Introduction to Road Materials Engineering

Part 1: Components, Soils, Aggregates, Road Construction

Presented by SARF

Presenter:
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INTRODUCTION TO ROAD MATERIALS ENGINEERING

Main aims of this course:

To achieve a PRACTICAL understanding of WHERE, WHY, and HOW the different types and qualities of materials are used in road construction

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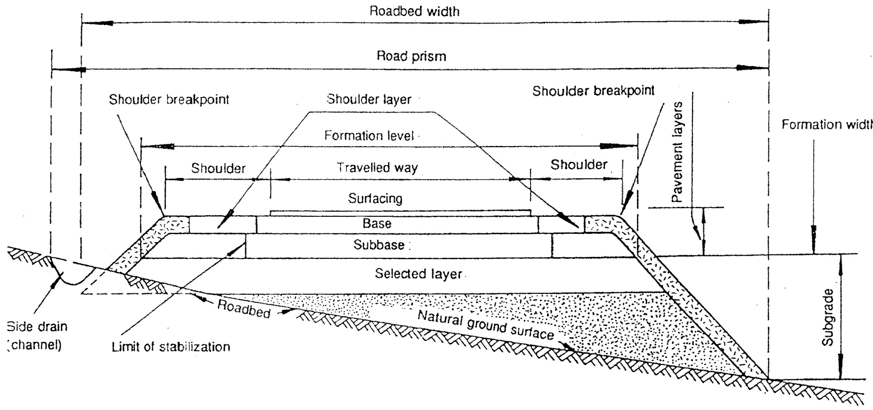
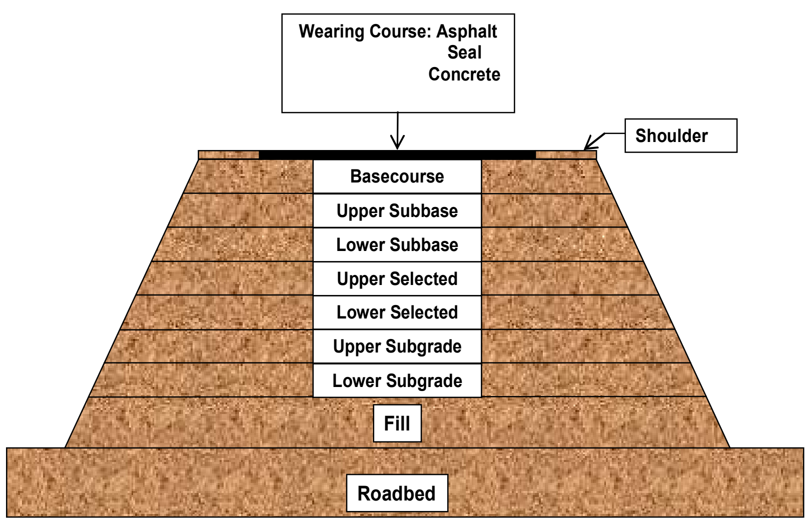
INTRODUCTION TO ROAD PAVEMENTS



Typical road pavement structure



Pavement types

Flexible pavements

Well-graded crushed stone base

Water-bound macadam base

Pavement types

Flexible pavements

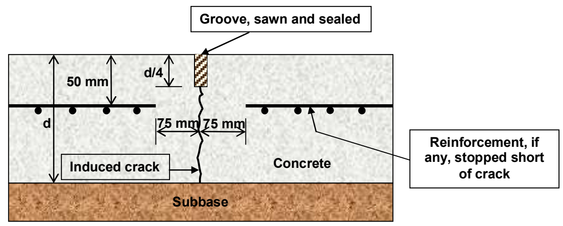
Hot-mixed asphalt base

Stabilized base

Pavement types
Rigid pavements

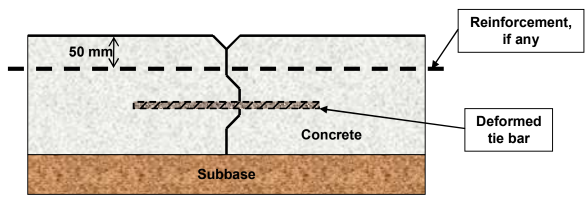
Jointed concrete (JCP)

Continuously reinforced concrete (CRCP)



Contraction Joint

Dowelled jointed concrete (Dowelled JCP)

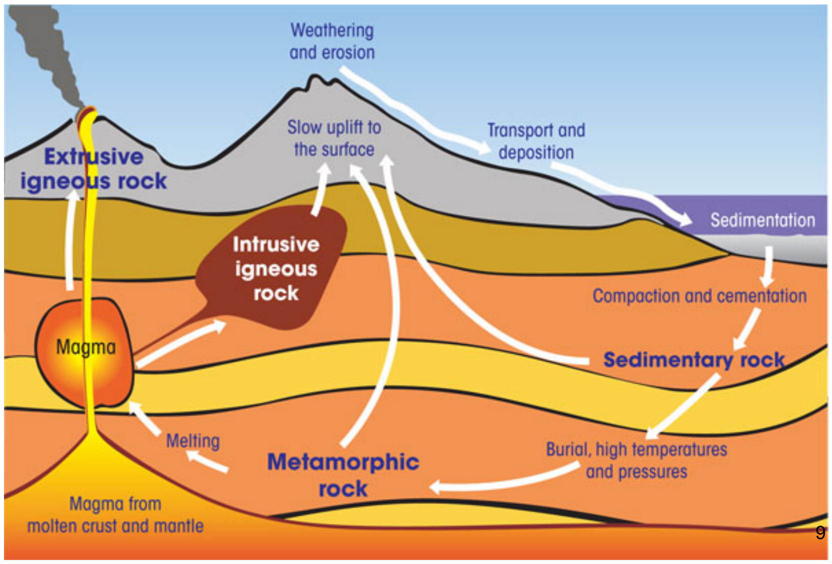


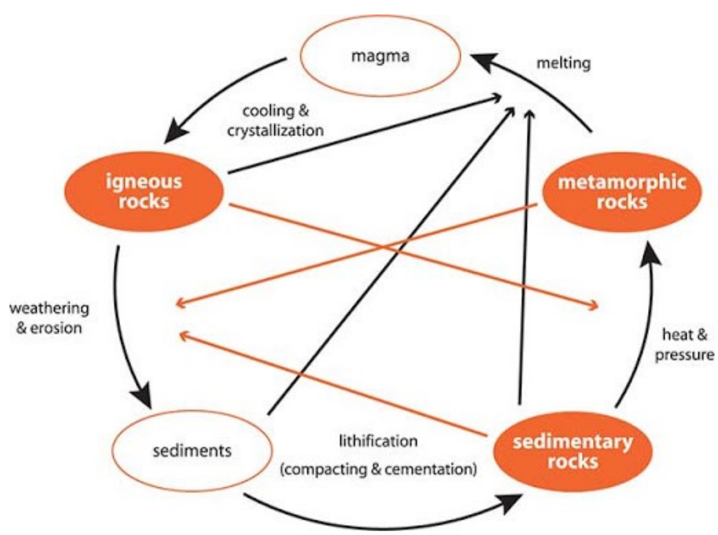
Construction Joint

Pavement types
Segmented block pavements

Where does soil come from?

