HIGHWAY ENGINEERING
SAB2832

ROAD CONSTRUCTION

CHE ROS ISMAIL (FKA, UTM)

cc BY NC SA

ROAD CONSTRUCTION

1. REVIEW MATERIALS
2. INTRODUCTION
3. SURVEY AND ALIGNMENT
4. SITE CLEARING
5. EARTHWORK
6. DRAINAGE WORK
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INTRODUCTION

- Aspects to be considered in road construction:
  - Terrain – capacity, cost, speed, earthwork
  - Soil properties – cost, treatment
  - Environmental impact - minimize
  - Economy and socio-economy – cost & benefit, finance
  - Politics – involve other country
  - Historical – heritage building, cemetery

SURVEYING & ALIGNMENT 1

- Involve measurement of angle, distance and height
- Data used to produce maps, contour, and other related drawings
- Five types of drawing in road works:

1. Map – scale 1:50,000 to 1:1250
2. Plan – produced form site survey, showing project location, drawn on 1:500 to 1:50 scale

SURVEYING & ALIGNMENT 2

3. Longitudinal section – showing ground levels along road CL, same scale as plan & drawn on the same sheet. Vertical scale usually exaggerated for ease of use.
4. Cross section – at bigger scale, numbered for reference according to chainage , compiled togeter under seperate drawing sheets.
5. Detail drawings – showing all details clearly, scale from 1:20 to 1:1, e.g culvert detail, pipe, retaining wall, etc.

SURVEYING & ALIGNMENT 3

- Surveying techniques have drastically changed with the aids of modern equipments and computer softwares.
- Generally there are four major processes:

1. Reconnaissance survey of the entire area – planning (aerial photo)
2. Reconnaissance survey of feasible route - planning
3. Preliminary survey of the best route - data used to produce map, plans, section drawings, etc.
4. Location survey ang site setting out – setting out points on site according to drawings e.g ROW, alignment, CL, leveling, etc.

SURVEY

SITE CLEARING - Rural

- Site clearing in rural area composed of three major processess:
- 1. Clearing – cutting/taking down, removal and disposal of everything above ground level
- 2. Grubbing – removal and disposal of surface vegetation, bases of stumps, roots, underground parts of structures, and other obstructions to a depths of at least 500 mm below ground level.
- 3. Stripping of topsoil – removal of topsoil to an average of 100 mm below ground level, and its stockpiling for use and/or disposal.

SITE CLEARING - Rural

- Clearing, grubbing, stripping of top soil shall be carried out in all areas of roadway excavation and embankment.
- Combustible materials may be piled up within the road reserve and burned, where burning is allowed, if not all unwanted material shall be disposed of in a safe and tidy manner at solid waste dump outside the site.

Undeveloped

SITE CLEARING - Developed

- Developed area – usually takes longer time and involve higher cost.
- Relocation of service line and structure on and underground.
- Details such as water supply pipe, electrical cable telephone, gas etc. have to be established to avoid service disruption and relocation works
- Cross section surveying will be carried out, cut and fill marker will be pegged after upon completion of the site clearing.

developed

SITE CLEARING- Developed

- Another aspect to be considered is disruption to traffic flow have to be minimized by providing proper or better detour or alternative route.
- Traffic signs and guide signs shall be posted to ensure smooth flowing and safety of traffic during construction
- Traffic control may be required in certain cases

Traffic Control

EARTHWORKS - Definition

- ***Definition:***

1. Formation level/subgrade –top surface of subgrade
2. Common excavation – any material not rock or hard
3. Unsuitable materials – silt, peat, stumps, mud, combustible, toxic, etc, LL >80, PI >55
4. Rock or artificial hard materials - need blasting or pneumatic tools, exclude can be loosened by track type tractor or ripper

Formation/Subgrade

Normal excavation

EARTHWORKS 2

- Consist of excavation, backfill, transportation, stockpiling, spreading, compaction, forming embankment and slopes, etc as is necessary up to the formation levels as shown on the drawings.
- Tests conducted on soil, if found to be unsuitable (e.g. organic, marine clay) need to be treated, remove and replaced with suitable material
- Provide temporary water course, ditches, drains, pumps and silt trap to maintains earthworks free from water.

