	Density Bottles with Stoppers, Water Bath, Vacuum Desiccator, Desiccator containing anhydrous silica gel, Thermostatically controlled Drying Oven, Balance, Filter/ Vacuum Pump, Spatula, Wash Bottle Sample Divider (multiple slot type), Rubber tubing

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
3.	Determination of Specific Gravity for Fine, Medium and Coarse Grained Soils **(IS: 2720 Part III/ Section 2)**	Gas Jar, Ground Glass Plate or Plastic Seal Cover, Mechanical Shaking Apparatus, Balance, Thermometer
4.	Grain Size Analysis **(IS: 2720 Part IV)**	IS Sieves with lid and pan (of various sizes as per requirement), Balance, Rubber Pestle and Mortar, Brushes, Trays or Bucket, Oven, Mechanical Sieve Shaker (optional), Riffler
5.	Determination of Liquid Limit and Plastic Limit (Plasticity Index) **(IS: 2720 Part V)**	Mechanical Liquid Limit Device, Grooving Tool, Porcelain Evaporating Device, Flat Glass Plate, Spatula, Palette Knives, Balance, Oven, Wash Bottle or Beaker, Containers
6.	Determination of Shrinkage Factors **(IS: 2720 Part VI)**	Evaporating Dish, Spatula, Shrinkage Dish, Straight Edge, Glass Cup, Glass Plates, Oven, Sieve, Balances, Mercury, Desiccator
7.	Determination of Water Content-Dry Density Relation using Light Compaction (Standard Proctor Compaction Test) **(IS: 2720 Part VII)**	Cylindrical Metal Mould, Sample Extruder (optional), Balances, Oven, Container, Steel Straight Edge, Sieves, Mixing Tools, Metal Rammer
8.	Determination of Water Content-Dry Density Relation using Heavy Compaction (Modified Proctor Compaction Test) **(IS: 2720 Part VIII)**	Cylindrical Metal Mould, Sample Extruder (optional), Balances, Oven, Container, Steel Straight Edge, Sieves, Mixing Tools, Metal Rammer
9.	Determination of Dry Density- Moisture Content Relation by Constant Mass of Soil Method **(IS: 2720 Part IX)**	Cylindrical Metal Tube with Base Plate, Metal Rammer, Balances, Oven, Container, Sieve (4.75 mm size), Pipette, Mixing Tools

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
10.	Determination of Unconfined Compressive Strength **(IS: 2720 Part X)**	Compression Device, Proving Ring, Deformation Dial Gauge, Vernier Callipers, Timer, Oven, Weighing Balances, Miscellaneous Equipment (Specimen trimming and carving tools, remoulding apparatus, water content cans etc.)
11.	Determination of the Shear Strength Parameters of a Specimen of Saturated Cohesive Soil tested in Unconsolidated Undrained Triaxial Compression without the Measurement of Pore Water Pressure **(IS: 2720 Part XI)**	Split Mould, Trimming Knife, Piano Wire Saw, Metal Straight Edge, Metal Scale, Non-corrodible Metal or Plastic End Caps, Seamless Rubber Membrane, Membrane Stretcher, Rubber Rings, Apparatus for Moisture Content Determination, Balance, Extruders, Thin-walled Tubes, Soil Lathe, Meter Box, Triaxial Test Cell, Apparatus for applying and maintaining the desired pressure on the fluid within the cell, Machine capable of applying axial compression to the specimen, Proving Rings
12.	Determination of Shear Strength Parameters of Saturated Soil from Unconsolidated Undrained Triaxial Compression Test with Measurement of Pore Water Pressure **(IS: 2720 Part XII)**	Triaxial Cell, Apparatus to apply cell pressure and maintain it at a constant magnitude, System to apply additional axial stress, System to measure pore water pressure, System to measure changes in volume of the soil sample
13.	Direct Shear Test for determination of shear strength of soil with a maximum particle size of 4.75 mm in undrained, consolidated undrained and consolidated drained conditions **(IS: 2720 Part XIII)**	Shear Box, Loading Frame, Weights, Proving Ring, Micrometer Dial Gauges, Sample Trimmer or Core Cutter, Stop Clock, Balance, Spatula, Straight Edge,

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
14.	Determination of Density Index (Relative Density) of Cohesionless Free Draining Soils **(IS: 2720 Part XIV)**	Vibratory Table, Moulds with Guide Sleeves, Surcharge Base Plates with Handle, Surcharge Passes, Dial Gauge Holder, Dial Gauge, Calibration Bar, Pouring Devices, Mixing Pans, Weighing Scale, Hoist, Metal Hand Scoop, Bristle Brush, Timing Device, Metal Straight Edge, Micrometer
15.	Determination of Consolidation Properties **(IS: 2720 Part XV)**	Consolidation Ring, Porous Stones, Consolidation Cell, Dial Gauge, Loading Device, Jack and Frame, Jig, Trimming Equipment, Equipment for measuring initial height of test specimen, Moisture Content Containers, Drying Air Oven, Desiccator, Balances, Timing Device
16.	Laboratory Determination of California Bearing Ratio (CBR) **(IS: 2720 Part XVI)**	Moulds (with Base Plate, Stay Rod and Wing Nut), Collar, Spacer Disc, Metal Rammer, Expansion Measuring Apparatus, Weights, Loading Machine, Penetration Plunger, Dial Gauges, Sieves, Miscellaneous Apparatus (Mixing Bowl, Straight Edge, Scales, Soaking Tank or Pan, Drying Oven, Filter Paper, Dishes, Calibrated Measuring Jar)
17.	Laboratory Determination of Permeability **(IS: 2720 Part XVII)**	Mould Assembly (including Drainage Base and Drainage Cap), Compaction Rammer, Set of Stand Pipes, Constant Head Tank, Vacuum Pump, Miscellaneous Apparatus (IS Sieves, Mixing Pan, Graduated Cylinder, Metre Scale, Stop Watch, 75 mm Wire Gauge, Thermometer, Source of de-aired water)
18.	Determination of Field Moisture Equivalent **(IS: 2720 Part VIII)**	Evaporating Dish, Spatula, Dropper, Containers, Balance, Pestle and Mortar, Oven, Sieves

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
19.	Determination of Centrifuge Moisture Equivalent **(IS: 2720 Part IX)**	Gooch Crucible, Filter Paper, Trunnion Cup, Centrifuge, Balance, Oven
20.	Determination of Linear Shrinkage of Remoulded Soils **(IS: 2720 Part XX)**	Palette Knives, Flat Glass Plate, Mould, Oven, Vernier Callipers, Silicone Grease or any other suitable grease
21.	Determination of Total Soluble Solids **(IS: 2720 Part XXI)**	Bottle Shaker, Oven, Chemical Balance, Buchner or Glass Funnel, Glazed Porcelain Dish or Glass Dish, Filtering Flask, Glass Bottle, Measuring Cylinder, Pipette, Vacuum Pump, Desiccator, Thermometer, Water Bath, Filter Candle, Filter Paper
22.	Determination of Organic Matter **(IS: 2720 Part XXII)**	Oven, Chemical Balance, Volumetric Flask, Burettes, Pipettes, Graduated Measuring Cylinders, Desiccator, Glass Weighing Bottle, Sieves, Wash Bottle
23.	Determination of Calcium Carbonate **(IS: 2720 Part XXIII)**	Burette, Conical Flask, Glass Funnel, Filter Paper
24.	Determination of Cation Exchange Capacity **(IS: 2720 Part XIV)**	**For Determination of Exchangeable Metallic Cations:** i) **Standard Method:** Buchner Funnel, Pipettes, Graduated Cylinders, Filter Paper, Silica Basins, Water Bath, Hot Plate, Muffle Furnace, Burette, Chemical Balance, Beaker, Flask ii) **Rapid Method:** Pipettes, Test Tube, Filter Paper, Evlenmeyer Flask, Beaker, Chemical Balance, Burette, Glass Rod **For Determination of Exchangeable Hydrogen Ions:** Carbon Filter Funnel, Conical Flask, Beaker

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
		For Determination of Cation Exchange capacity (Metallic and Hydrogen Ions together): Centrifuge Tubes, Centrifuge, Beaker, Conical Flask, Pipette, Burette
25.	Determination of Silica Sesquioxide Ratio **(IS: 2720 Part XV)**	Glass Bottles, Cylinder, Porcelain Dishes, Buchner Funnel, Vacuum Trolley, Aspirator, Flasks, Crucible with Lid, Tongs, Platinum Dish, Beakers, Muffle Furnace, Filter Paper
26.	Determination of pH Value **(IS: 2720 Part XVI)**	pH Meter, Analytical Balance, Glass Beakers, Volumetric Flasks, Wash Bottle, Mortar with Rubber covered Pestle
27.	Determination of Total Soluble Sulphates **(IS: 2720 Part XVII)**	i) **Precipitation Method:** Analytical Balance, Glass Beaker, Glass Funnel, Glass Bottle, Crucible, Heating Equipment, Pipette, Burette, Mortar with Rubber covered Pestle, Filter Paper, Muffle Furnace, Mechanical Shaker, Drying Oven ii) **Volumetric Method:** Analytical Balance, Glass Beaker, Glass Funnel, Measuring Flasks, Pipette, Burette, Conical Flasks, Filter Paper, Heating Equipment, Drying Oven iii) **Colorimetric/ Turbidimetric Method:** Conical Flask, Volumetric Flask, Analytical Balance, Photoelectric Colorimeter or Turbidimeter, Filter Paper
28.	Determination of Dry Density of Soils In-Place by the Sand Replacement Method **(IS: 2720 Part XVIII)**	i) **Small Pouring Cylinder Method (for fine and medium grained soils):** Small Sand Pouring Cylinder, Tools for Excavating Holes, Cylindrical Calibrating Container, Balance, Plain Surface, Metal Containers, Cylindrical Steel Core Cutter, Metal Tray with Hole