The Rock Cycle:





Rock Cycle

https://www.youtube.com/watch?v=EGK1KkLjdQY

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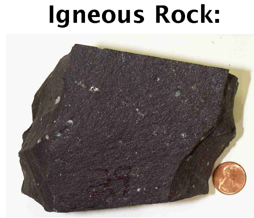
Igneous Rock:

Basalt:



Porphyry:

Granite:

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Types of Igneous Rock

https://www.youtube.com/watch?v=PrN7jygu4cQ

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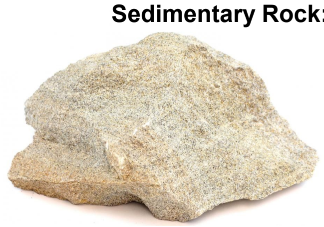
Sedimentary Rock:

Sand Stone:



Shale:

Dolomite:

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Sedimentary Rock types

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https://www.youtube.com/watch?v=uozyWZ6XQzM

Metamorphic Rock:

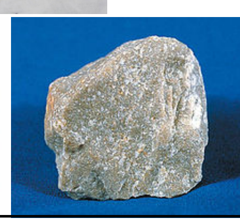
Marble:

From Limestone or Dolomite

Slate:

From Shale

Quartzite:



From sandstone

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Metamorphic Rock types

Scheme for Metamorphic Rock Identification

TEXTURE		GRAIN SIZE	COMPOSITION	TYPE OF METAMORPHISM	COMMENTS	ROCK NAME	MAP SYMBOL
FOLIATED	MINERAL ALIGNMENT	Fine	MICA	Regional	Low-grade metamorphism of shale	Slate	
FOLIATED	MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET	(Heat and pressure increase with depth)	Foliation surfaces shiny from microscopic mica crystals	Phyllite	
FOLIATED	MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET		Platy mica crystals visible from metamorphism of clay or feldspars	Schist	
FOLIATED	BAND-ING	Medium to coarse	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE		High-grade metamorphism; some mica changed to feldspar; segregated by mineral type into bands	Gneiss	
NONFOLIATED		Fine	Variable	Contact (Heat)	Various rocks changed by heat from nearby magma/lava	Hornfels	
NONFOLIATED		Fine to coarse	Quartz	Regional or Contact	Metamorphism of quartz sandstone	Quartzite	
NONFOLIATED		Fine to coarse	Calcite and/or dolomite	Regional or Contact	Metamorphism of limestone or dolostone	Marble	
NONFOLIATED		Coarse	Various minerals in particles and matrix	Regional or Contact	Pebbles may be distorted or stretched	Metaconglomerate	

ShowMe.com

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https://www.youtube.com/watch?v=D4eG_8v4Rfk

What do we mean by SOILS and AGGREGATES ?

Typical soils profile

Top soil – humus enriched, fertile

Sandy or clayey soil, gravel – transported or residual

Weathered or fresh rock

Quality improves

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What do we mean by SOILS and AGGREGATES ?

Typical soils profile

Soils

Top soil – humus enriched, fertile

Sandy or clayey soil, gravel – transported or residual

Weathered or fresh rock

Rock – crushed to produce aggregates

What do we mean by SOILS and AGGREGATES ?

Typical soils profile

Top soil – humus enriched, fertile	Remove, stockpile, spread & re-vegetate	
Sandy, clayey or silty soil, gravel – transported or residual	Use in fill and lower layerworks	*Cuts or borrowpits*
Weathered or fresh rock	Crush into various sized aggregates for use in upper pavement layers, chip seal surfacings, asphalt and concrete	*Quarries*

Most important properties of soils:

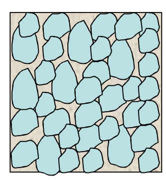
- Grading
- Plasticity
- Strength

Grading

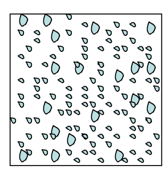
(Particle size distribution)

Poorly graded materials

Coarsely graded –large particle sizes



Finely graded – small particle sizes



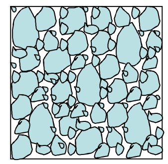
But both are poorly graded !

(poor particle distribution)

Grading

(Particle size distribution)

Well graded materials



Good particle distribution –

The different sized particles "pack' into the available spaces

Can be described as "continuously graded"

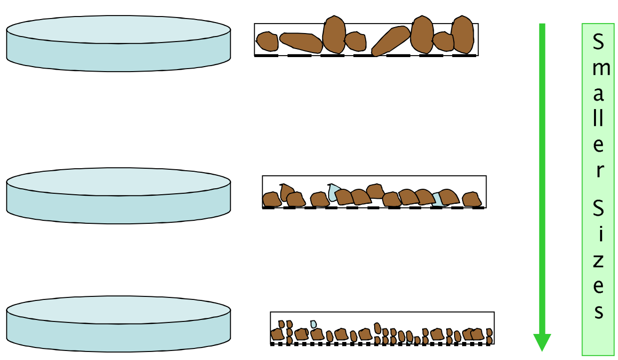
Comparison with poorly graded materials:

- higher degree of compaction possible
- reduced permeability
- usually higher strengths

