A practical guide for the application of procedures for designing asphalt mixes as per Sabita Manual 35/TRH8

2. Mix design process -
Evaluate design situation

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Module 2

Introduction

2 Evaluate Design Situation

3 Design Objectives

4 Mix Type Selection

5 Constituent Materials

6 Laboratory Design Procedures

7 Special Mixes

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Aim of asphalt mix design

Cost effective combination of mineral aggregates and bituminous binder:

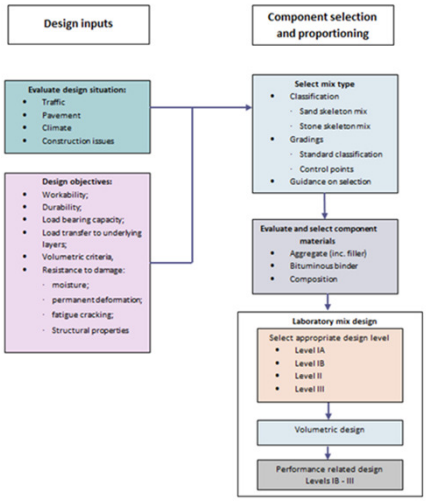
- ***Workable*** in the field;
- Contains sufficient bitumen for ***durability***
- ***Aggregate arrangement*** providing:
  - structure; and
  - space between particles for sufficient binder without flushing and / or bleeding.
- Wearing course
  - ***waterproof*** (except porous asphalt)
  - ***functional requirements*** such as friction, noise reduction and comfort.

Approach

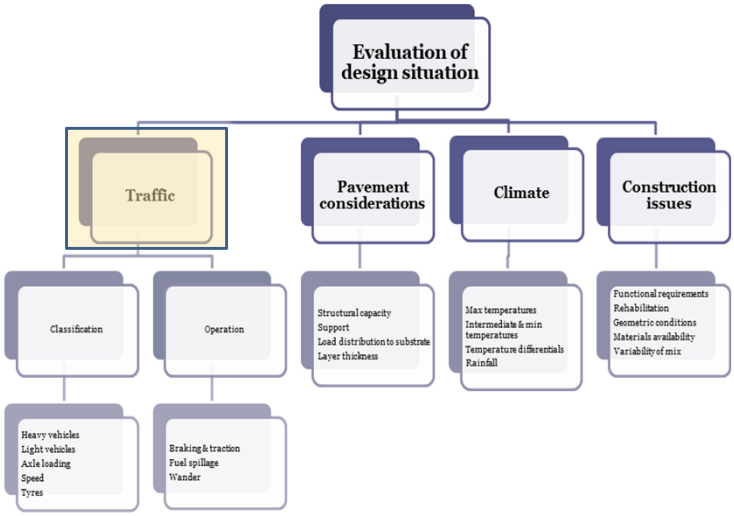
- Mix ***properties*** defined and evaluated in terms of the ***loading and environment*** in service.
- ***Test parameters*** - direct relation to the ***performance*** of the material in the pavement structure

Performance related design procedure

Components



Evaluation of design situation



Mix Design Inputs

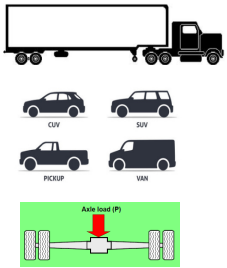
Design Situation

- Traffic
- Pavement Considerations
- Climate
- Construction Issues

Design Situation

Traffic

Classification



- Heavy Vehicles
- Light Vehicles
- Axle Loading
- Vehicle Speed
- Tyres

Traffic - classification

- ***Number of axle loads*** need to be taken into account in the mix design
- Large volumes of truck traffic require resistance to:
  - ***rutting*** if the underlying pavement is stiff
  - ***fatigue cracking***,
- Early trafficking on newly laid (hot) asphalt might cause premature distress – allow time for ***cooling of the layer*** before opening to traffic.