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
		ii) **Large Pouring Cylinder Method (for fine, medium and coarse grained soils):** Large Sand Pouring Cylinder, Tools for Excavating Holes, Cylindrical Calibrating Container, Balance, Plain Surface, Metal Containers, Metal Tray with Hole
29.	Determination of Dry Density of Soils In-Place by the Core Cutter Method **(IS: 2720 Part XIX)**	Cylindrical Core Cutter, Steel Dolley, Steel Rammer, Balance, Palette Knife, Steel Rule, Grafting Tool or Spade or Pick Axe, Straight Edge, Apparatus (optional) for extracting samples from the cutter, Apparatus for determination of water content
30.	Laboratory Vane Shear Test of Cohesive Soils having Low Shear Strength for Determining their Undrained Shear Strength **(IS: 2720 Part XXX)**	Hand operated or motorized Apparatus with Vane (having four blades) and Torque Applicator
31.	Field Determination of California Bearing Ratio (CBR) **(IS: 2720 Part XXXI)**	Loading Device (Mechanical Screw Loading Jack with Swivel Head), Equipment (truck, tractor, truss or any other suitable equipment) for Providing Reaction for Loading, Track type Jacks, Proving Ring, Metal Penetration Piston, Internally threaded Pipe or Rod Extensions, Connectors, Dial gauge, Dial Gauge Support, Surcharge Weight, Spirit Level, Pick, Spade, Scoop, Brush, Apparatus for Moisture Determination, Apparatus for Density Determination
32.	Determination of the Density In-Place by the Ring and Water Replacement Method **(IS: 2720 Part XXXIII)**	Density Ring and Steel Spikes (if required), Straight Edge, Plastic Film, Pointer gauge Assembly and Supports, Quick setting Plaster or Sand filled Gunny Bags, Apparatus for delivering into the hole, measuring and removing the

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
		volume of water required, Balance, Apparatus for determining moisture content, Platform Weighing Machine, Containers, Hand Tools for excavating and cleaning holes, IS Sieves (as per requirement), Syphon Can, Measuring Cylinders
33.	Determination of Density of Soils In-Place by the Rubber Balloon Method **(IS: 2720 Part XXXIV)**	Calibrated Vessel, Balances, Apparatus for Determination of Moisture Content, Small Pick, Chisels, Spoons for digging test holes, Plastic Bags, Buckets with Lids for retaining the soil taken from the test holes, Thermometer for determining temperature of water, Small Paint Brush
34.	Measurement of Negative Pore Water Pressure **(IS: 2720 Part XXXV)**	Balancing Manometer, Null Indicator, Water Bottle, Top Cup, Rubber Rings, Seamless Rubber Membrane, Fine Ceramic Porous Stone, Air Lead, Coarse Porous Stone, Polyester Fabric Discs, Triaxial Cell, Pressure Gauge, Air Pressure Regulator, Air Filter, Burette, Air Compressor, Calibrated Pressure Mercury Manometer, Screw Control Cylinder, Self Compensating Mercury Pot System, Reservoir of de-aired water, Tubing and Valves, Accessories (for preparation of soil specimens, extrusion, trimming and for measurement of size, weight, water content etc.)
35.	Laboratory Determination of Permeability of Granular Soils by a Constant Head Method and under conditions of Laminar Flow of Water **(IS: 2720 Part XXXVI)**	Permeameter, Constant Head Filter Tank, Large Funnels, Specimen Compaction Equipment, Vacuum Pump or Water Faucet Aspirator, Balance, Scoop, Thermometers, Clock with Sweep Second Hand, Graduated Cylinder, Mixing Pan

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
36.	Determination of Sand Equivalent Value of Soils and Fine Aggregates **(IS: 2720 Part XXXVII)**	Graduated Cylinder, Irrigator Tube, Siphon Assembly, Weighted Foot Assembly, Measuring Can, Sieve, Funnel, Bottles, Flat Pan, Timing Device, Sand Equivalent Shaker (mechanical or manually operated)
37.	Compaction Control Test (Hilf Method) **(IS: 2720 Part XXXVIII)**	Cylindrical Metal Mould, Metal Rammer, Rigid Foundation, Balance, Apparatus for Water Content Determination, Sieves, Spatula, Steel Straight Edge, Miscellaneous Mixing Apparatus (Pan or Bowl, Spoon, Scoop, Trowels, Water Spray etc.), Rule, Airtight Containers, Sample Extruder
38.	Direct Shear Test for Soils containing Gravel (Laboratory Test) **(IS: 2720 Part XXXIX/ Section 1)**	Shear Box, Container for Shear Box, Gripper Plates, Top and Bottom Plates, Base Plate, Loading Plate, Loading Device, Weights (if necessary), Proving Ring, Micrometer Dial Gauges, Stop Clock, Balance,
39.	Direct Shear Test for Soils containing Gravel (In Situ Shear Test) **(IS: 2720 Part XXXIX/ Section 2)**	Shear Box, Top Loading Plate, Hydraulic Jack, Rolled Steel Joist and Wooden Sleepers, Rollers, Datum Bars, Spring Balance
40.	Determination of Free Swell Index of Soils **(IS: 2720 Part XXXX)**	IS Sieve (425 micron size), Glass Graduated Cylinders
41.	Measurement of Swelling Pressure of Soils **(IS: 2720 Part XXXXI)**	i) **Consolidometer Method:** Consolidometer, Dial Gauge, Water Reservoir, Moisture Room, Soil Trimming Tools, Oven, Desiccator, Balance, Containers ii) **Constant Volume Method:** Consolidometer, Dial Gauge, Moisture Room, Soil Trimming Tools, Oven, Desiccator, Balance, Moisture Content Cans, Loading Unit of 5000 Kg capacity, High Sensitive Proving Ring of 200 Kg capacity

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
42.	Standard Penetration Test for Soils **(IS:2131)**	Drilling Equipment, Split-Spoon Sampler, Driving Weight Assembly, Lifting Bail, Tongs, Rope, Screw Jack

15. TESTS FOR AGGREGATES

Table 37 indicates the various tests for aggregates along with the requisite apparatus and applicable BIS Codes.

Table 37: Tests for Aggregates

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
1.	Particle Size and Shape **(IS:2386 Part I)**	i) **Sieve Analysis:** IS Sieves, Balance ii) **Determination of Materials finer than 75 micron:** IS Sieves, Balance, Container, Oven, iii) **Determination of Flakiness Index:** IS Sieves, Balance, Metal Gauge iv) **Determination of Elongation Index:** IS Sieves, Balance, Metal Gauge v) **Determination of Angularity Number:** Metal Cylinder, Tamping Rod, Balance, Scoop
2.	Estimation of Deleterious Materials and Organic Impurities **(IS:2386 Part II)**	i) **Determination of clay lumps:** IS Sieves, Balance, Containers ii) **Determination of clay, fine silt and fine dust (Sedimentation Method):** Water-tight screw-topped Glass Jar, Device for rotating Jar, Sedimentation Pipette (Andreason type), Measuring Cylinder, Balances or Scales, Oven (well-ventilated and thermostatically controlled) iii) **Determination of light weight pieces (coal and lignite):** Balances, Containers, Skimmer, Hot-Plate or Oven iv) **Determination of soft particles:** Brass Rod having Rockwell hardness of 65-75 HRB

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
		v) **Estimation of organic impurities:** Graduated Bottle, Stopper
3.	Specific Gravity, Density, Voids, Absorption and Bulking **(IS:2386 Part III)**	i) **Determination of Specific Gravity and Water Absorption:** a) **Aggregate larger than 10 mm:** Balance, Oven (well-ventilated and thermostatically controlled), Wire Basket or Perforated Container, Water-tight Container, Absorbent Cloths, Shallow tray, Air-tight Container b) **Aggregate between 40 mm and 10 mm:** Balance, Oven (well-ventilated and thermostatically controlled), Glass Vessel or Jar, Absorbent Cloths, Shallow tray, Air-tight Container c) **Aggregate smaller than 10 mm:** Balance, Oven (well-ventilated and thermostatically controlled), Glass Vessel, Device for supplying a current of warm air (such as hair dryer), Shallow tray, Air-tight Container, Filter Papers and Funnel ii) **Determination of Bulk Density and Voids:** Balance, Cylindrical Metal Measure, Tamping Rod iii) **Determination of Necessary Adjustment for Bulking of Fine Aggregate (Field Method):** Containers, Steel Rule, Steel Rod, Measuring Cylinder iv) **Determination of Surface Moisture in Fine Aggregate (Field Method):** Balance, Flask