Coarse well graded – large maximum size

Fine well grade – small maximum size

Grading

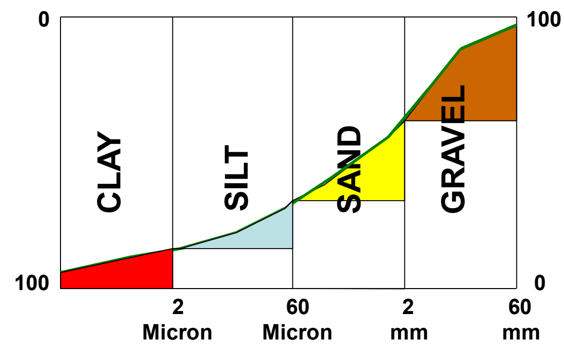


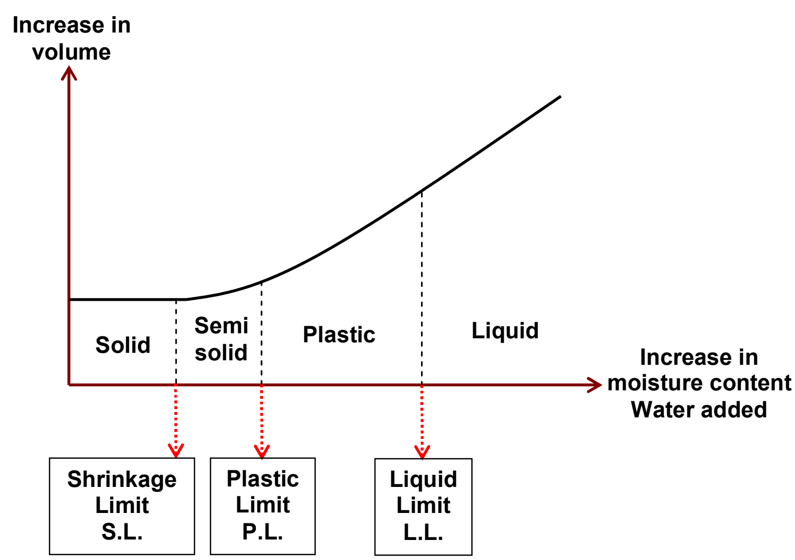
Nest of sieves

INDICATOR TESTS

GRADING ANALYSIS

Classification according to particle size





INDICATOR TESTS

ATTERBERG LIMITS

← PI →

SOLID	PLASTIC	LIQUID

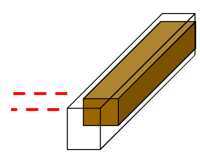
Dry — Add Water → Wet

PL = Moisture Content @ the Plastic Limit

LL = Moisture Content @ the Liquid Limit

PI = LL – PL = Plasticity Index

Liquid limit device – used to determine liquid limit



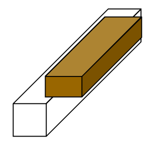
Linear shrinkage trough – used to determine linear shrinkage

INDICATOR TESTS

LINEAR SHRINKAGE

LS = Linear Shrinkage of the soil fines from the Liquid Limit test in a metal trough on drying

Provides a useful check of plasticity and moisture sensitivity
(2 x LS = roughly PI)



GRADING, PI and LS can with experience and knowledge of the soil type provide a very good preliminary guide to the engineering properties of a soil

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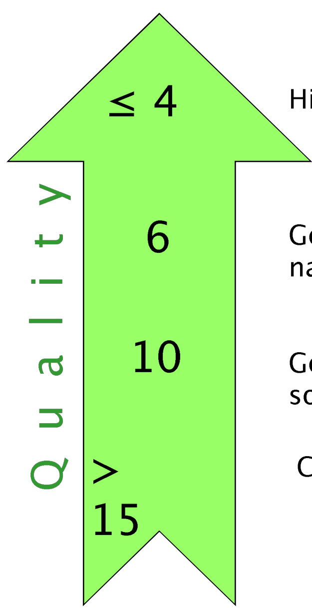
The most important properties of soils and aggregates

Indication of quality based on plasticity index (PI)



High quality crushed stone, sand

Good quality crushed stone and natural gravel

Good quality natural gravel, sandy soils

Clayey soils

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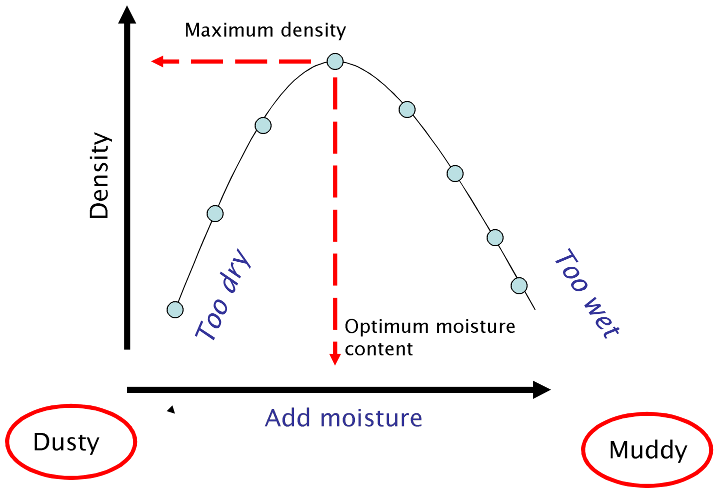
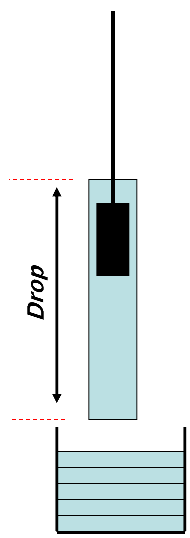
Moisture/density relationship



Moisture/density relationship



Modified AASHTO Maximum Dry Density Test
[TMH1 – A7] Revised SANS 3001-GR30

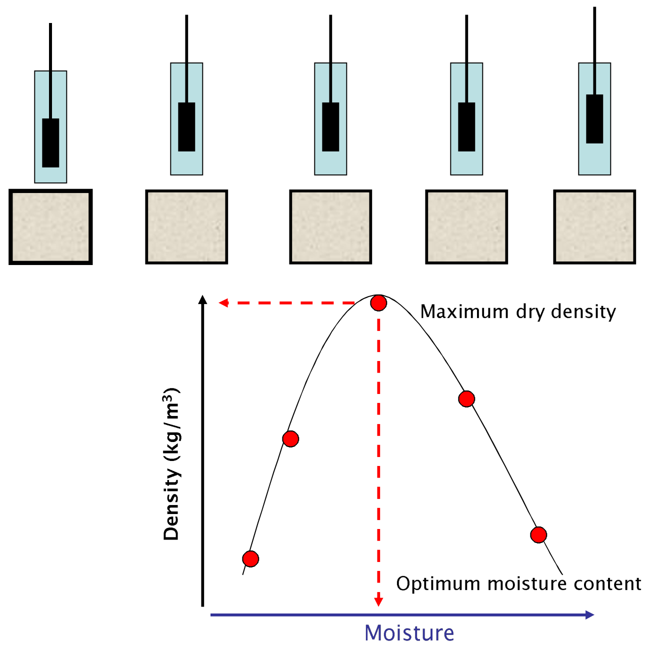
Uses standard mould, rammer, drop, number of layers and blows