USM

Vertical Drain

EARTHWORKS 3 – Cut & Fill

- Excavation – excavation of material from cutting area to fill area or dispose
- Backfilling – soil need to be replaced or formation level higher
- Works carried out according to mass-haul diagram (earthwork management i.e., design, financing, choice of plants, project & future planning)
- Suitable & unsuitable material need to be separated
- Excavation of rock/hard materials – use appropriate and safe methods
- All fill materials shall the suitable materials, deposited in layers of suitable thickness for proper compaction
- Thickness determine tru trial lay (min 8m x 15m)

Cut

EARTHWORKS 4 - Compaction

- Soil properties improved – bearing capacity, permeability, compressibility
- Factors affecting compaction – soil characteristics, moisture content, plants, layer thickness
- Conduct lab compaction test (BS 1377, 4.5 kg) to determine MDD and OMC
- Field compaction carried out as soon as the material is spread
- No. of passes, layer thickness, determine tru trial lay at OMC (max thickness 300mm), conduct FDT
- Control MC – wet, dry, replace

EARTHWORKS 5 – Formation

- Subgrade to be compacted with suitable compactor at OMC.
- If necessary prior to compaction material shall be watered, dried, or replaced with new material to bring its moisture content to a uniform level, suitable for compaction
- For top 300mm, compacted to > 95 % for cohesive and 100% for cohesionless material of the MDD obtained in the lab.
- Cut area - top 300 mm scarified and re-compacted to the required density.
- If in its natural state possesses a density exceeding requirement, surface trimmed and rolled to obtain smooth finish
- The top surface shall have the required shape, superelevation, level and grades (within +10mm and -30mm of required level)

FDT – Sand Replacement

EARTHWORKS 6 – Compactor

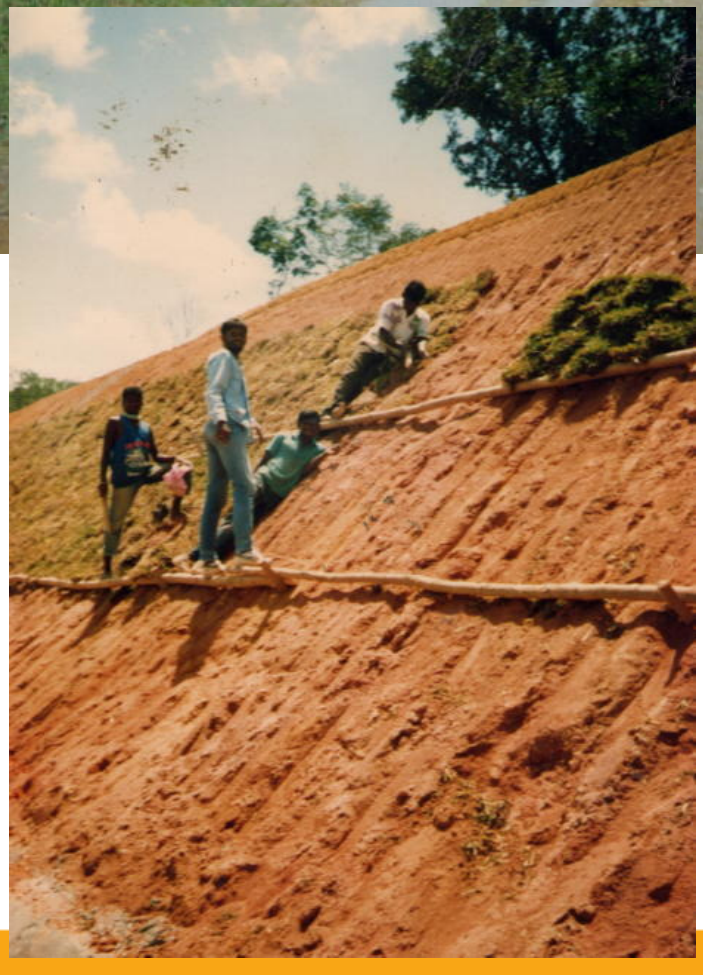
- Smooth wheel – compaction by dead weight, additional pressure (ballasted with water/sand), vibrate, for granular and premix
- Pneumatic – 12 > 200 ton, for cohesive, sandy soil, premix, surface dressing
- Vibratory – rearrange soil grains through vibration, suitable for coarse grained soil
- Sheep foot – compact from bottom upwards, 3 > 27 ton, for clay, silt, fine grained soil