Light traffic

- Loading by light vehicles does not cause damage when designed to carry heavy vehicles
- ***Volume and speed*** of light traffic need to be taken into account for ***functional*** properties:
  - friction:
  - noise reduction; and
  - riding quality

Light traffic in residential areas

- Densification of the layer under the action of light traffic is unlikely to be significant
- Initial resistance of the layer to the ***passage of air and water*** into or through the mix is an ***important consideration*** in the design and construction of such layers

Sabita Manual 27

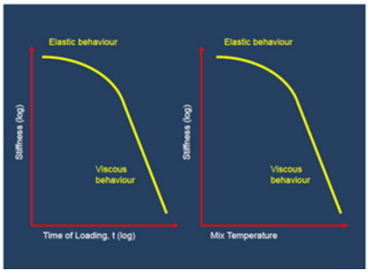
Heavy vehicle axles

- Currently volumes > 10 mill E80s common on important routes (incl. BRT routes)
- May have to cater for 100 million E80s
- Requires special consideration:
  - Aggregate packing to carry loads
  - Resistance to (permanent) viscous flow
  - Fatigue strength (durability)
  - Load spreading to underlying layers
- Lack of thorough law enforcement - large %age of axle loads on SA roads exceed 80 kN

Vehicle speed

- ***Both the volume and speed*** of, particularly, heavy vehicles will have an influence on the tendency of an asphalt layer to deform (i.e. shove or rut).
- At ***high speeds*** (i.e. short loading times) asphalt displays higher stiffness and behaves ***elastically*** - will recover (rebound) with little permanent deformation
- At ***low speeds*** (i.e. longer loading times) ***viscous behaviour*** sets in, with reduced stiffness and a greater potential for permanent deformation.

Visco-elastic behaviour



- Tensile strains at the bottom of the asphalt layer may decrease by as much as 50 % as vehicle speeds increase from creep speed to about 80 km/h
- Mixes designed for ***low speed situations*** (climbing lanes, intersections) where heavy vehicle speeds are mostly < 30 km per hour, require ***special consideration***

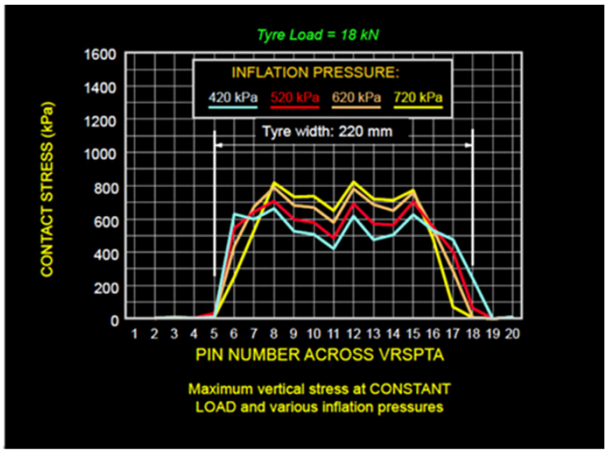
Tyres

- Ignoring tyre wall stresses, ***contact stresses*** at the tyre pavement interface is roughly the same as the ***inflation pressure***.
- Modern trucks - ***fewer tyres*** exerting much ***higher contact stresses***
- ***High pressures*** associated with ***super-single*** tyres clearly place ***greater stress*** on the asphalt layers located in the upper zone of the pavement

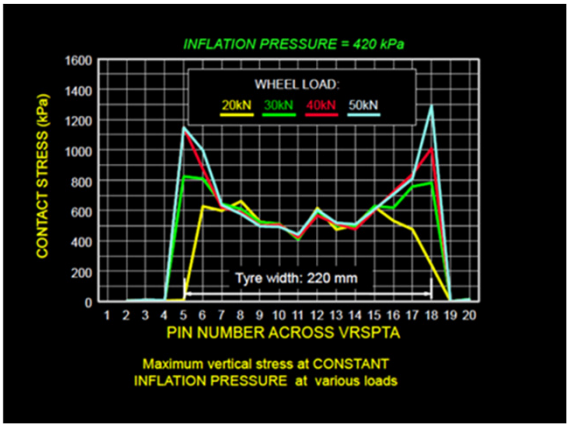
Take note

- Whereas nominal values of traffic volumes are adopted in the design of asphalt wearing course and base layers, ***tyre type*** and ***pressures*** give rise to a ***large range of stresses on the upper pavement layers***, which will adversely affect the performance of the asphalt layers