To provide a STANDARD COMPACTIVE EFFORT

The material is prepared by screening on a 19mm sieve, the oversize material is lightly crushed and added back into the sample

5 samples are compacted at a range of moisture contents

The most important properties of soils and aggregates



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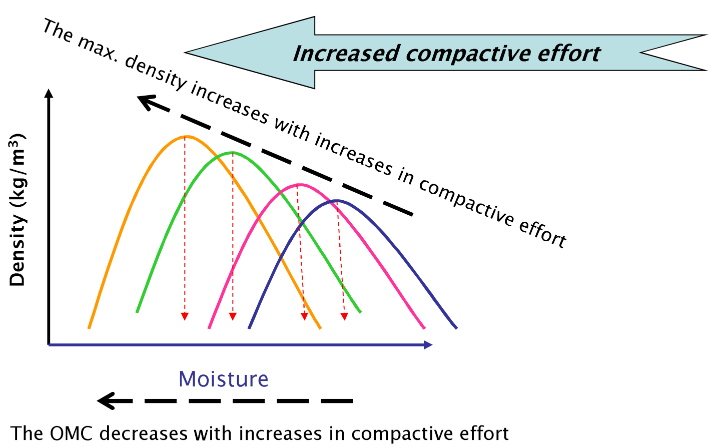
The most important properties of soils and aggregates



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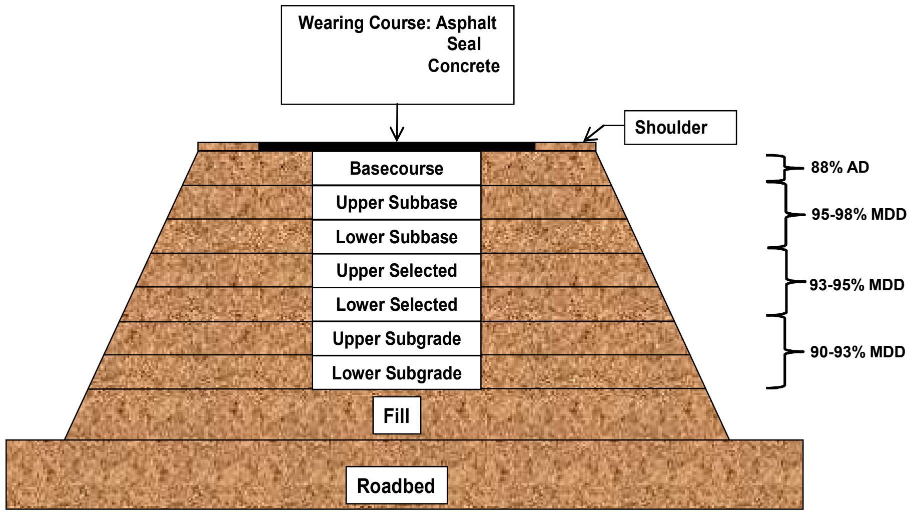


RELATIVE COMPACTION

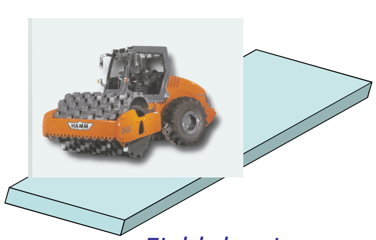
When the actual density obtained is compared to the Standard Density the result, in percent, is termed the Relative Compaction

For Example:-

Field Density = 1985 kg/m^3

MDD = 2120 kg/m^3

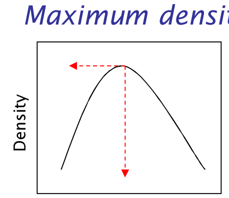
Relative Compaction (MDD) = 1985 ÷ 2120 X 100 = 93.6%



Field density

/

Maximum density



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RELATIVE COMPACTION

CALIFORNIA BEARING RATIO (CBR)

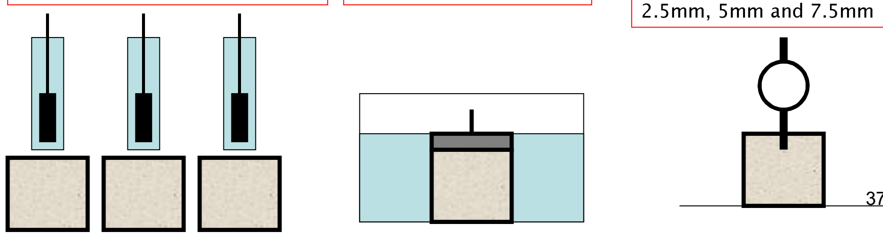
CRUDE TEST OF (BEARING) STENGTH

- Samples prepared at MDD OMC using three compactive efforts which give: 100%, about 96% and 93% Relative Compaction
- After soaking, a standard plunger (2ins Diam) is forced into the sample and the resisting force is measured at 2,5mm, 5mm and 7,5mm penetration
- The resisting force is divided by the Standard Force (OJ Porter) to give the CBR

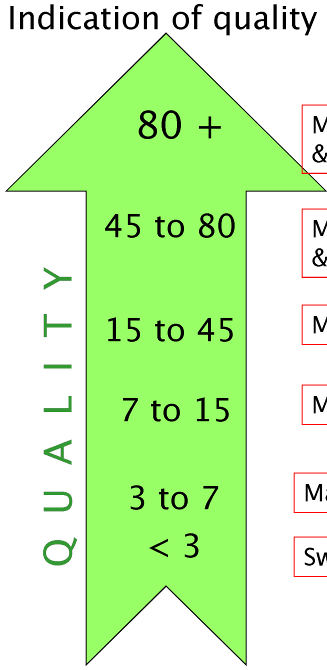
Prepare 3 moulds at OMC using different compaction efforts

Soak in water bath for 4 days, measure "SWELL"