Smooth wheel

EARTHWORKS 7 - Turfing

- ***Protective Vegetation (Erosion Control)***
- Topsoil spread and lightly compacted, thickness 50mm
- Block 250 x 250 mm, free of lallang and weeds
- Slope steeper than 1:3, pegged with bamboo stakes
- Seeding/hydroseeding – submit 4 weeks in advance with proposed method and material
- All turf shall be regularly watered and fertilised
- Dead turf to be replaced with new turf

TURFING



PAVEMENT WORKS

- Consists of:
- Drainage layer
- Subbase
- Roadbase
- Coating
- Surfacing
- Shoulder

PAVEMENT WORKS 1 – Drainage Layer

- ***Laying and compaction of drainage layer***
- Laid on a prepared and accepted subgrade (any damage or deterioration on subgrade shall be made good before laying drainage layer).
- Coarse aggregate (screened crushed hard rock), fine aggregate (screened quarry dust or sand)
- Laid and compacted at MC +1 to -2% of OMC without drying out or segregation to the required width and thickness

PAVEMENT WORKS 2 - Subbase

- Material – natural or artificial mixture of locally available material such as sand, gravel, crushed aggregate, free from organic matter, clay lumps and other deleterious materials.
- Spec: CBR soaked ≥ 30% (if ≥ 10% retained on 20mm, can be assumed passed), PI ≤ 12, TFV ≥ 30kN, sand equivalent ≥ 45
- Laid in 100 - 200 mm compacted thickness, compacted at MC +1 to -2% of OMC without drying out or segregation to the required width and thickness
- Compaction in longitudinal direction, lower edge towards the crown, in superelevation towards the upper edge to produce density ≥ 95% MDD

PAVEMENT WORKS 3 - Roadbase

- ***Crushed Aggregate Roadbase***
- Material – crusher rock, crushed gravel or a mixture or crushed rock and gravel
- Spec: PI ≤ 6, ACV ≤ 25, FI ≤ 30, Soundness ≤ 18, CBR ≥ 80, sand equivalent ≥ 45
- Spread using motor grader or approved spreader at OMC ± 1%, laid in 100 - 200 mm compacted thickness, maintain uniform gradation, prevent drying out or segregation to the required width and thickness
- Compaction in longitudinal direction, lower edge towards the crown, in superelevation towards the upper edge to produce density ≥ 95% MDD

Roadbase

PAVEMENT WORKS 3 - Roadbase

- ***Wet Mix***
- Material – crusher rock, crushed gravel or a mixture or crushed rock and gravel
- Spec: ACV ≤ 25, FI ≤ 30, Soundness ≤ 18, sand equivalent ≥ 45
- Spread using paving machine at OMC ± 0.5%, laid in 100 - 200 mm compacted thickness, maintain uniform gradation, prevent drying out or segregation to the required width and thickness
- Compaction in longitudinal direction, lower edge towards the crown, in superelevation towards the upper edge to produce density ≥ 95% MDD

PAVEMENT WORKS 3 - Roadbase

- ***Bituminous Roadbase***
- Material – conform to the physical and mechanical quality requirement in asphaltic concrete section
- Design, equipment and construction methods as specified for asphaltic concrete section.

PAVEMENT WORKS 4 - Coating

- Two types of coating:

1. Prime coat – liquid bitumen, sprayed onto clean unbound roadbase using pressure distributor at the rate of 0.5 – 1 liter/m^2
   - MC-70 (50°C -70°C), SS-1K (25°C - 45°C) cured for 24 hours to achieve maximum penetration
2. Tack coat – bitumen emulsion, sprayed onto bituminous layer, rate 0.25 – 0.55 liter/m^2
   - RS-1K, 25°C - 45°C

- Carried out in dry, warm weather and dry surface, prevent spattering adjacent trees, furniture etc, not to be discharged into drains, gutter, keep traffic off
- Equipment – power broom, compressed air blower, pressure distributor

Spraying

PAVEMENT WORKS 5 - Surfacing

- ***Asphaltic Concrete***
- Binder course will be laid on the broomed, clean and prime coated roadbase.
- Laying and compacting job shall be carried out in dry weather
- After binder course has been properly compacted, sprayed with tack coat, wearing course will then be laid and compacted
- Bituminous mix for surfacing shall pass all tests specified for aggregate, bitumen, and bituminous mixture.
- Aggregate: LAAV $\leq$ 25, soundness $\leq$ 18%, FI $\leq$ 25, WA $\leq$ 2%, PSV $\geq$ 40, coating $\geq$ 95%, grading.