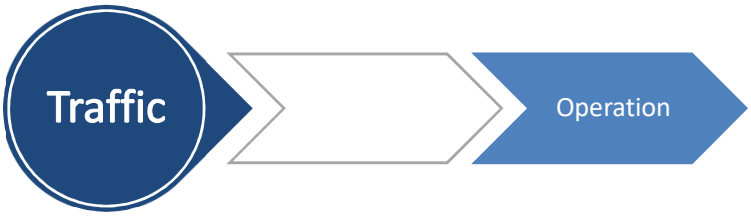
Effect of tyre pressure



Effect of wheel load



Design Situation

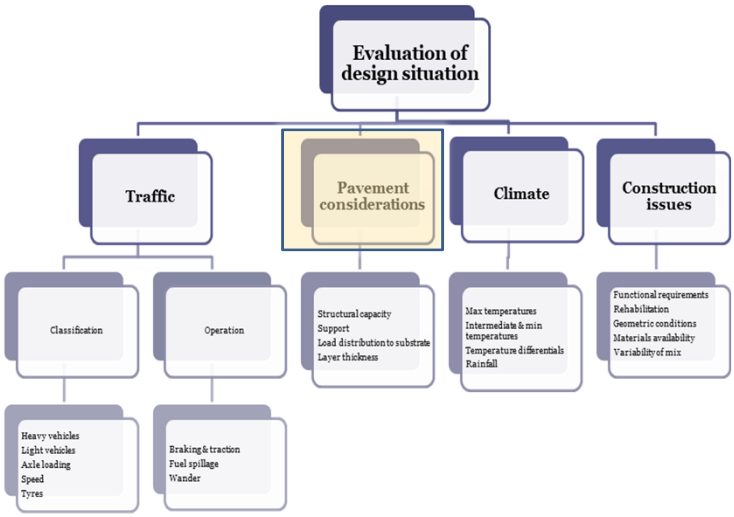


- Braking & Traction
- Fuel Spillage
- Wander

Traffic operation

- **Braking and traction**
  At intersections or steep upgrades – these actions can cause increased ***horizontal shear stresses*** and the potential for ***distortion or tearing*** of the layer
- **Fuel spillage**
  Spilled diesel cause softening of the asphalt & ***require special measures*** to protect the asphalt layer or use a binder type, which is fuel resistant e.g. an EVA modified type.
- **Wander**
  Areas of narrow wander i.e. more concentrated loading occur typically on ***bus rapid transit routes*** and at work zones with lane closures more intense loading than nominal values

Evaluation of design situation



Design Situation

Pavement Considerations

Integration of asphalt mix design and pavement structural design

- Structural Capacity
- Support
- Layer Thickness

- Provide 4 x Design Routines i.t.o. Design Traffic
- Influence Performance & Ease of Construction
- Thickness : Aggregate Size

Pavement considerations

- Fundamental point - the design of asphalt mixes cannot proceed in isolation
- ***Integration*** of the ***mix design*** process and ***structural design*** of the pavement is a basic engineering principle
- Design procedure in Manual 35 strives to establish a ***relationship*** between ***laboratory tests and the performance*** of the mix

Structural capacity

- Method - ***standard routines*** to design asphalt to cater for traffic > 100 million E80's
- Design routines divided into ***four procedures*** with increasing complexity as the traffic category increases.
- Ensure that ***risks of inadequate performance*** are ***reduced as traffic increases***.

Support layers

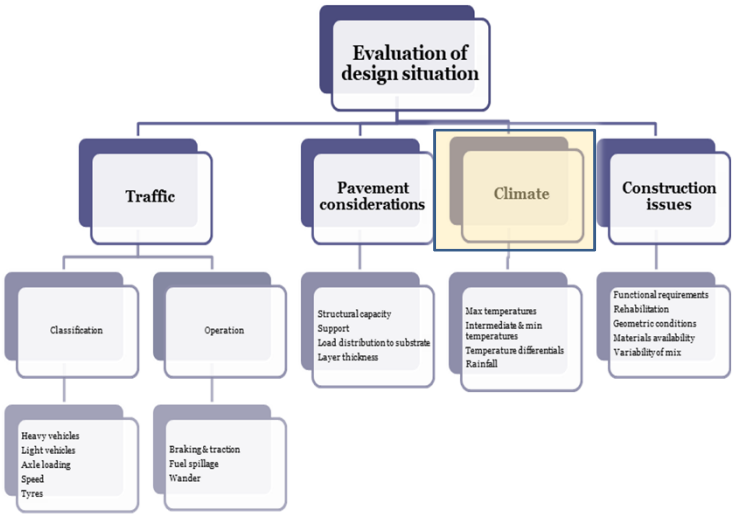
- Performance of asphalt layers much influenced by quality of support layer
  - asphalt wearing course - by base quality
  - asphalt base – by sub base / substrate
- For asphalt layers < 50 mm behaviour influence almost completely by stiffness of support
- For asphalt layers > 80 mm behaviour less influenced by support, moderately by asphalt stiffness
- Compactability of asphalt influenced by support stiffness