Penetrate in press, measuring resisting force at depths of 2.5mm, 5mm and 7.5mm



Indication of quality based on CBR value



Max swell 0.2 %. High quality crushed stone & gravel

Max swell 0.5 %. Good quality crushed stone & gravel

Max swell 0.5 %. Good quality natural gravels

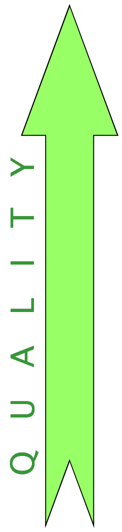
Max swell 1.5 %. Gravel soils

Max swell 1.5 %. Sandy soils

Swell > 1.5 %. Unsuitable soils

TRH 14 : 1985 Guidelines for road construction materials

Properties of untreated materials



Type	Summary of Requirements	
Graded crushed stone	G1	Crushed from solid good rock. Strict grading requirement. Non-parent fines disallowed. High degree of compaction specified – typically 89% ARD. LL max 25, PI max 4, LS max 4, ACV max 29%, 10% FACT min 110 kN
	G2 & G3	Crushed from rock, boulders, or coarse gravel. Strict grading requirement. May include non-parent fines. LL max 25, PI max 6, LS max 3. CBR ≥ 80, Swell max 0.2%
Natural gravels	G4	Natural gravel that may require crushing. Grading specified. May contain non-parent fines. LL max 25, PI max 6, LS max 3. CBR ≥ 80, Swell max 0.2%
	G5	Natural gravel that may require crushing. LL max 30, PI max 10, LS max 5, CBR ≥ 45, Swell max 0.5%
	G6	PI ≥ 12 or 3GM+10. CBR ≥ 25 at 93% compaction. Swell max 1.0%
Gravel - soils	G7	PI ≥ 12 or 3GM+10. CBR ≥ 15 at 93% compaction. Swell max 1.5%
	G8	CBR ≥ 10 at 90% compaction. Swell max 1.5%
	G9	CBR ≥ 7 at 90% compaction. Swell max 1.5%
	G10	CBR ≥ 3 at 90% compaction. Swell max 1.5%

Note: Some additional requirements in COLTO

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Problem materials

Type	Situation	Remedy
Soft soils	Vlei and estuarine. Prone to settlement	Investigate extent to decide most practical treatment. Consider: • remove and replace • install subsoil drainage • install geofabrics • treat (stabilize) with lime
Expansive clays	Use PI and clay component with van der Merwe activity chart. Usually: LL > 30, PI >12, LS >8	Investigate extent to decide most practical treatment. Consider: • remove and replace at least 600mm with stable material • stabilize with lime • employ methods to keep moisture content stable
Collapsible soils	Typically low density sandy materials which densify at high moisture contents.	Consider impact rolling or ripping and recompacting to at least 600mm
Dispersive soils	Soils form dongas, gullies and tunnels. Contain sodium or lithium ions	Minimum use of these materials in fills. Consider: • removal to depth of at least 600mm • treat with gypsum

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Aggregates

Typical sieve sizes

Sieve Size (mm)	Class.
37.5	C
28.	O
20.	A
14	R
10	S
7	E
5	
2	F
1	I
0.600	N
0.300	E
0.150	
0.075	Filler

Single sized aggregates for surfacing

Sieve Size (mm)	20 Nominal size	14 Nominal size	10 Nominal size	7 Nominal size
37.5				
28	100			
20	85-100	100		
14	0-30	85-100	100	
10	0-5	0-30	85-100	100
7		0-5	0-30	85-100
5			0-5	0-30
2				0-5
1				
0.600				
0.300				
0.150				
0.075				

The nominal maximum particle size (NMPS) is the one sieve size larger than the largest sieve to retain a minimum of 15 percent of the aggregate particles

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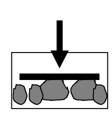
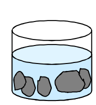
The most important properties of soils and aggregates

Aggregates

Most important properties:

- Grading 
- Shape 
- Strength 
- Durability 

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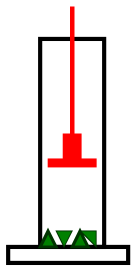
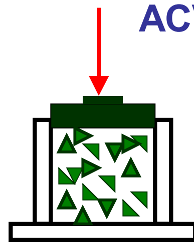
Aggregate Strength Tests

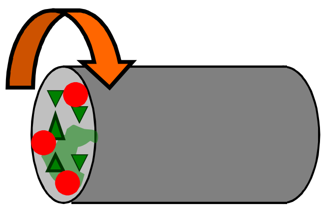
Treton





ACV : % Fines
@ 400kN Load

10%FACT : Load
to Generate
10% Fines



Modified Ball-Mill
60 rpm for 10mins
B-M I = P0,425 x PI
Using max values

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AGGREGATE STRENGTH

- ✓ Treton Test - Impact Resistance on
  -20mm +16mm stone

- ✓ Aggregate Crushing Value (ACV) and
  10%FACT : (SANS 3001 – AG10), wet and dry on
  -14mm + 10mm stone – Crushing Resistance

- ✓ Modified Ball-Mill Test, (SANS 3001 – AG16)
  wet and dry, on whole sample - Resistance to
  degradation during construction and during
  pavement life

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Basic compaction technology

STATIC ROLLER

Used mostly for compacting hot-mixed asphalt and in the construction of chip seals . Some road authorities prefer to use it for compacting water-bound macadam

SMOOTH DRUM VIBRATING ROLLER

Extensively used for the compaction of rock-fill and soils in the construction of earthworks as well as the granular pavement layerworks

PADFOOT VIBRATING ROLLER

Used extensively used for compaction in the construction of earthworks and lower pavement layerworks. Breaks down soft rock such as mudstone and shale.