Brooming

PAVEMENT WORKS 6 - Surfacing

- ***Mix design***
- Bituminous mix has to be designed properly to obtain optimum quality.

1. Job Mix Formulae – carried out in the lab under controlled conditions for each type of mix
2. Plant trial – after approval of JMF, to mix, lay and compact. Minimum of 20 tonnes of HMA

- Each mix produced subjected to be tested according to Marshall procedure and volumetric properties and meet the specification in JKR/SPJ/2005:

Mix design

- Design objectives – Develop an economical blend of aggregates and asphalt that meet design requirements
- Historical mix design methods

1. Marshall – use impact hammer
2. Hveem – use kneading compactor

- New

1. Superpave gyratory – use gyratory compactor to simulate field compaction, able to accommodate large size aggregate

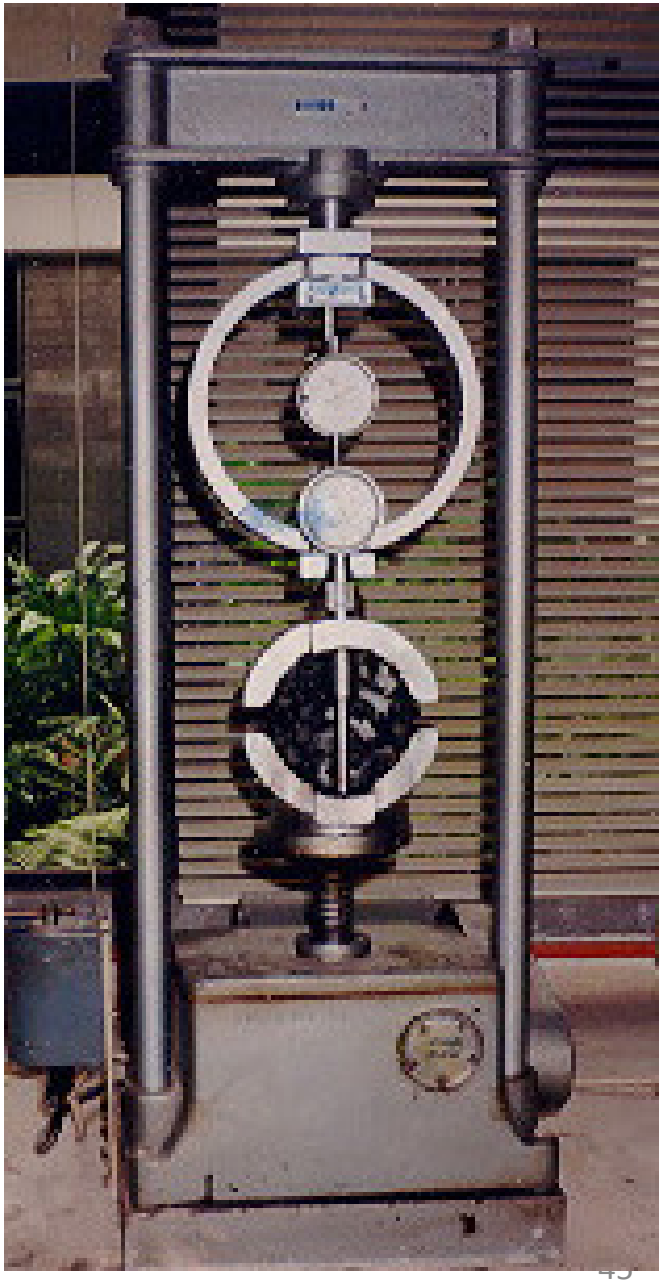
Requirements in Common

- Sufficient asphalt to ensure a durable pavement
- Sufficient stability under traffic loads
- Sufficient air voids
  - Upper limit to prevent excessive environmental damage
  - Lower limit to allow room for initial densification due to traffic
- Sufficient workability