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
4.	Mechanical Properties **(IS:2386 Part IV or IS:5640** ***(for aggregate impact value))***	i) **Determination of Aggregate Crushing Value:** Open-ended Steel Cylinder with Plunger and Base Plate, Straight Metal Tamping Rod, Balance, IS Sieves, Compression Testing Machine, Cylindrical Metal Measure ii) **Determination of the 10 percent Fines Value:** Open-ended Steel Cylinder with Plunger and Base Plate, Straight Metal Tamping Rod, Balance, IS Sieves, Compression Testing Machine, Cylindrical Metal Measure, Dial Gauge iii) **Determination of Aggregate Impact Value:** Impact Testing Machine, IS Sieves, Cylindrical Metal Measure, Straight Metal Tamping Rod, Balance, Oven (well-ventilated and thermostatically controlled) iv) **Determination of Aggregate Abrasion Value:** Los Angeles Machine or Deval Machine (with 1.70 mm size IS Sieve) v) **Determination of Polished Stone Value:** Accelerated Polishing Machine, Friction Tester, IS Sieves vi) **Determination of Crushing Strength:** Compression Testing Machine, Oven (well-ventilated and thermostatically controlled)
5.	Soundness **(IS:2386 Part V)**	IS Sieves, Containers, Suitable Means for Temperature Regulation, Balances, Drying Oven
6.	Measuring Mortar making Properties of Fine Aggregate **(IS:2386 Part VI)**	Flow Table and Flow Mould, Tamping Bar, Trowel, Moulds, Tamping Rod, Testing Machine

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
7.	Alkali Aggregate Reactivity **(IS:2386 Part VII)**	i) **Determination of Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar Bar Method):** Scales, Weights, IS Sieves, Glass Graduates, Specimen Moulds, Mixing Bowl, Tamper, Trowel, Covered Containers, Length Comparator ii) **Determination of Potential Reactivity of Aggregates (Chemical Method):** Scales, Weights, Balances, Crushing and Grinding Equipment, IS Sieves, Reaction Containers, Constant Temperature Bath, Photometer, Glassware
8.	Petrographic Examination **(IS:2386 Part VIII)**	i) **Method-I (for routines purposes):** Screens conforming to the IS Sieve designations, Balance, Anvil and Hammer, Hand Lens, Stereoscopic Microscope, Petrographic Microscope, Auxiliary Equipment for adequate petrographic examination and identification of rocks and minerals ii) **Method-II (for detailed investigations):** Rock cutting saw, Horizontal grinding wheel, Polishing Wheel, Prospector's pick, Microscope slides, Mounting medium, Laboratory oven, Plate glass squares, Jones riffle sampler with pans, Micro cover glasses, Polarizing microscope, Microscope lamps, Stereoscopic microscope, Magnet, Needle holder and points, Dropping bottle, Forceps, Petri culture dishes, Lens paper, Immersion media, Counter, Photomicrographic camera and accessories

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
9.	Determination of Sand Equivalent Value of Soils and Fine Aggregates **(IS: 2720 Part XXXVII)**	Graduated Cylinder, Irrigator Tube, Siphon Assembly, Weighted Foot Assembly, Measuring Can, Sieve, Funnel, Bottles, Flat Pan, Timing Device, Sand Equivalent Shaker (mechanical or manually operated)
10.	Determination of Stripping Value of Road Aggregates **(IS:6241)**	Heat resistant Glass Beaker, IS Sieves (20 mm and 12.5 mm sizes), Mixer, Balance, Water Bath preferably with a thermostat

16. TESTS FOR BITUMEN

Table 38 indicates the various tests for bitumen along with the requisite apparatus and applicable BIS Codes.

Table 38: Tests for Bitumen

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
1.	Determination of Specific Gravity **(IS:1202)**	i) **Pyknometer Method:** Specific Gravity Bottles, Constant Temperature Bath, Bath Thermometer ii) **Balance Method:** Analytical Balance, Thermometer, Balance Straddle, Thread, Brass Moulds
2.	Determination of Penetration **(IS:1203)**	Container, Needle, Water Bath, Transfer Dish, Penetration Apparatus, Thermometer, Timing Device
3.	Determination of Residue of Specified Penetration **(IS:1204)**	Container, Heating Bath, Hot Plate, Thermometer, Needle, Water Bath, Penetration Apparatus
4.	Determination of Softening Point **(IS:1205)**	Ring and Ball Apparatus with steel balls, brass rings, ball guide, support, thermometer, bath and stirrer
5.	Determination of Industrial Viscosity **(IS:1206 Part I)**	Tar Viscometer with cup, valve, water bath, sleeve, stirrer, curved shield, receiver, thermometers

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
6.	Determination of Absolute Viscosity **(IS:1206 Part II)**	Viscometers, Thermometer, Bath, Vacuum System, Timing Device
7.	Determination of Kinematic Viscosity **(IS:1206 Part III)**	Viscometers, Thermometers, Bath, Timing Device
8.	Determination of Equiviscous Temperature (EVT) **(IS:1207)**	Tar Viscometer with cup, valve, water bath, sleeve, stirrer, curved shield, receiver, thermometers
9.	Determination of Ductility **(IS:1208)**	Brass Mould, Water Bath, Testing Machine, Thermometer
10.	Determination of Flash Point and Fire Point **(IS:1209)**	Pensky-Martens Closed Tester with cup, lid, attiring device, cover proper, shutter, flame exposure device, stove, top plate, thermometers
11.	Float Test **(IS:1210)**	Float, Collar, Thermometer, Water Bath
12.	Determination of Water Content (Dean and Stark Method) **(IS:1211)**	Flask, Condenser, Receiver, Graduated Cylinder, Heater
13.	Determination of Loss on Heating **(IS:1212)**	Oven, Perforated Metal Shelf, Thermometer, Container
14.	Distillation Test **(IS:1213)**	Distillation Flask, Thermometer, Water Condenser, Adapter, Shield, Crow Receivers, Residue Container
15.	Determination of Solubility in Carbon Disulphide or Trichloroethylene **(IS:1216)**	Gooch Crucible, Conical Glass Flask
16.	Determination of Flash Point and Fire Point (Cleveland Open Cup Method) **(IS:1448 Part 69)**	Cleveland Open Cup Apparatus, Shield, Thermometer, Barometer

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
17.	Viscosity Test (using Saybolt Furol Viscometer) **(IS:3117)**	Oil Tube, Bath with Stirring Device, Glass Receiver, Oil Tube Thermometers, Timing Device, Withdrawal Tube or Pipette
18.	Determination of Bitumen Content **(IS:3117)**	Glass Beakers, Glass Rods, Balance, Oven
19.	Settlement Test **(IS:3117)**	Graduated Cylinders, Glass Pipette
20.	Demulsibility Test **(IS:3117)**	IS Sieve Iron Wire Cloth, Metal Beakers, Metal Rods, Glass Burette
21.	Miscibility in Water **(IS:3117)**	Graduated Cylinder, Glass Beaker, Glass Rod
22.	Modified Miscibility in Water **(IS:3117)**	Graduated Cylinder, Glass Beaker, Glass Tube, Supporting Strip, Glass Rod, Crucibles, Oven (of constant temperature), Balance
23.	Cement Mixing Test **(IS:3117)**	IS Sieves, Round bottom dish or kitchen saucepan, Stirring Rod, Graduated Cylinder
24.	Coating Ability and Water Resistance **(IS:3117)**	IS Sieves, Steel Spatula, Round bottom dish or kitchen saucepan, Balance
25.	Sieve Test **(IS:3117)**	850 micron size IS Sieve, Shallow Metal Pan or Tin Box Cover
26.	Test for Particle Charge **(IS:3117)**	Battery, Rheostat, Ammeter, Copper Plates, Glass Container
27.	Determination of Foaming Characteristics (Half Life, Expansion Ratio) of Hot Bitumen	Apparatus for producing foamed bitumen, Metal Containers, Dipstick, Timer, Balance, Heat Resistant Gloves, Safety Goggles

17. TESTS FOR CEMENT AND CONCRETE

Table 39 indicates the various tests for cement and concrete along with the requisite apparatus and applicable BIS Codes.