DOUBLE DRUM VIBRATING ROLLER

Compaction of hot-mixed asphalt

PNEUMATIC (RUBBER) TYRED ROLLER

Compaction of hot-mixed asphalt, as well as in the construction of chip seals

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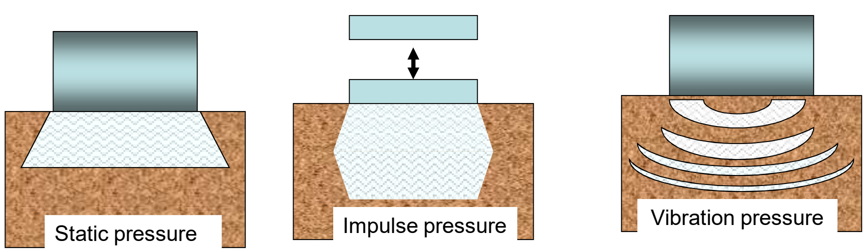
Basic compaction technology

Main forms of compaction

Static | Impact | Vibration



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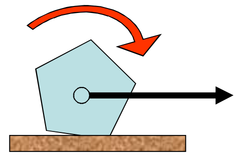
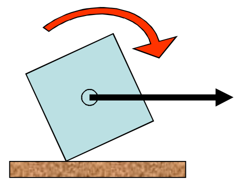
Impact rollers

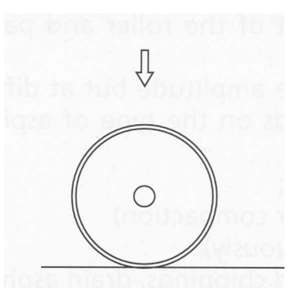
Used for compaction of earthworks. Useful in dry regions and for compaction of collapsible materials

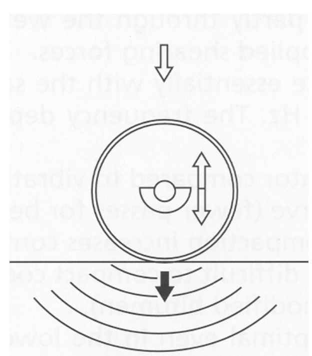
Impact rollers may be 4 or 5 sided





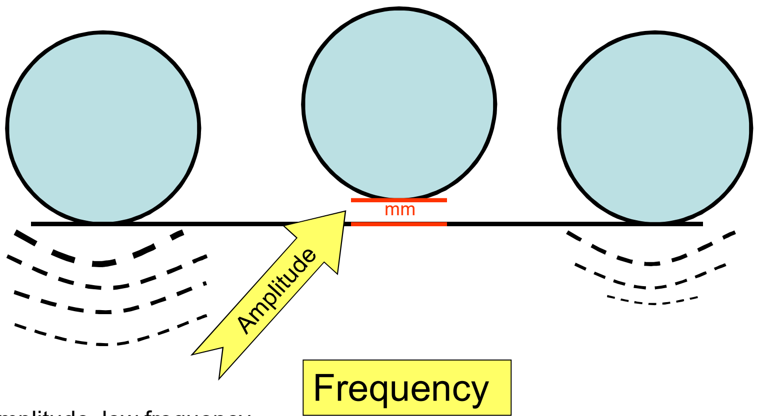
PRINCIPLES OF VIBRATORY COMPACTION



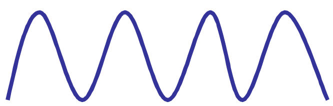


Static compaction *Vibratory compaction*

Principles of vibration rollers



High amplitude, low frequency



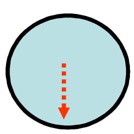
eg 30 Hz

High frequency, low amplitude

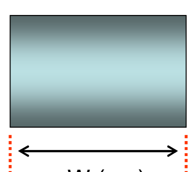
eg 50 Hz

Important criteria for vibratory rollers

Static linear load



Drum axle load (kg)



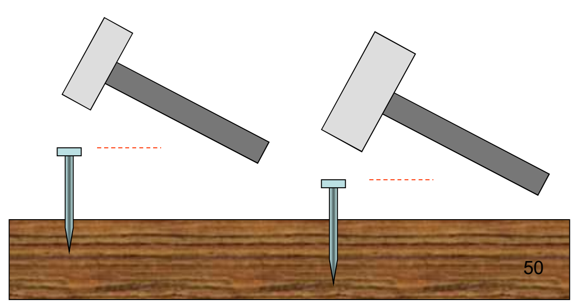
W (cm)

Depth of compaction is proportional to static linear load

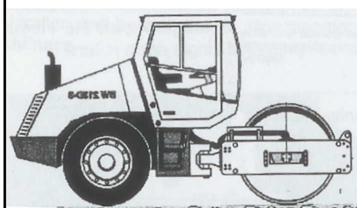
Static linear load = drum axle load ÷ drum width

Vibrating mass

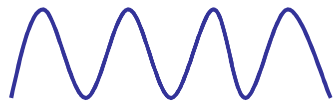
Higher vibrating mass = higher compaction performance



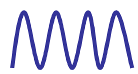
Vibratory roller settings for rockfill, soils and gravels



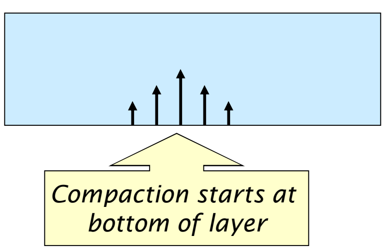
1. *Start the compaction using HIGH AMPLITUDE / LOW FREQUENCY setting*



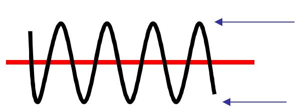
2. *Complete the compaction using LOW AMPLITUDE / HIGH FREQUENCY setting*



PRINCIPLES OF VIBRATORY COMPACTION

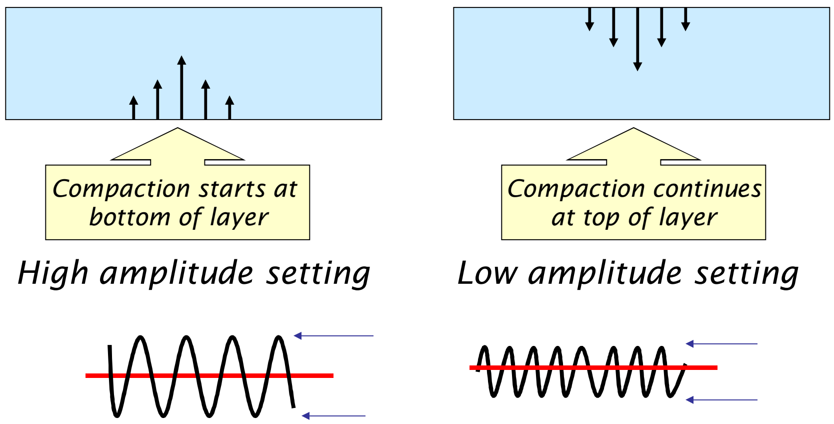


High amplitude setting



Basic compaction technology

PRINCIPLES OF VIBRATORY COMPACTION



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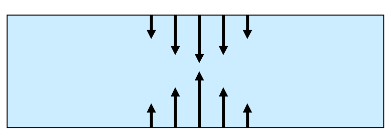
Basic compaction technology