Lab Mix - Procedure

1. Select and test: aggregate & bitumen
2. Select gradation
3. Develop trial blends
4. Calculate blended specific gravity – SG_{agg} blend
5. Establish mixing and compaction temperatures
6. Heat and mix bitumen and aggregates
7. Compact specimen (100 mm diameter)
8. Calculate bulk specific gravity of compacted samples
9. Stability and flow test (Marshall test)
10. Determination of optimum bitumen content (AI & NAPA)

Lab Mix – Marshall Test



Lab Mix – Marshall Form

%BIT SPEC. NO.	%BIT. SPEC. NO.	WEIGHT-gm			BULK VOL. cc.	SPEC.GRAV.	VOLUME-%TOTAL		VOIDS-%				STABILITY-kg			FLOW	STIFFNESS
		Saturated surface dry	IN AIR	IN WATER		BULK	MAX. THEOR.	BIT	AGG.	VOIDS	AGG.	FILLED (BIT)	TOTAL MIX		MEAS.	CORR.	mm	
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
%Bit. by wt. of Agg.	%Bit. by wt. of MIX.				c-e	d f		k x g SGbit	(100-k)g SGag	100-i-j	100-j	100(i/l)	100-(100g/h)	CORR FACTOR		p x o		s r
	4.50	1200.8	1195.3	685.9	514.9	2.321								1.00	1161	1161	3.27	
		1196.4	1193.7	685.9	510.5	2.338								1.00	1100	1100	3.17	
		1195.7	1192.7	685.4	510.3	2.337								1.00	1150	1150	3.33	
AVG						**2.332**	**2.498**	**10.2**	**83.2**	**6.6**	**16.8**	**60.6**	**6.6**			**1137**	**3.26**	**349.1**
	5.00	1197.9	1194.7	690.7	507.2	2.355								1.04	1191	1239	3.70	
		1195.8	1192.7	690.2	505.6	2.359								1.04	1163	1210	3.71	
		1200.5	1197.1	692.4	508.1	2.356								1.04	1151	1197	3.83	
AVG						**2.357**	**2.480**	**11.4**	**83.6**	**5.0**	**16.4**	**69.8**	**5.0**			**1215**	**3.75**	**324.3**
	5.50	1202.8	1199.9	695.2	507.6	2.364								1.04	1321	1374	4.30	
		1180.3	1176.4	682.7	497.6	2.364								1.04	1298	1350	4.29	
		1178.6	1174.8	681.2	497.4	2.362								1.09	1239	1351	3.93	
AVG						**2.363**	**2.461**	**12.6**	**83.4**	**4.0**	**16.6**	**76.0**	**4.0**			**1358**	**4.17**	**325.4**
	6.00	1185.0	1182.3	685.8	499.2	2.368								1.04	1163	1210	4.63	
		1196.0	1191.5	690.6	505.4	2.358								1.04	1135	1180	4.72	
		1188.8	1184.0	685.6	503.2	2.353								1.04	1111	1155	4.69	
AVG						**2.360**	**2.443**	**13.7**	**82.8**	**3.4**	**17.2**	**80.0**	**3.4**			**1182**	**4.68**	**252.5**
	6.50	1172.7	1168.2	675.9	496.8	2.351								1.04	870	905	5.31	
		1185.6	1180.8	685.6	500.0	2.362								1.04	870	905	5.48	
		1178.9	1172.4	679.6	499.3	2.348								1.04	919	956	5.69	
AVG						**2.354**	**2.426**	**14.9**	**82.2**	**3.0**	**17.8**	**83.3**	**3.0**			**922**	**5.49**	**167.8**