Table 39: Tests for Cement and Concrete

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
1.	Determination of Fineness by Dry Sieving **(IS:4031 Part 1)**	Test Sieve, Balance, Brush
2.	Determination of Fineness by Blaine Air Permeability Method **(IS:4031 Part 2)**	Variable Flow type Air Permeability Apparatus (Blaine type), Timer, Balances, Standard Weights, Pyknometer, Manometer, Circular discs of Filter Paper
3.	Determination of Soundness **(IS:4031 Part 3)**	i) **Le Chatelier Method:** Soundness Testing Apparatus (Le Chatelier), Balance, Weights, Water Bath ii) **Autoclave Method:** Balance, Weights, Graduated Glass Cylinders, Moulds, Autoclave with high pressure steam boiler and suitable safety device, Length Comparator
4.	Determination of Consistency of Standard Cement Paste **(IS:4031 Part 4)**	Vicat Apparatus, Balance, Standard Weights, Gauging Trowel
5.	Determination of Initial and Final Setting Times **(IS:4031 Part 5)**	Vicat Apparatus, Balance, Standard Weights, Gauging Trowel
6.	Determination of Compressive Strength of Hydraulic Cement other than Masonry Cement **(IS:4031 Part 6)**	Vibration Machine, Poking Rod, Cube Mould, Gauging Trowel, Balance, Standard Weights, Graduated Glass Cylinders

Sl. No.	Test with Relevant Code of Practice	Apparatus/Equipment
7.	Determination of Compressive Strength of Masonry Cement **(IS:4031 Part 7)**	Balance, Standard Weights, Cube Moulds, Planetary Mixer, Flow Table and accessories, Tamping Rod
8.	Determination of Transverse and Compressive Strength of Plastic Mortar using Prism **(IS:4031 Part 8)**	Balance, Standard Weights, Planetary Mixer, Moulds, Jolting Apparatus, Scraper, Demoulding Device
9.	Determination of Heat of Hydration **(IS:4031 Part 9)**	Calorimeter, Mortar and Pestle, Glass/Plastic Vials, Stop Watch or Timer, IS Sieves, Muffle Furnace, Analytical Balance, Standard Weights, Weighing Bottles, Camel Hair Brush
10.	Determination of Drying Shrinkage **(IS:4031 Part 10)**	Balance, Weights, Trowel, Length Comparator, Flow Table and accessories, Mould, Control Cabinet
11.	Determination of Density **(IS:4031 Part 11)**	Standard Le Chatelier Flask, Analytical Balance, Standard Weights, Constant Temperature Water Bath
12.	Determination of Air Content of Hydraulic Cement Mortar **(IS:4031 Part 12)**	Cylinder Measure, Balance, Standard Weights, Planetary Mixer, Flow Table and Accessories, Tamping Rod
13.	Measurement of Water Retentivity of Masonry Cement **(IS:4031 Part 13)**	Apparatus Assembly for Water Retention Test, Balance, Standard Weights, Planetary Mixer, Flow Table and Accessories, Tamping Rod
14.	Determination of False Set **(IS:4031 Part 14)**	Vicat Apparatus, Balance, Weights, Gauging Trowel, Graduated Glass Cylinders, Mixing Slab
15.	Determination of Fineness by Wet Sieving **(IS:4031 Part 15)**	IS Sieve (45 micron size), Spray Nozzle, Pressure Gauge, Balance, Standard Weights, Oven

18. ESSENTIAL EQUIPMENT FOR CENTRAL LABORATORY

A list of essential equipment required to be maintained in a Central Laboratory is given below.

18.1 Soil Testing Equipment

i) Weigh Balances

   a) 5-20 kg capacity Electronic type - Accuracy 1 gm

   b) 500 gm capacity Electronic type - Accuracy 0.01 gm

   c) 5 kg capacity Electronic type - Accuracy 0.5 gm

   d) 100 gm capacity Chemical Balance - Accuracy 0.001 gm

ii) Oven - electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

iii) IS Sieves: 200 mm internal diameter (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid

iv) Sieve shaker capable of shaking 200 mm diameter sieves - electrically operated with time switch

v) Stop watches Accuracy - 1/5 sec

vi) Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc)

vii) Enamel trays

   a) 600 mm x 450 mm x 50 mm

   b) 450 mm x 300 mm x 40 mm

   c) 300 mm x 250 mm x 40 mm

viii) Liquid Limit device with ASTM grooving tools as per IS:2720 (Part 5)

ix) Sampling pipettes fitted with pressure and suction inlets, 10 ml capacity

x) Compaction apparatus (Proctor) as per IS:2720 (Part 7) complete with collar, base plate and hammer and all other accessories

xi) Modified AASHTO Compaction apparatus as per IS:2720 (Part 8) or heavy compaction

xii) Sand pouring cylinder with conical funnel and tap and complete as per IS:2720 (Part 28) including modern equipment

xiii) Ennore standard sand

xiv) Sampling tins with lids 100 mm diameter x 75 mm height, ½ kg capacity and miscellaneous items like moisture tins with lid 50 gm etc.

xv) Lab CBR testing equipment for conducting CBR testing, load frame with 5 Tonne capacity, electrically operated with speed control as per IS:2720 (Part 16) and consisting of following:

   a) CBR moulds 150 mm diameter – 175 mm height

   b) Tripod stands for holding dial gauge

   c) CBR plunger with settlement dial gauge

   d) Surcharge weight 147 mm diameter 2.5 kg weight spacers disc 148 mm diameter 47.7 mm height with handle

   e) Perforated plate (Brass)

   f) Soaking tank for accommodating CBR moulds

   g) Proving rings capacity of 10 kN, 20 kN, 25 kN and 30 kN

   h) Dial gauges 25 mm travel – 0.01 mm/division

xvi) Dynamic cone penetration test equipment

xvii) Nuclear moisture density meter or equivalent

xviii) Speedy moisture meter complete with chemicals

xix) Rifle Box

xx) Differential Free Swell Index as per IS:2720 (Part 40)

18.2 Aggregate Testing Equipment

i) Sieves as per IS:460

   a) IS sieves of required sizes (450 mm internal diameter) sets as per BIS complete with lid and pan

   b) IS sieve 200 mm internal diameter (brass frame and steel/ brass wire cloth mesh) consisting of sets of required sieve sizes complete with lid

ii) Sieve shaker capable of shaking 200 mm, 300 mm and 450 mm diameter sieves -electrically operated with time switch

iii) Enamel trays

  a) 600 mm x 450 mm x 50 mm

  b) 450 mm x 300 mm x 40 mm

  c) 300 mm x 250 mm x 40 mm

  d) Circular plates of 250 mm diameter

iv) Flakiness and Elongation Index Test Apparatus

v) Aggregate Impact Test Apparatus as per IS:2386 (Part 4)

vi) Los Angeles Abrasion Test Apparatus as per IS:2386 (Part 4)

vii) Apparatus for determination of specific gravity of fine coarse aggregates as per IS:2386 (Part 3)

viii) 0.5 cft, 1 cft cylinder for checking bulk density of aggregate with tamping rod.

18.3 Cement and Cement Concrete Testing Equipment

i) High frequency mortar cube vibrator for cement testing

  a) Cement motor moulds (70.6 mm Width x 70.6 mm Length x 70.6 mm Height)

ii) Vicat needle apparatus for setting time with plungers as per IS:269

iii) Soundness testing apparatus for cement (Le Chatelier)

iv) Weigh balances

  a) 5-20 kg capacity electronic type – accuracy 1 gm

  b) 500 gm capacity electronic type – accuracy 0.01 gm

  c) 5 kg capacity electronic type – accuracy 0.5 gm

  d) 50 kg capacity electronic type – accuracy 2 gm

v) Concrete mixer power driven, 1 cft capacity

vi) Moulds

  a) 150 mm diameter x 300 mm height cylinder with capping component along with the capping set

b) Cubes 150 mm and 100 mm (each size)

vii) Apparatus for slump test

viii) Variable frequency and amplitude vibrating table size 1 m x 1 m as per the relevant British Standard

ix) Compression and Flexural Strength testing machine of 200 ton capacity with additional dial flexural testing

x) Core Cutting Machine with 10 cm diameter diamond cutting edge

18.4 Bitumen Testing Equipment

i) Constant temperature bath for accommodating bitumen test specimen, electrically operated and thermostatically controlled (to accommodate minimum six specimens)

ii) Penetrometer automatic type, including adjustable weight arrangement and needles as per IS:1203

iii) Bitumen laboratory mixer including required accessories (20 ltrs)

iv) Ductility Meter

v) Furol Viscometer

vi) Softening Point Test Apparatus (Ring and Ball Apparatus)

vii) Digital Thermometer

viii) Rifle Box

ix) Thin Film Oven Test Apparatus for modified binder either with PMB or CRMB

x) Mastic Asphalt Hardness Testing Equipment

xi) Sand Equivalent Test Apparatus

xii) Thermometers

xiii) Gas Stove and Cylinder

xiv) Soxhlet Extraction or Centrifuge type Apparatus complete with extraction thimbles with solvent and filter paper

xv) Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc) and metallic thermometers ranging up to 300°C

xvi) Hot Plates 200 mm diameter (1500 Watt)

xvii) Oven – electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

xviii) Marshall Compaction Apparatus, automatically operated as per ASTM 1559-62 ton complete with accessories (with 180 N Marshall Moulds)

xix) Core Cutting Machine suitable for up to 150 mm diameter core

18.5 Sub- Soil Testing Equipment

i) Determining the shear strength properties by conducting Direct Shear (Proving rings capacity of 2 kN and 2.5 kN)

ii) Weigh Balances

  a) 5 kg capacity electronic type - accuracy 0.5 gm

  b) 500 gm capacity electronic type - accuracy 0.01 gm

iii) Oven – electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

iv) Sieves as per IS:460-IS sieve 200 mm internal diameter (brass frame and steel/ brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid and pan

v) Liquid Limit Device with ASTM grooving tools as per IS:2720 (Part 5)

vi) Sampling Pipettes fitted with pressure and suction inlets, 10 ml capacity

vii) Sampling Tins with lids (100 mm diameter x 75 mm height) of 500 gm capacity and miscellaneous items like moisture tins with lid 50 gm etc.