PRINCIPLES OF VIBRATORY COMPACTION



The result:

The full thickness of the layer is properly compacted

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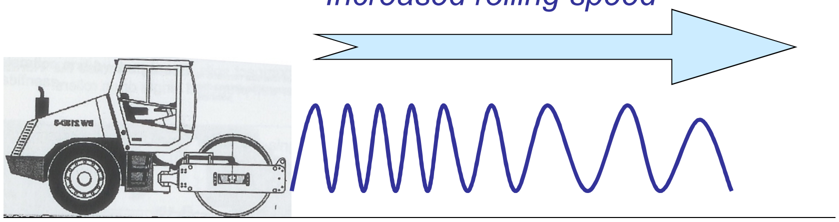
Effect of rolling speed on compaction

Increased rolling speed



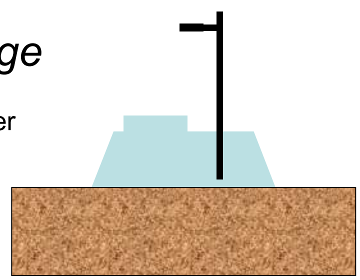
The number of vibration impacts decreases as speed increases causing reduction in compaction – required more passes to achieved same level of compaction

TYPICAL OPTIMUM ROLLER SPEEDS	
Rockfill	1 – 2.5 km/h
Gravel, sand	2 – 4 km/h

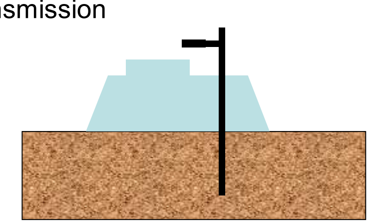
Measurement of compaction

Nuclear gauge

Back scatter



Direct transmission



Measurement of compaction

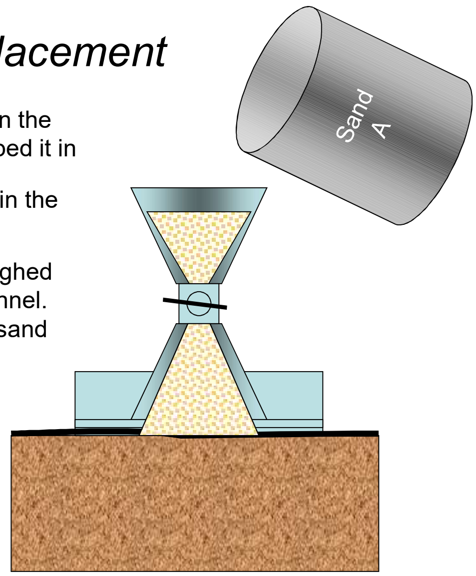
Sand replacement

Place the density ring on the pavement surface and bed it in

Seat the density funnel in the ring

Pour the calibrated, weighed sand into the density funnel. Close the tap once the sand has stopped running in

Pour the sand in the top of the density funnel back into the container

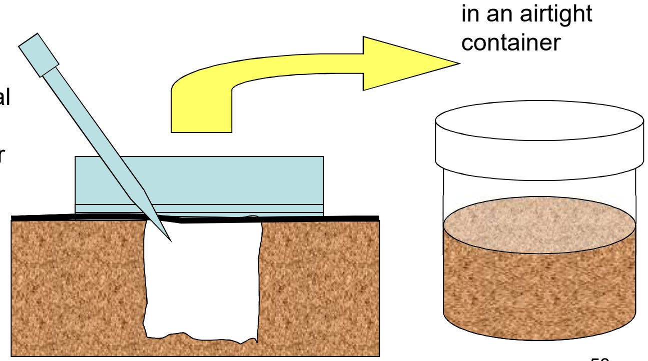


Measurement of compaction

Sand replacement

Remove material from the compacted layer using a chisel

Place the material in an airtight container

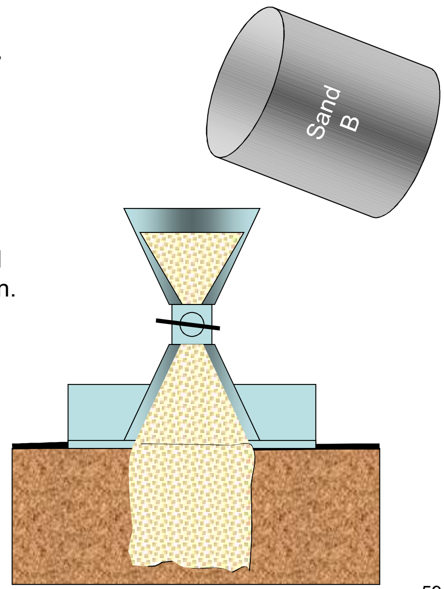


Measurement of compaction

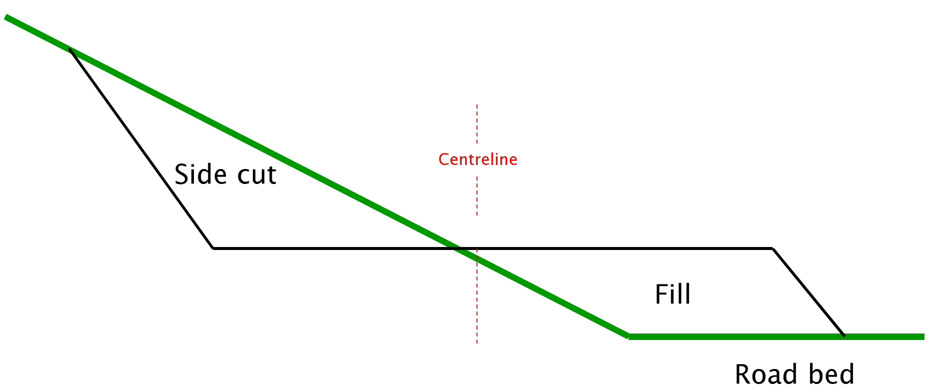
Sand replacement

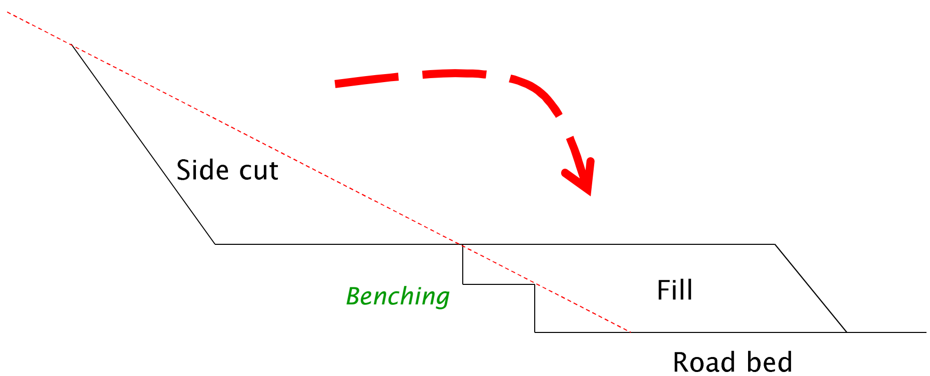
Once the hole is complete, refit the density funnel to the ring