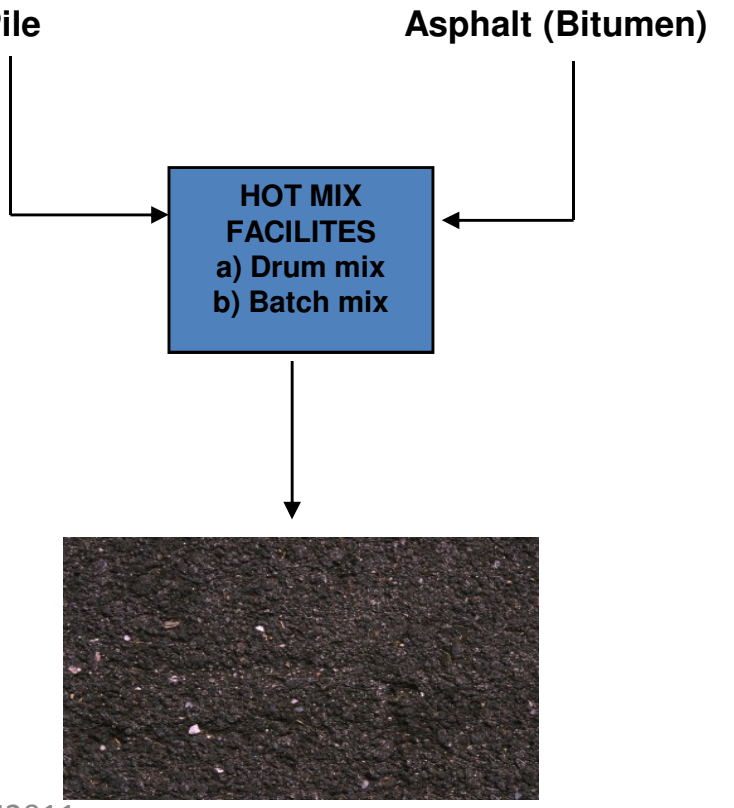
PAVEMENT WORKS 7 - Specification

- ***Parameter for AC JKR/SPJ/2008***
- .

Parameter	WC	BC
Stability (S)	> 8000 N	> 8000 N
Flow (F)	2.0 - 4.0 mm	2.0 – 4.0 mm
Stiffness (S/F)	> 2000N/mm	> 2000 N/mm
Air Voids in Mix (VTM)	3.0 – 5.0 %	3.0 – 7.0 %
Voids filled with Bitumen (VFB)	70 – 80 %	65 –75 %

WHAT IS PREMIX PRODUCTION?

- Premix production is a process of mixing the aggregates and asphalt in the hot mix facilities, to be used as road material regardless whether it's an ACW, ACB or DBM.



Agregate Stockpile

Premix - Materials

HOT MIX ASPHALT FACILITIES

- purpose of an HMA facility is to properly proportion, blend, and heat aggregate and asphalt to produce an HMA that meets the requirements of the job mix formula.
- two basic types of HMA plants commonly in use today: the **drum mix** and **batch** facilities.
- drum plants produce HMA in a continuous operation while batch facilities produce HMA in individual batches

DIFFERENCE

- drum mix plants dry the aggregate and blend it with asphalt in a continuous process and in the same piece of equipment.
- batch plants dry and heats the aggregate and then in a separate mixer blend the aggregate and asphalt one batch at a time

DRUM MIX

BATCH PLANT

PAVEMENT WORKS 9 – Check List

- ***Observations and tests at site of JMF***

1. Record type and weight of rollers, check tyre pressure
2. Record type of paver
3. Check that trial area is suitable (not on soft ground, uneven surface, or actual contract site)
4. Take sample of each mix and carry out test: binder and grading; bulk SG of sample: volumetric properties, stability and flow.
5. Check premix temp on lorry (> 5 ton load), plant and sites (never exceed 163°C and not less 125°C prior to loading into paver hopper)
6. Record laying (uncompacted) thickness
7. Check texture of paved surface before rolling (no blemishes and irregularities)

PAVEMENT WORKS 9 – Check List

8. Record temperature immediately before rolling start
9. Record rolling pattern
10. Check texture of compacted surface
11. Cut core sample after laid premix hardened (at least 3 samples from each lorry load)
12. Record compacted thickness and density from core samples

- As a result of the plant trials, amendments, further test and analysis and additional plant trials, to JMF may be required
- Full scale production can only be produced after satisfaction and full report of plant trial was documented.