19. ESSENTIAL EQUIPMENT FOR PLANT/SITE LABORATORY

A list of essential equipment required to be maintained in a Plant/Site Laboratory is given below.

19.1 Wet Mix Plant

i) Sieves as per IS:460

   a) IS sieves of required sizes (450 mm internal diameter) sets as per BIS complete with lid and pan
   b) IS sieves 200 mm internal diameter (brass frame and steel/ brass wire cloth mesh) consisting of sieve sets required sieve sizes complete with lid and pan.

ii) Sieve shaker capable of shaking 200 mm and 450 mm diameter sieves - electrically operated with time switch

iii) Apparatus for testing Aggregate Impact Value (AIV), Soundness, Crushing Value, Flakiness and Elongation Index, Polished Stone Value

19.2 Hot Mix Plant

i) Sieves as per IS:460
   a) IS sieves 450 mm internal diameter of sieve sets as per BIS of required sieve sizes complete with lid and pan
   b) IS sieve 200 mm internal diameter (brass frame and steel/brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid

ii) Sieve shaker capable of shaking 200 mm and 450 mm diameter sieves - electrically operated with time switch

iii) Apparatus for testing Aggregate Impact Value (AIV), Soundness, Crushing Value, Flakiness and Elongation Index, Polished Stone Value

iv) Oven – electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

v) Constant temperature bath for accommodating bitumen test specimen, electrically operated, and thermostatically controlled (to accommodate minimum six specimens)

vi) Penetrometer, automatic type, including adjustable weight arrangement and needles as per IS:1203

vii) Furol Viscometer

viii) Softening Point Test Apparatus (Ring and Ball Apparatus)

ix) Distant Reading Thermometer

x) Mastic Asphalt Hardness Test Apparatus

xi) Sand Equivalent Test Apparatus

xii) Thermometers

xiii) Gas Stove and Cylinder

xiv) Soxhlet Extraction or Centrifuge type Apparatus complete with extraction thimbles with solvent and filter paper

xv) Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc) and metallic thermometers ranging up to 300°C

xvi) Hot Plates 200 mm diameter (1500 watt)

xvii) Oven – electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

19.3 Concrete Batching Plant

i) High frequency mortar cube vibrator for cement testing

  a) Cement motor moulds (70.6 mm Width x 70.6 mm Length x 70.6 mm Height)

ii) Vicat needle apparatus for setting time with plungers as per IS:269

iii) Soundness testing apparatus for cement (Le Chatelier)

iv) Weigh balances

  a) 5 - 20 kg capacity electronic type – accuracy 1 gm

  b) 500 gm capacity electronic type – accuracy 0.01 gm

  c) 5 kg capacity electronic type – accuracy 0.5 gm

  d) 50 kg capacity electronic type – accuracy 2 gm

v) Moulds

  a) 150 mm diameter x 300 mm height cylinder with capping component along with the capping set

  b) Cubes 150 mm and 100 mm (each size)

vi) Apparatus for slump test

vii) Variable frequency and amplitude vibrating table size

1 m x 1 m as per the relevant British Standard

viii) Compression and Flexural Strength testing machine of 200 ton capacity with additional dial flexural testing

20. INVENTORY OF CONSUMABLES FOR LABORATORY

20.1 Soil Testing

Distilled water, Filter Paper, Sodium Hexameta Phosphate, Sodium Carbonate, Kerosene.

20.2 Aggregate Testing

Sodium Sulphate, Magnesium Sulphate.

20.3 Cement Testing

Cement, Admixtures, Distilled Water.

20.4 Bitumen Testing

Bitumen, Benzene, Gas Cylinder, Filter Paper.

20.5 Concrete Testing

NIL.

20.6 Sub-Soil Testing

Distilled Water, Filter Paper, Sodium Hexameta Phosphate, Sodium Carbonate, Kerosene.

PART E : EQUIPMENT FOR DISASTER MANAGEMENT

21. ESSENTIAL EQUIPMENT FOR RESTORATION WORKS IN LANDSLIDE MANAGEMENT

The institutional mechanism for disaster management at the Centre, State and District levels is to ensure that the States manage disasters in an effective manner. Each State shall work out a time bound program with district authorities for updating of equipment inventory list as a part of capacity building measures required to be undertaken under **Section 31(3)(c)** of the Disaster Management Act, 2005. It shall be mandatory for all commercial bulk suppliers (manufacturers, dealers, distributors, etc.) of emergency material resources and all employers (companies, contractors, societies, etc.) of emergency human resources in a district to furnish information on availability of such emergency resources to the designated Nodal Resources Officer in the District at an interval of not more than three months.

The following is the inventory of equipment to be maintained at the District Level:

21.1 Heavy Equipment

i) Crawler Dozer
ii) Wheel Dozer
iii) Tracked Excavator
iv) Wheeled Excavator
v) Backhoe Loader
vi) Skid Steer Loader
vii) Hydraulic Crane
viii) Recovery Vehicle
ix) Aerial Platform (Mobile)
x) Boom Lift (Mobile)
xi) Air Compressor
xii) Fork Lift
xiii) Dumpers
xiv) Tipper Truck

21.2 Power Tools

i) Rock Drill
ii) Jack Hammer

iii) Cutters
iv) Bolt Cutters
v) Hydraulic Cutter
vi) Pneumatic Chisel
vii) Circular Saw with Diamond Plate
viii) Electric Drill
ix) Diamond Blade Disk Cutter
x) Chipping Hammer

21.3 Lighting Equipment

i) Inflatable Lighting Tower
ii) Commando Search Light
iii) Working Lamp with 50 M lead

21.4 Hand Tools

i) Plier
ii) Vise grip
iii) Chisel
iv) Screw Driver Set
v) Saw
vi) Hammer
vii) Shovel
viii) Axe
ix) B.A. Set
x) Crow Bar

21.5 Miscellaneous Utility Items

i) Disaster Management Kit
ii) Tarpaulin
iii) Bucket
iv) Rope
v) Steel Pipe

21.6 Individual Kit

i) Reflective Jackets Waterproof

ii) Safety Helmets
iii) Boots Hard Toe Steel Shank
iv) Safety Torches
v) Water Bottles (Light Weight with Protective Carrier)

21.7 Personal Protection Gear

i) PVC Suit
ii) Heavy Duty Work Gloves
iii) Face Shield
iv) Safety Goggles
v) Head Light
vi) Nose Mask
vii) Dusk Mask
viii) Earplug
ix) Knee Pad Cushion

21.8 Radio and Communication Equipment

i) Walkie Talkie Set
ii) Satellite Phones
iii) Portable Radio Set

21.9 Lightweight Temporary Bridges

i) Bailey Bridges
ii) Hamilton Bridges
iii) Modular Bridges
iv) Cable Stayed Bridges (Class 9)
v) Portable Aluminium bridges developed by DRDO
vi) Pontoon Bridges

21.10 Skilled Human Resources

i) Operators for different types of Equipment
ii) Erection specialist for Bailey Bridges

As a measure of preparedness for disasters, it has been decided that the inventory of all the above mentioned equipment at the State level, including the Bailey bridges, available with the Border Roads

Organisation (BRO) for disaster management and which are capable of discharging emergency support functions, should be made available to the Ministry of Road Transport & Highways. The inventory should include all the equipment, owned both by the Government as well as by the private sector, along with their identified location, so that these could be kept in readiness for use during the disaster. A list of all the suppliers of equipment should also be maintained, so that such equipment could be utilised in emergency. Specialised training needs to be imparted to the skilled workers and operators of equipment at regular intervals, in order to keep them in readiness for deployment during disasters.

22. BAILEY BRIDGE

22.1 The Bailey Bridge is a prefabricated, portable steel bridge of the "through" type with the roadway being carried between two main steel panels/girders. They are designed on the "Unit Construction" principle – the basic unit being a 3.048 m long bay. These bays, when assembled together, create bridges of various lengths (in multiples of 3.048 m). Foot walks, if required, may be provided on one or both sides of the bridge. Ramps may also be provided at both ends of the bridge to ensure easy access to the bridge deck from the access road.

The load carrying capacity of the girder can be increased by adding extra panels alongside (called "truss" arrangement) and on top of the original panels (called "storey" arrangement).

Each of the bridge components can easily be transported in a truck or trailer to the site, where they are assembled to form the bridge.