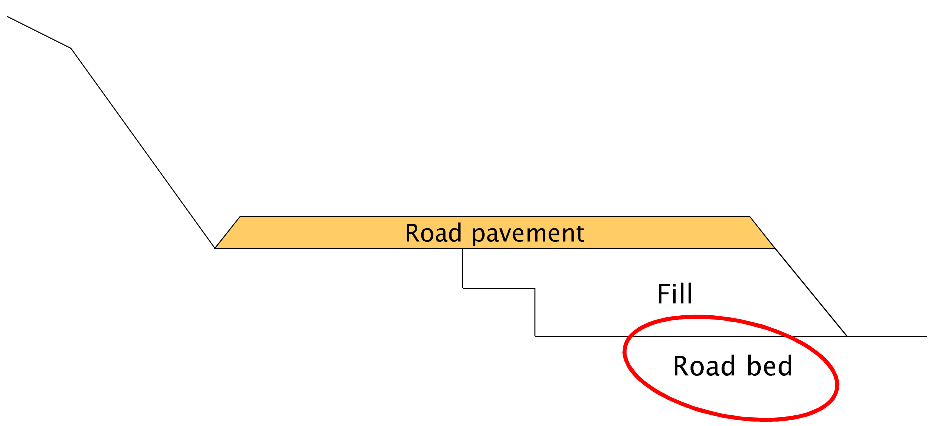
Pour in the calibrated, weighed sand into the funnel until it stops running in. Close the tap and transfer the sand from the top of the funnel into the container



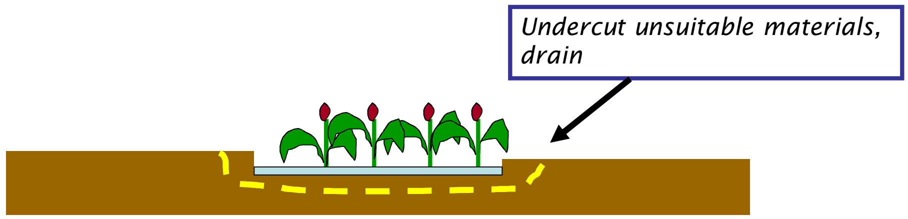
Road construction



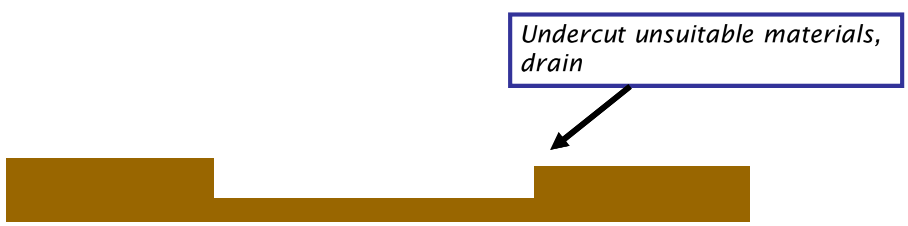

Side cut
Benching
Fill
Road bed


Road pavement
Fill
Road bed

Roadbed preparation

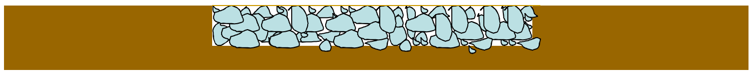


Roadbed preparation



Roadbed preparation

Replace with granular material



Compact the roadbed using a vibrating tamper roller – ensure that the roadbed is stable without signs of "heaving"

Normally minimum 90% Modified AASHTO compaction required

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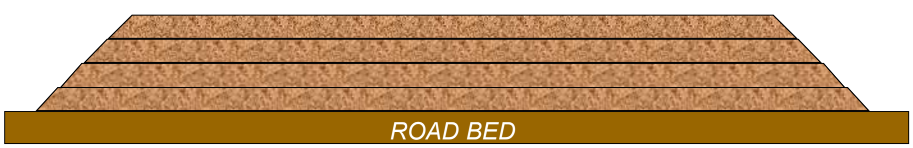
Fill construction

Compacted layer thickness ≤ 200 mm, except for rockfill

Minimum G10 quality



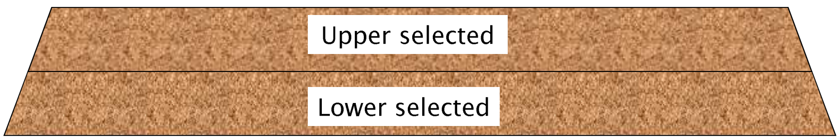
Normally compaction is minimum 90% Modified AASHTO

66

Road construction

Selected layers

Minimum G7 quality, compacted to min. 93% Mod. AASHTO



Minimum G9 quality, compacted to min. 93% Mod. AASHTO

The thickness of the selected layers are normally 150 mm

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Road construction

Subbase

Granular pavement types

- G5 or G6 (for lighter pavement designs

Stabilised subbase pavement types

- C3 or C4 (usually heavier pavement designs

The subbase layer is compacted to 95% to 98% Modified AASHTO depending upon the pavement design

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Base
Flexible pavements

Well-graded crushed stone base

G1 – very high quality, well-graded crushed stone, compacted to min. 89% ARD

G2 – high quality, well graded crushed stone, compacted to min. 85% BRD

Water-bound macadam base

WB – high quality, large, single sized crushed stone, with finely graded, clean crusher dust vibrated into voids. Usually constructed and compacted in accordance to method specification

Base
Flexible pavements

Hot-mixed asphalt base

Normally continuously graded mix. Usually reserved for heavier pavement designs

Stabilised base

Normally restricted to lighter pavement designs in areas where other pavement designs are not feasible. Prone to block cracking