- Laying asphalt on weak / variable support not good practice

Layer thickness

- Manual 35 - important guidance on minimum layer thickness ***in terms of aggregate size***
- This aspect often overlooked and is very important to assure uniformity and soundness of completed layer

Evaluation of design situation



Design Situation

Climate

Marked influence on asphalt behaviour, especially due to rheological behaviour of bitumen

Temperature

- Max, intermediate & min temperatures and extreme differentials

Rainfall

- Limit permeability and potential for stripping

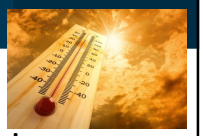
Moisture Sensitivity

- Moisture barrier (impermeable)

Climate

- Climate has a ***marked influence*** on the behaviour and performance of asphalt layers, as a result of the behaviour of ***bituminous binders***
- Factors related to climate to consider are:
  - Temperature
  - Rainfall
  - Moisture sensitivity of substrate

Temperature



- **Maximum temperature**
  - Elevated temperature - key factor influencing ***plastic deformation*** (rutting and shoving)
  - High asphalt temperatures likely to occur for large percentage of time requires special attention to counter permanent deformation:
    - aggregate configuration (***skeletal structure*** and maximum aggregate size)
    - aggregate type; and
    - ***binder type*** (in terms of PG classification)

SATS 3208

Low temperature

- Low temperatures have a significant influence on
  - asphalt fatigue and
  - low temperature fracture

- Selection of binder is of crucial importance:
  - fatigue and low temperature fracture occur as a result of ***loss of cohesion within the binder***,
  - influence of aggregate packing is somewhat less or secondary

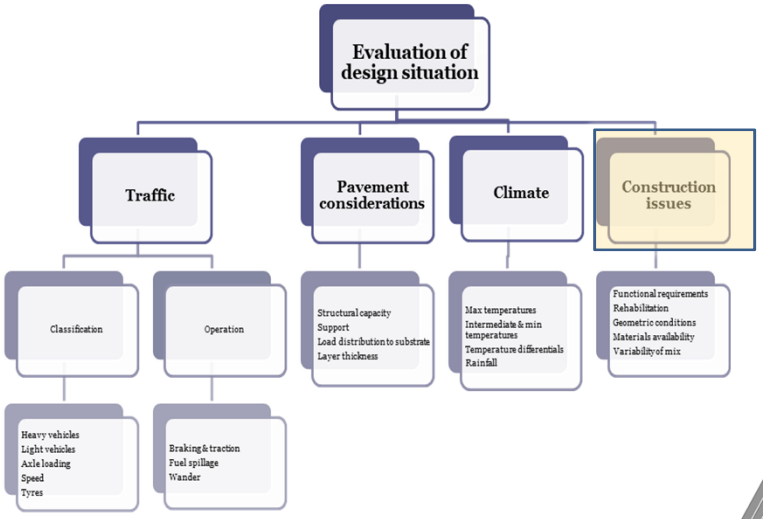
Large temperature differentials

- High annual differentials require a fine balance in the design:
  - to achieve good rutting resistance during prolonged periods of elevated temperatures
  - protecting the mix against fatigue and low temperature fracture during extreme low temperatures
- Extreme care in the ***selection & composition*** of ***aggregate*** and ***binder grade***

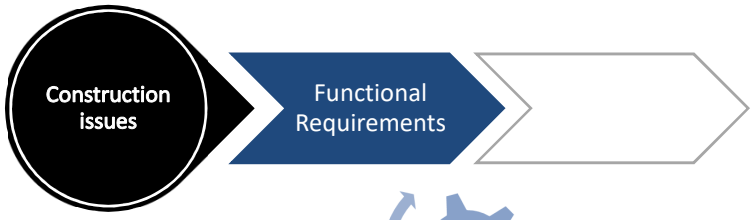
Rainfall

- In areas of long and / or high rainfall
  - limit permeability
  - special attention to skid resistance