22.2 Bailey Bridge may be classified on the basis of:

i) Number of trusses and storeys which form its main girders

ii) Type of Deck

iii) Width of Roadway

22.3 Based on the number of trusses and storeys which form its main girders, bailey bridge may have five different configurations (**Figure 132**):

i) Single Single (SS)

ii) Double Single (DS)

iii) Triple Single (TS)

iv) Double Double (DD)

v) Triple Double (TD)

Note: *The number of trusses is indicated first, followed by the number of storeys. For example, TD configuration indicates a bailey bridge with three trusses and two storeys on each of the two girders.*

SS is the lightest combination possible while TD is the heaviest.

The various configurations stated above can be reinforced by the addition of chord reinforcements to the top and bottom of each truss. Reinforced construction is annotated by the addition of the letter "R" (e.g. Double Single Reinforced bridge is indicated as DSR).

Selection of a suitable configuration (**Tables 40** to **47**) for a bailey bridge depends upon the bridge span as well as its load class as per IRC:6.

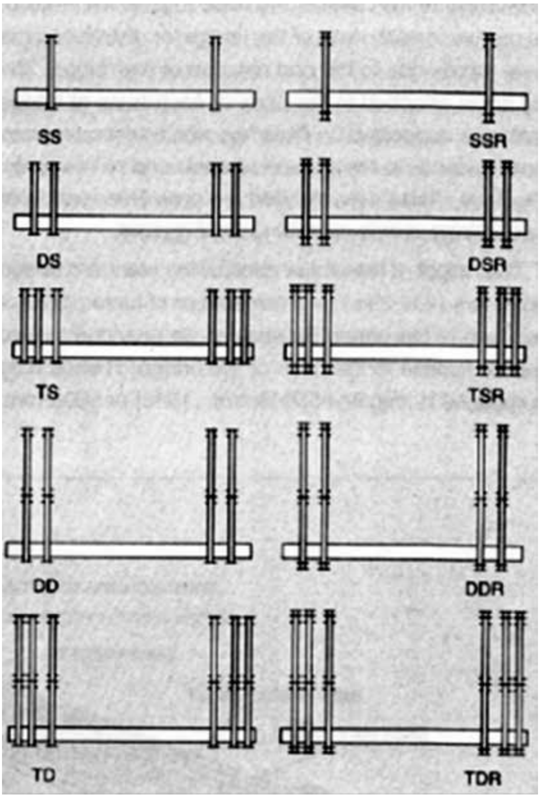


Figure 132: Bailey Bridge Configuration of Trusses and Storeys

Table 40: Recommended Construction of Standard Width Bailey Bridge (Wooden Deck) with 2 Transoms per Bay

SPAN → (FT) / LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-9R	1	SS	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	DSR	DSR	DD	DD	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	DSR	DD	DD	DDR	DDR	DDR
CLASS-12R	1	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	SSR	DSR	DSR	DD	DD	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	DSR	DSR	DD	DD	DDR	DDR	DDR
CLASS-18R	1	SS	SS	SS	SS	SSR	SSR	SSR	SSR	SSR	TS	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SSR	SSR	SSR	TS	DSR	DSR	DSR	DD	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-24R	1	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	TS	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SSR	SSR	SSR	TS	TS	DSR	DSR	DD	DD	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-B	1	SS	SS	SS	SS	SSR	SSR	SSR	TS	TS	TS	DSR	DD	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SSR	SSR	TS	DSR	DD	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR

Note: 1. Temporary Bridge 2. Semi-Permanent Bridge

Table 41: Recommended Construction of Extra Wide Bailey Bridge (Wooden Deck) with 2 Transoms per Bay

SPAN → (FT) LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-9R	1	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	TSR	DD	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	TSR	DD	DDR	DDR	DDR	DDR
CLASS-12R	1	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR
CLASS-18R	1	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SSR	SSR	SSR	TS	DSR	DSR	DSR	DD	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-24R	1	SS	SS	SS	SSR	DS	DS	TS	TS	DSR	DSR	DSR	TSR	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SSR	DS	DS	TS	TS	DSR	DSR	DD	TSR	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-B	1	SS	SS	SS	SS	SSR	SSR	DS	TS	DSR	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR	TDR
	2	SS	SS	SS	SS	SSR	SSR	TS	DSR	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR	TDR

Note: 1. Temporary Bridge 2. Semi-Permanent Bridge

Table 42: Recommended Construction of Standard Width Bailey Bridge (Wooden Deck) with 4 Transoms per Bay

SPAN → (FT) LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-30R	1	DS	DS	DS	DS	DS	TS	TS	DSR	DSR	DSR	TSR	TSR	DDR	DDR	DDR	DDR	TDR	TDR
	2	DS	DS	DS	DS	TS	TS	DSR	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR	TDR	TDR
CLASS-40R	1	DS	DS	DS	DS	TS	TS	TS	DSR	DSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	-
	2	DS	DS	DS	DS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	TDR	-
CLASS-50R	1	DS	DS	DS	TS	TS	TS	DD	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	-	-
	2	DS	DS	DS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-	-
CLASS-60R	1	DS	DS	DS	TS	TS	DD	DD	TSR	TSR	TSR	DDR	DDR	TDR	TDR	TDR	TDR	-	-
	2	DS	DS	DS	TS	DD	DD	DD	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-	-	-
CLASS-70R	1	DS	TS	TS	TS	DD	DDR	TD	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
	2	DS	TS	DD	DD	DDR	TD	TDR	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
CLASS-A	1	DS	DS	DS	DS	DS	TS	TS	DSR	DSR	TSR	TSR	DDR	DDR	DDR	DDR	TDR	TDR	-
	2	DS	DS	DS	DS	TS	DSR	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-

Note: 1. Temporary Bridge   2. Semi-Permanent Bridge

Table 43: Recommended Construction of Extra Wide Bailey Bridge (Wooden Deck) with 4 Transoms per Bay

SPAN → (FT) LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-30R	1	DS	DS	DS	DS	DS	TS	TS	DSR	DSR	TSR	TSR	DDR	DDR	DDR	DDR	TDR	TDR	TDR
	2	DS	DS	DS	DS	TS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR
CLASS-40R	1	DS	DS	DS	DS	TS	TS	DSR	DSR	TSR	TSR	TSR	DDR	DDR	TDR	TDR	TDR	-	-
	2	DS	DS	DS	DS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-
CLASS-50R	1	DS	DS	DS	TS	TS	DD	DD	TSR	TSR	TSR	DDR	DDR	TDR	TDR	TDR	TDR	-	-
	2	DS	DS	DS	TS	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-	-
CLASS-60R	1	DS	DS	DS	TS	TS	DD	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	-	-	-
	2	DS	DS	DS	TS	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-	-	-
CLASS-70R	1	TS	TS	TS	TS	DD	TD	TD	TDR	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-
	2	TS	TS	TS	DD	DD	TD	TD	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
CLASS-A	1	DS	DS	DS	DS	DS	TS	TS	DSR	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	-
	2	DS	DS	DS	DS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-

Note: 1. Temporary Bridge 2. Semi-Permanent Bridge

Table 44: Recommended Construction of Standard Width Bailey Bridge (Steel Deck) with 2 Transoms per Bay

SPAN → (FT) LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-9R	1	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	SSR	DSR	DSR	DD	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	DSR	DD	DDR	DDR	DDR	DDR
CLASS-12R	1	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	SSR	TS	DSR	DD	DD	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	DSR	DD	DD	DDR	DDR	DDR	DDR
CLASS-18R	1	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SSR	SSR	SSR	TS	DSR	DSR	DSR	DD	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-24R	1	SS	SS	SS	SSR	SSR	DS	DS	TS	TS	DSR	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SSR	SSR	DS	TS	TS	DSR	DSR	DD	TSR	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-B	1	SS	SS	SS	SS	SSR	SSR	SSR	TS	TS	DSR	DSR	TSR	DDR	DDR	DDR	DDR	DDR	TDR
	2	SS	SS	SS	SS	SSR	SSR	TS	DSR	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR	TDR

Note: 1. Temporary Bridge 2. Semi-Permanent Bridge

Table 45: Recommended Construction of Extra Wide Bailey Bridge (Steel Deck) with 2 Transoms per Bay

SPAN → (FT) LOAD CLASS ↓ AS PER IRC: 6		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-9R	1	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR
CLASS-12R	1	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR
CLASS-18R	1	SS	SS	SS	SS	SSR	SSR	SSR	SSR	TS	TS	DSR	DD	TSR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SS	SSR	SSR	SSR	TS	DSR	DSR	DSR	DD	TSR	DDR	DDR	DDR	DDR	DDR
CLASS-24R	1	SS	SS	SS	SSR	DS	DS	TS	TS	TS	DSR	DSR	DD	DDR	DDR	DDR	DDR	DDR	DDR
	2	SS	SS	SS	SSR	DS	DS	TS	TS	DSR	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	DDR
CLASS-B	1	SS	SS	SS	SS	SSR	SSR	DS	TS	TS	DSR	DSR	DDR	DDR	DDR	DDR	DDR	TDR	TDR
	2	SS	SS	SS	SS	SSR	SSR	TS	DSR	DD	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR

Note: 1. Temporary Bridge 2. Semi-Permanent Bridge

Table 46: Recommended Construction of Standard Width Bailey Bridge (Steel Deck) with 4 Transoms per Bay

