HIGHWAY ENGINEERING
SAB2832

ROAD
CONSTRUCTION

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ROAD CONSTRUCTION

1. REVIEW MATERIALS
2. INTRODUCTION
3. SURVEY AND ALIGNMENT
4. SITE CLEARING
5. EARTHWORK
6. DRAINAGE WORK
7. PAVEMENT WORK
8. FINISHING
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
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 together under separate 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 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 and site setting out – setting out points on site according to drawings e.g ROW, alignment, CL, leveling, etc.
SITE CLEARING - Rural

• Site clearing in rural area composed of three major processes:

• 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.
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 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
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 $\geq 30\%$ (if $\geq 10\%$ retained on 20mm, can be assumed passed), $PI \leq 12$, $TFV \geq 30kN$, sand equivalent $\geq 45$

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 $\geq 95\%$ 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/m²
     • 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/m²
     • 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
<table>
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<th>% BIT SPEC. NO.</th>
<th>SPEC. NO.</th>
<th>SPEC. GRAY VOLUME</th>
<th>% TOTAL</th>
<th>VOIDS-%</th>
<th>STAILITY-kg</th>
<th>FLOW</th>
<th>STIFFNESS</th>
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<td>% BIT. WEIGHT-qm</td>
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### PAVEMENT WORKS 7 - Specification

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

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<th>Parameter</th>
<th>WC</th>
<th>BC</th>
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<td>Stability (S)</td>
<td>&gt; 8000 N</td>
<td>&gt; 8000 N</td>
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<tr>
<td>Flow (F)</td>
<td>2.0 – 4.0 mm</td>
<td>2.0 – 4.0 mm</td>
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<tr>
<td>Stiffness (S/F)</td>
<td>&gt; 2000N/mm</td>
<td>&gt; 2000 N/mm</td>
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<tr>
<td>Air Voids in Mix (VTM)</td>
<td>3.0 – 5.0 %</td>
<td>3.0 – 7.0 %</td>
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<tr>
<td>Voids filled with Bitumen (VFB)</td>
<td>70 – 80 %</td>
<td>65 – 75 %</td>
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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
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)
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/m²
  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 m²

- **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**

<table>
<thead>
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<th>Pavement Layer</th>
<th>Tolerance</th>
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<tbody>
<tr>
<td>Wearing</td>
<td>± 5 mm</td>
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<tr>
<td>Binder</td>
<td>± 5 mm</td>
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<tr>
<td>Roadbase</td>
<td>+ 0 mm, - 20 mm</td>
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<tr>
<td>Subbase</td>
<td>+ 10 mm, - 20 mm</td>
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</table>
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
REFERENCES

1. Mohd Rosli Hainin, Che Ros Ismail and Haryati Yaacob HIGHWAY ENGINEERING NOTES, Published for Internal Circulation, 2011.


4. Wright, P.H. and Dixon, K.K., HIGHWAY ENGINEERING, John Wiley & Sons, 2004