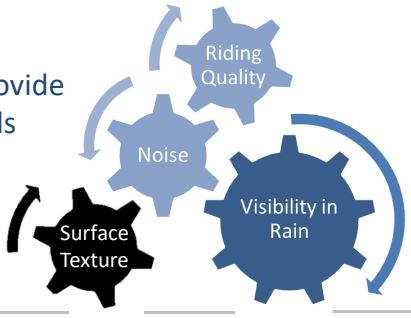
Evaluation of design situation



Design Situation



Where asphalt provide interface of wheels and pavement



Functional requirements

- In addition to satisfactory structural performance of wearing courses should yield acceptable functional performance:
  - Surface texture for:
    - adequate skid resistance
    - surface water draining during rain: and
    - limited noise generation potential (especially in urban areas);
  - Riding quality;
  - Visibility during rain, and
  - Low noise generation

Surface texture

- The texture influences friction between the tyre and surface
- Skid resistance is influenced by ***micro-texture*** and ***macro-texture*** of the aggregates in the road surface. (See Table 4 and Figure 1 of Manual 35)

Sabita Manual 35

- Table 7 of the Manual 35 indicates that ***stone skeleton*** mixes - suitable to provide ***skid resistance*** and / or ***reduce road noise***
- Carefully designed ***Sand skeleton*** mixes, can provide adequate skid resistance - for ***low speeds***
- High ***macro texture*** (or high mean profile depth - MPD) when speed of light traffic exceeds 60 km/h.
- Manual 35 does ***NOT*** condone the practice of ***rolled-in-chips on continuously graded*** asphalt in view of adverse effect on mix performance in terms of durability and permeability

Riding Quality

- ***Lack of evenness*** after paving:
  - Introduces ***dynamic loads***
  - ***accelerate the rate of deterioration*** of ***riding quality***
- Ensure that mix is not susceptible to shoving during paving and rolling which lead to:
  - an uneven surface
  - built-in cracks due to excessive horizontal movement of the mat during compaction.
- ***Precautions during the paving*** to ***ensure good riding*** quality of the layer are given in Sabita Manual 5.

Manual 5: Guidelines for the manufacture and construction of hot mix asphalt

Noise generation

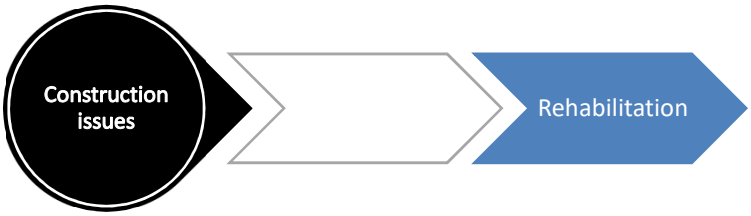
- Porous asphalt - most effective means of reducing road noise
- Interconnected voids (> 20%) combined with layer thicknesses of at least 40 mm, serves to attenuate road noise generated by vehicle tyres – 50% less than dense asphalt

Visibility during rain

- To improve ***visibility*** by reducing backsplash from (especially) trucks - ***porous asphalt*** should be considered on important routes.
- The design covered in Sabita Manual 17.

Manual 17: Porous asphalt mixes – design and use

Design Situation



Designers to note:

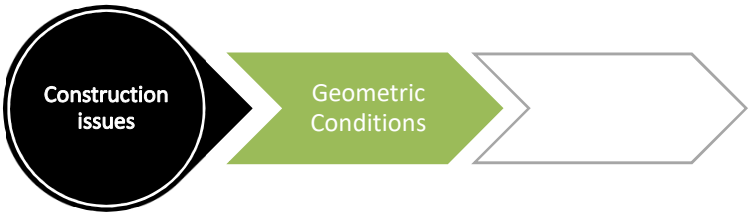
- Joint construction and position
- Water ingress

Fewer joints, larger areas

Rehabilitation

- Consideration should be given to the rehabilitation of larger areas resulting in fewer joints
- Numerous joints both at the surface and in depth which would render the project more susceptible to water ingress