SPAN → (FT) / LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-30R	1	SS	SS	SS	DS	DS	DS	TS / DSR	TS / DSR	DSR	DSR	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR
	2	SS	DS	DS	DS	DS	DS	DSR	DSR	DSR	DSR	TSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR
CLASS-40R	1	DS	DS	DS	DS	DSR	DSR	DSR	DD	TSR	TSR	TSR	DDR	DDR	TDR	TDR	TDR	TDR	-
	2	DS	DS	DS	DS	DSR	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	TDR	-
CLASS-70R	1	TS	TS	TS	DD	DD	TD	TD	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
	2	TS	TS	TS	DD	DD	TD	TD	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
CLASS-A	1	DS	DS	DS	DS	DS	DSR	DSR	DSR	TSR	TSR	TSR	DDR	DDR	TDR	TDR	TDR	TDR	-
	2	DS	DS	DS	DS	DSR	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	TDR	-

Note: 1. Temporary Bridge   2. Semi-Permanent Bridge

Table 47: Recommended Construction of Extra Wide Bailey Bridge (Steel Deck) with 4 Transoms per Bay

SPAN → (FT) LOAD CLASS AS PER IRC: 6 ↓		30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
CLASS-30R	1	DS	DS	DS	DS	DS	DSR	DSR	DSR	DSR	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	TDR
	2	DS	DS	DS	DS	DSR	DSR	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	TDR
CLASS-40R	1	DS	DS	DS	DS	DSR	DSR	DSR	DD	TSR	TSR	DDR	DDR	DDR	TDR	TDR	TDR	-	-
	2	DS	DS	DS	DS	DSR	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-
CLASS-70R	1	TS	TS	TS	DD	DD	TD	TD	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
	2	TS	TS	TS	DD	DD	TD	TD	TDR	TDR	TDR	TDR	TDR	-	-	-	-	-	-
CLASS-A	1	DS	DS	DS	DS	DS	DSR	DSR	DSR	TSR	TSR	TSR	DDR	DDR	TDR	TDR	TDR	-	-
	2	DS	DS	DS	DS	DSR	DSR	DD	DD	DDR	DDR	DDR	DDR	DDR	TDR	TDR	TDR	-	-

Note: 1. Temporary Bridge 2. Semi-Permanent Bridge

22.4 Based on the type of deck, the bailey bridge may be of the following types:

i) Wooden Deck (**Figures 134** and **135**)

ii) Steel Deck (**Figure 133**)

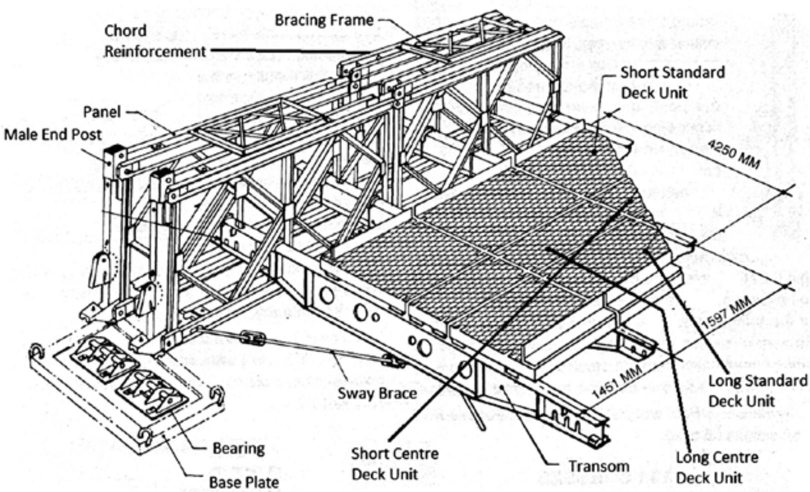


Figure 133: Extra Wide Double Single Reinforced Bailey Bridge with Steel Decking

22.5 Based on the width of roadway between the two girders, the bailey bridge may be of the following types:

i) **Standard Width Type (Figure 134)** – Width of roadway is 3.277 m for wooden decking and 3.320 m for steel decking. Distance between the inside edges of the inner trusses of the main girders is 3.760 m.

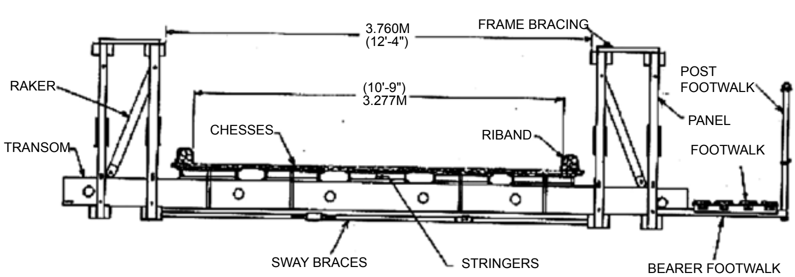


Figure 134: Standard Width Bailey Bridge with Wooden Deck

ii) **Extra Wide Type (Figure 135)** – Width of roadway is 4.190 m for wooden decking and 4.250 m for steel decking. Distance between the inside edges of the inner trusses of the main girders is 4.775 m.

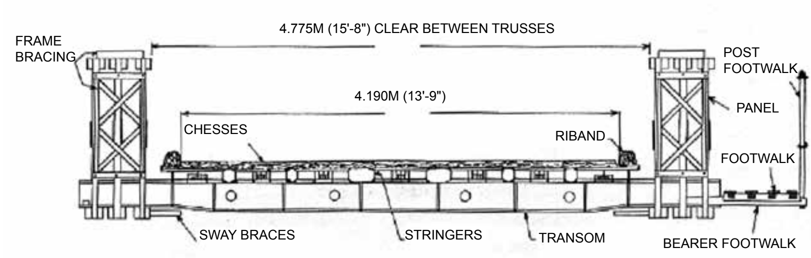


Figure 135: Extra Wide Bailey Bridge with Wooden Deck

22.6 Erection and Launching – The site preparation has to be done in consultation with the user department to remove any obstacles, to create facilities for turnaround for vehicle movement, roller layouts, unloading arrangements and area for assembly, launching, ramp assembly, jacking make and movement in unison, measurement of gap, soil conditions, deciding nose tip sag, truss types, grillage, counter weights and balancing while launching.

The Bailey Bridge is so designed that it can be completely erected on rollers on one side of the gap to be bridged and then launched across without the use of any temporary support within the gap. This is achieved by building on to the front end of the bridge a temporary skeleton cantilever structure, called “Launching Nose”, which is constructed from the same standard components as the bridge. To raise the skeleton launching nose up for facility of landing on the far bank, a special component known as Launching Link is inserted in the bottom chord between two panels of the skeleton nose. The nose is built up of such a length that when the whole structure is rolled forward, the tip of the nose lands on the rollers on the far bank before the point of balance is reached.

Once the bridge is in position across the gap, the launching nose is dismantled and the bridge jacked up off the rollers and lowered on to its permanent bearings on the abutments.

Rocking rollers are required on the home bank and far bank at positions 2 and 3 (**Figure 136**) and these should be set accurately to the same plane within ±3 mm. The bearings/ base plates should also be set so that difference between the upstream side and downstream side bearings/ base plates on each abutment does not exceed ±3 mm. The thickness of grout under the base plate/ bearing should be adjusted to satisfy above requirement.

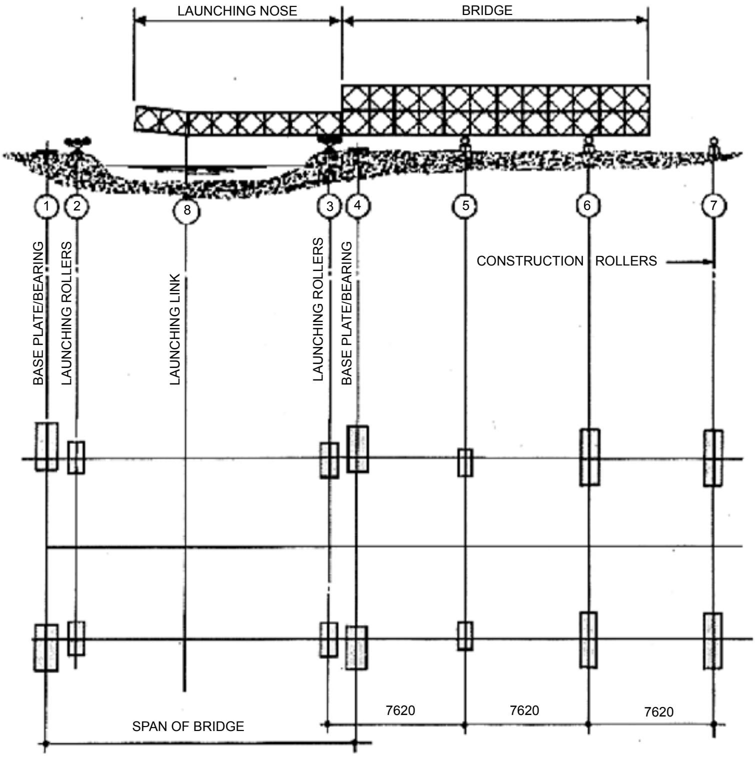


Figure 136: Erection and Launching of Bailey Bridge

Panel crib piers (**Figure 137**) made of trusses with panels set horizontally or vertically may be used as intermediate support for long bailey bridges. They are fabricated from the same standard components as the bridge and can be set on concrete or masonry footings, timber grillage etc.