Premix temperature

PAVEMENT WORKS 10 - Rolling

- ***Premix compaction***
- Consists of:
  1. Breakdown/initial – smooth wheel, <5 km/hr
  2. Intermediate/principal – pneumatic, < 8 km/hr, weight ≥ 15 ton, tyre pressure ≥ 0.7 N/m^2
  3. Final – smooth wheel, eliminate irregularities, tyre tracks
- Temperature at the commencement of rolling ≥ 110°C
- Operate longitudinal direction with driven wheels towards the paver, lower to higher edge
- Passes overlapped half width of the roller

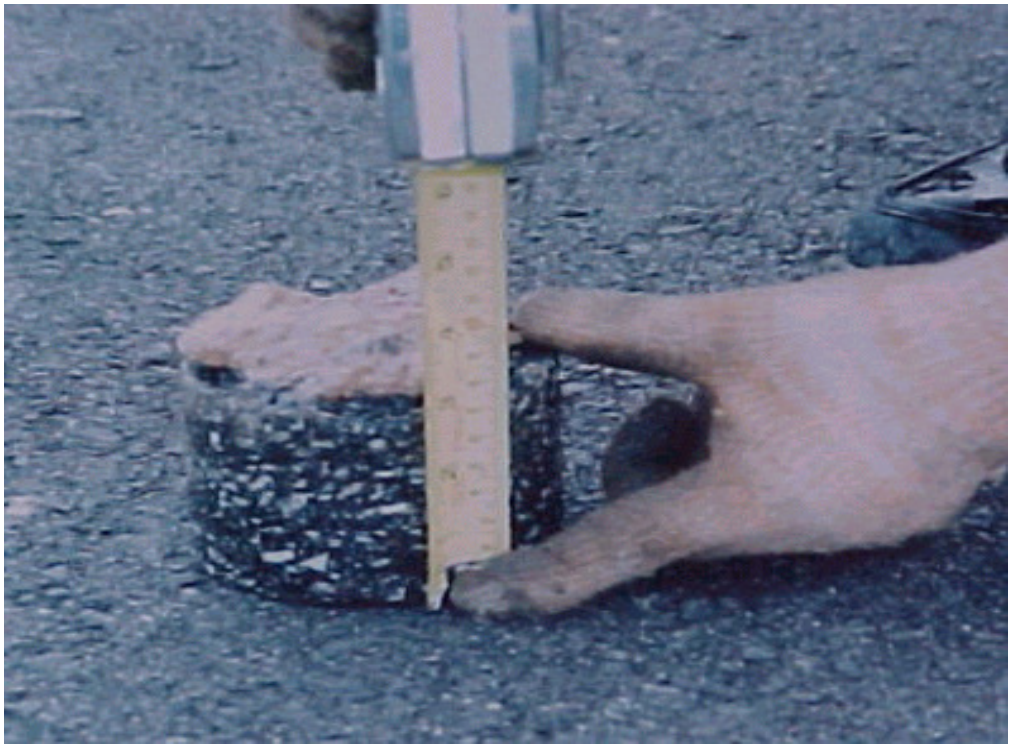
Paving

Wearing course

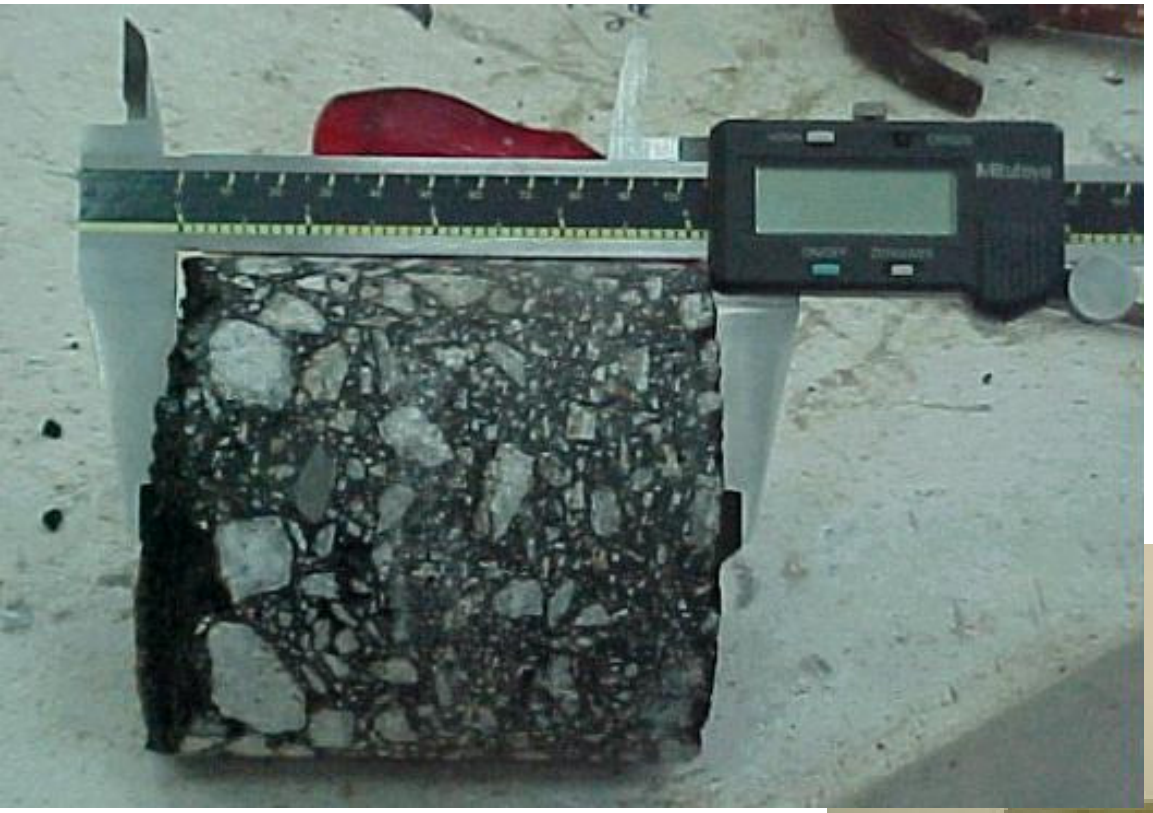
PAVEMENT WORKS 10 - Rolling

- ***Premix compaction***
- Construction joint cut back straight, brushed on with RS-1K 10-15 minutes before laying of next section, no joints along wheelpaths
- Rollers, heavy vehicles shall not be allowed to stand on newly laid mix before compaction completed and thoroughly cooled and set.
- Core diameter ≥ 100mm, 1 sample every 500 m^2
- tests (density, thickness, and quality), > 24 hrs
- Open to traffic > 4 hrs, < 30 km/hr, no sharp turning
- Compaction requirement – 90, 95, 98% of Marshall density at OBC

Coring



thickness & density



Extraction

PAVEMENT WORKS 11 - Shoulder

- Consists of furnishing, compacting and shaping earth, gravel, or paved shoulder
- Paved – constructed as normal bituminous layer
- Gravel – using approved material for gravel surfacing
- Earth – using suitable material as described in earthwork section
- Thickness of each layer according to the drawing, based on material used and compacted to the required minimum density