Design Situation

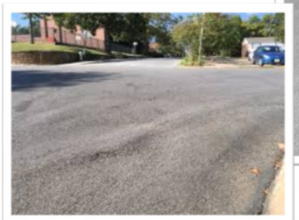


- Increased performance required on areas of braking, acceleration, crawling & turning
- Wander
  - Significant effect on rutting and fatigue distress

Geometric considerations

- Where braking, acceleration, crawling and turning of heavy vehicles occur on a regular basis - careful consideration of:
  - aggregate packing
  - binder
  - mix proportions

  To counter:
  - Rutting
  - Shoving
  - skidding
  - ravelling



- Difficult to achieve specified finish tolerances and compaction at intersections, steep grades, and on highly flexible substrates - hence ***maintaining a minimum layer thickness*** would require ***special attention***

Wander

- Lateral spread of traffic paths - significant effect on rutting and fatigue distress
- On high speed roads, (wider lane widths) the degree of wander > than on narrow lanes with slowly moving heavy traffic e.g. on dedicated bus routes
- In the latter situation, channelisation is increased and consequently rutting resistance should take account of the increased concentration of loading.

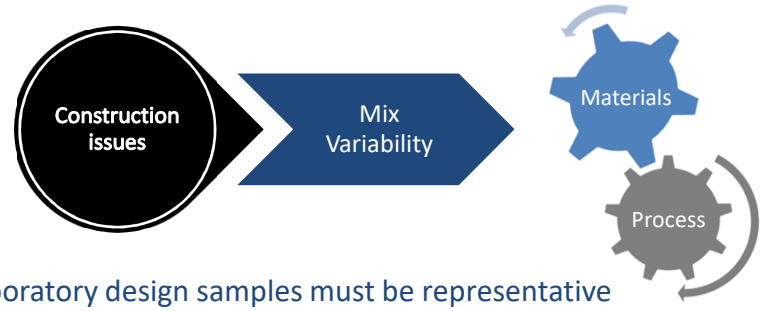
Design Situation

- Certain mixes more forgiving i.t.o. variations in aggregate and grading
- Quality of available local materials
  - Commercially available aggregates and bitumen summarised in Tables 5 & 6 (Manual 35)

Materials availability

- Performance of some mixes more sensitive to variations in aggregate properties and grading
- It should be borne in mind that marginal or variable aggregates should not be used in mixes that are highly dependent on aggregate interlock, such as Stone Mastic Asphalt (SMA)
- If available aggregates are unlikely to provide sufficient deformation resistance a ***high viscosity or modified binder*** should be considered

Design Situation



- Laboratory design samples must be representative of stockpile
- Delivery of stock material must be consistent, representative quality
- Be aware of variation in mix properties and across paver-mat
- Segregation, temp. differences (loads & mat), binder drainage during haul

Mix variability

- Mix variability derives from
  - variability of the component materials – especially aggregate and natural filler
  - construction processes
- Segregation may be made worse during loading and paving of large aggregate mixes (Sabita Manual 5)

Manual 5: Guidelines for the manufacture and construction of hot mix asphalt

Component materials

- A key feature of success - ***design is based on component materials*** that will ***actually be used*** during the ***construction***
- This success depends on two factors:
  - The ***samples used in laboratory design*** are ***representative*** of ***material stock***;
  - ***Materials delivered*** into stockpiles at the plant are ***consistently the same*** as those on which the design is based.
- Essential component of such a quality management process is ***proper construction and use of aggregate stockpiles*** - consistency and conformity of the material.

Manual 5: Guidelines for the manufacture and construction of hot mix asphalt

Component materials - RA

- ***Reclaimed asphalt*** is now increasingly being used as a significant component of asphalt mixes
- Consultation of TRH21: *Use of reclaimed asphalt in the production of asphalt is recommended*.

Sabita Manual 36 / TRH 21

Construction process

- ***Variation*** across width and length - due to:
  - the mix segregating in paver box
  - differences in temperature of truck loads delivered to the paver
  - drainage of the binder in the truck body during haulage
  - differential cooling of the paved mat
- Areas that appear visually coarse, fine or rich or lean in relation to uniform sections should be ***regarded as distinct*** and should be ***tested separately*** as discrete uniform sections.

Manual 5: Guidelines for the manufacture and construction of hot mix asphalt

THAT WAS MODULE 2

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