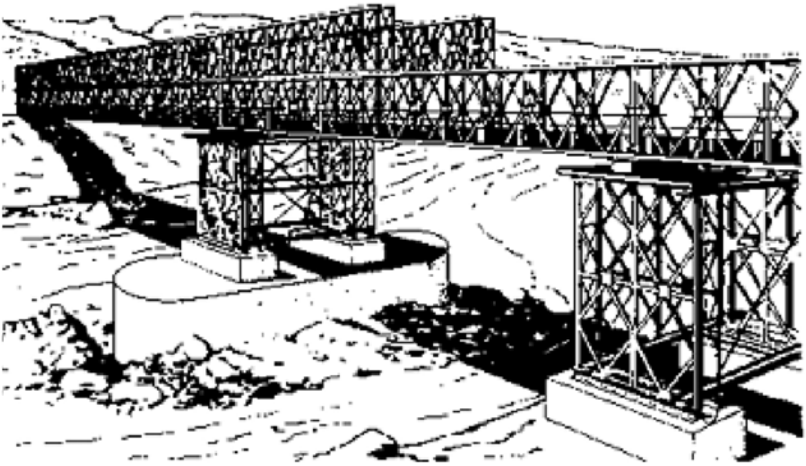


Figure 137: Bailey Bridge Supported on Crib Piers

APPENDIX - I

EMISSION AND NOISE LIMITS FOR DIESEL GENSET (UP TO 800 KW)

A. Emission Limits

The emission limits for new diesel engines (up to 800KW) for generator sets were notified by the Environment (Protection) (Third Amendment) Rules vide GSR 771(E) dated 11.12.2013 at Sl. No. 95 and its amendments GSR 232(E) dated 31.03.2014, GSR 789(E) dated 11.11.2014, GSR 105(E) dated 17.02.2015, GSR 54(E) dated 23.01.2015, under the Environment (Protection) Act 1986.

Table 48 lists out the emission limits for new diesel engines up to 800 KW for genset applications.

Table 48: Emission Limits for Diesel Gensets up to 800 KW

Power Category	Emission Limits (gm/KW-hr)			Smoke Limit (Light Absorption Coefficient, m^{-1})
	NOx + HC	CO	PM	
Up to 19 KW	≤ 7.5	≤ 3.5	≤ 0.3	≤ 0.7
More than 19 KW up to 75 KW	≤ 4.7	≤ 3.5	≤ 0.3	≤ 0.7
More than 75 KW up to 800 KW	≤ 4.0	≤ 3.5	≤ 0.2	≤ 0.7

B. Noise Limits

Noise limits for generator sets run with diesel were notified by Environment (Protection) Second Amendment Rules vide GSR 371(E) dated 17.05.2002 at Sl. No. 94 and its amendments vide GSR 520(E) dated 01.07.2003, GSR 448(E) dated 12.07.2004, GSR 315(E) dated 16.05.2005, GSR 464(E) dated 07.08.2006, GSR 566(E) dated 29.08.2007 and GSR 752(E) dated 24.10.2008; GSR 215(E) dated 15.03.2011 under the Environment (Protection) Act 1986.

For new DG sets with rated capacity up to 1000 KVA, manufactured on or after the 1st January, 2005, the maximum permissible sound pressure level shall be 75 dB(A) at 1 m from the enclosed surface. The DG sets should be provided with integral acoustic enclosure.

APPENDIX-II

EMISSION NORMS FOR CONSTRUCTION EQUIPMENT VEHICLES

As per the Government of India, Ministry of Road Transport and Highways, Notification No. GSR 276(E) dated 10.11.2007, as amended from time to time, the limit values of emission norms applicable for both Type Approval (TA) and Conformity of Production (COP) testing in respect of construction equipment, are given in **Table 49**.

Table 49: Emission Norms for Construction Equipment Vehicles as notified by MoRTH

Bharat Stage III	Applicable with effect from	CO	HC + NO_x	PM
Category		**gm/KW-hr**		
KW < 8	1-Apr-2011	8.00	7.50	0.80
8 ≤ KW < 19	1-Apr-2011	6.60	7.50	0.80
19 ≤ KW < 37	1-Apr-2011	5.50	7.50	0.60
37 ≤ KW < 75	1-Apr-2011	5.00	4.70	0.40
75 ≤ KW < 130	1-Apr-2011	5.00	4.00	0.30
130 ≤ KW ≤ 5600	1-Apr-2011	3.50	4.00	0.20

APPENDIX-III

IRC/BIS CODES FOR ROAD AND BRIDGE CONSTRUCTION EQUIPMENT

Most of the road and bridge construction equipment have been covered in this document. For more information on such equipment, the relevant IRC/BIS Codes may be referred. **Table 50** gives a listing of such codes for key Road Construction Equipment.

Table 50: IRC/BIS Codes for Road and Bridge Construction Equipment

Sl. No.	Equipment/Plant/Machinery	Relevant IRC / BIS Code
1.	Dozer	IRC:125
2.	Hydraulic Excavator	IS/ISO:7135, IS:11399 (Part 1)
3.	Motor Grader	IS/ISO:7134
4.	Scraper	IS/ISO:7133
5.	Front End Loader	IS/ISO:7131, IS:13936
6.	Jaw Crusher	IS:4254
7.	Cone Crusher	IS:4255
8.	Wheel Barrow	IS:2431, IS:4184
9.	Wet Mix Plant	IRC:126
10.	Hot Mix Plant	IRC:90
11.	Paver Finisher	IRC:SP:86
12.	Roller, Plate Compactor, Rammer	IRC:SP:97
13.	Concrete Batching and Mixing Plant, Concrete Mixer	IRC:SP:96
14.	Transit Mixer	IS:5892
15.	Internal Concrete Vibrator	IS:2505, IS:3558
16.	External Concrete Vibrator	IS/ISO:18652
17.	Screed Concrete Vibrator	IS:2506, IS:11993
18.	Vibrating Table	IS:2514

Sl. No.	Equipment/Plant/Machinery	Relevant IRC / BIS Code
19.	Pneumatic Breaker	IS:3559
20.	Mobile Slurry Seal/ Micro-Surfacing Equipment	IRC:SP:81
21.	Mobile Cold Bituminous Mixing Plant	IS:5435
22.	Concrete Pump	IS/ISO:21573 (Part 1)
23.	Pile Driving Hammer	IS:6426
24.	Pile Boring Equipment (Cable Percussion Rig without the use of bentonite for stabilisation)	IS:14362
25.	Prestressing Equipment	IS:1343
26.	Grouting Equipment	IS:1343, IS:6066, IS:5878 (Part 7)
27.	Shotcreting Equipment	IS:9012, IS:6433
28.	Diamond Core Drill	IS:11710 (Part 1), IS:11710 (Part 2), IS:10208, IS:15481 (Part 1), IS:6926
29.	Crane	IS/ISO:4301 (Part 2), IS/ISO:4306 (Part 2), IS:4573, IS:13558, IS:13834, IS:13870, IS:14469, IS/ISO:8686 (Part 5), IS/ISO:4306 (Part 3)
30.	Mobile Air Compressor	IS:6430
31.	Electric Genset	IS/ISO:8528

APPENDIX-IV

EQUIPMENT CALIBRATION

Bulk of the equipment used for construction, operation, maintenance or inspection/testing (quality control) of roads, bridges and tunnels involves use of measuring devices (e.g. load cells, temperature/ pressure gauges, flow meters, proving rings etc.) to monitor various performance parameters. The accuracy of these measuring devices is critical to the success and longevity/quality of the concerned project. It is, therefore, imperative that every equipment equipped with measuring devices be calibrated.

Calibration is the process of adjusting the settings for known levels of accuracy. Every time a measurement is made, there is an actual result/ value and a measured result/ value. Due to randomness and variability with a definite pattern, the measured value usually differs from the actual value. Calibration is done to identify/ rectify the non-random variability or account for it in such a way that the difference between the actual and measured results is negligible and within acceptable limit. Calibration is done using a reference or standard instrument, which is used to determine the actual result against which the result measured by the device to be calibrated is compared.

The accuracy of any equipment degrades with time due to various factors like normal wear and tear, electrical or mechanical shock, hazardous working environment etc. Calibration restores the accuracy of such equipment so that reliability in terms of quality and/or quantity can be ensured.

To ensure valid results, every equipment should be calibrated or verified prior to use and also at regular intervals, as specified by the manufacturer or relevant IRC/BIS Code, whichever is earlier. Calibration shall always be done against measurement standards traceable to national or international measurement standards, and where such standards do not exist, the basis for calibration or verification needs to be documented.

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(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)