- Top level of shoulder should be level and flushed with pavement and uniformly free draining away from carriageway.

Shoulder

PAVEMENT WORKS 12 - Tolerance

- ***Horizontal Alignment***
- Determine from the CL of the pavement surface, edge and all parallel line correct within +50mm and -0mm
- Kerb, channel blocks and edge line +25mm and -0mm

- ***Surface levels***

Pavement Layer	Tolerance
Wearing	± 5 mm
Binder	± 5 mm
Roadbase	+ 0 mm, - 20 mm
Subbase	+ 10 mm, - 20 mm

PAVEMENT WORKS 12 - Tolerance

- ***Surface Regularities***

- Riding quality depends on roughness
- Roughness due to – uneven settlement, undulation, rutting, wide cracking, potholes etc.
- IRI used to measure roughness
- Lane IRI measured using walking profiler – for the whole road length and each 100m section < 2.m/km

PAVEMENT WORKS 13 - Defects

- ***Surface defects***
- Some of the factors contributing to surface defects are:
- Design – wrong material spec, low/substandard spec, inadequate design thickness
- Mixing and transporting – bad grading, low quality binder, inadequate binder, temperature, low aggregate quality
- Laying/Paving – uneven or dirty surface, inadequate coating, low quality workmanship, inadequate compaction, thickness, plant and equipment not in good working condition.

CONSTRUCTION PLANTS

- Plants used in road construction depends on material type and quantity involved in each activity
- Same plants may be used in several different activities
- Other plant and equipments – for specific job or activities


KOMATSU


DYNAPAC
CC20


BUNI HIWAY


TECHNIC


AWAS

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