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.

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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

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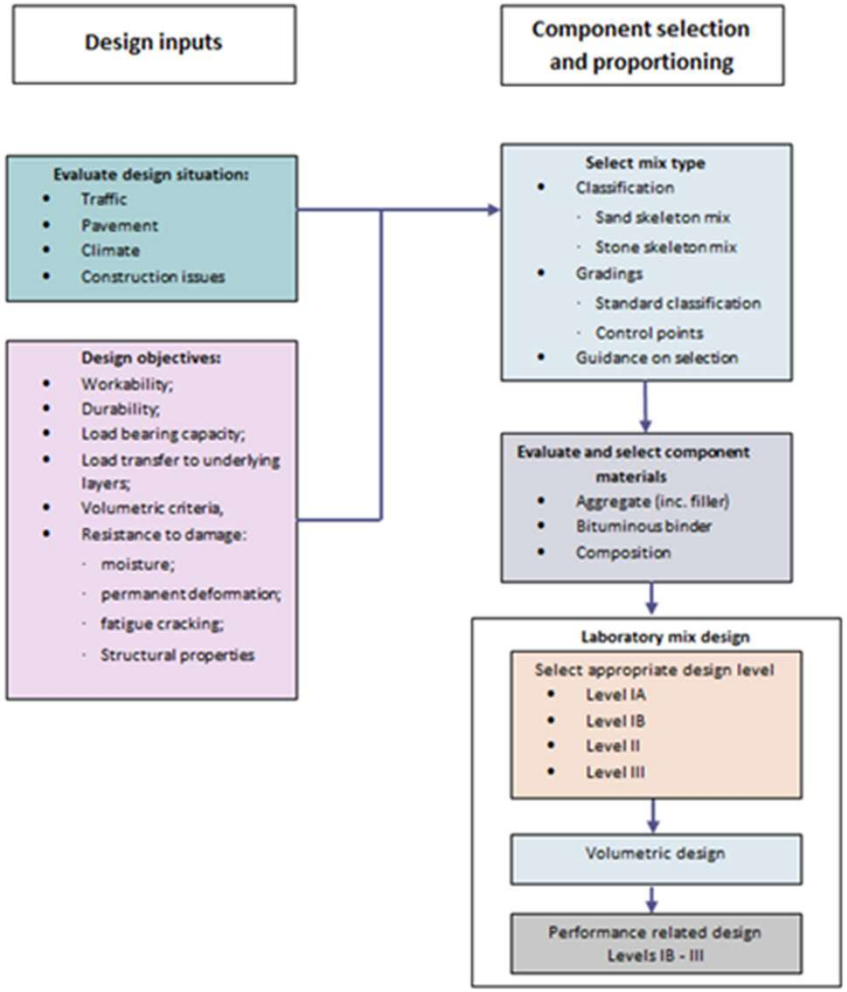
Components



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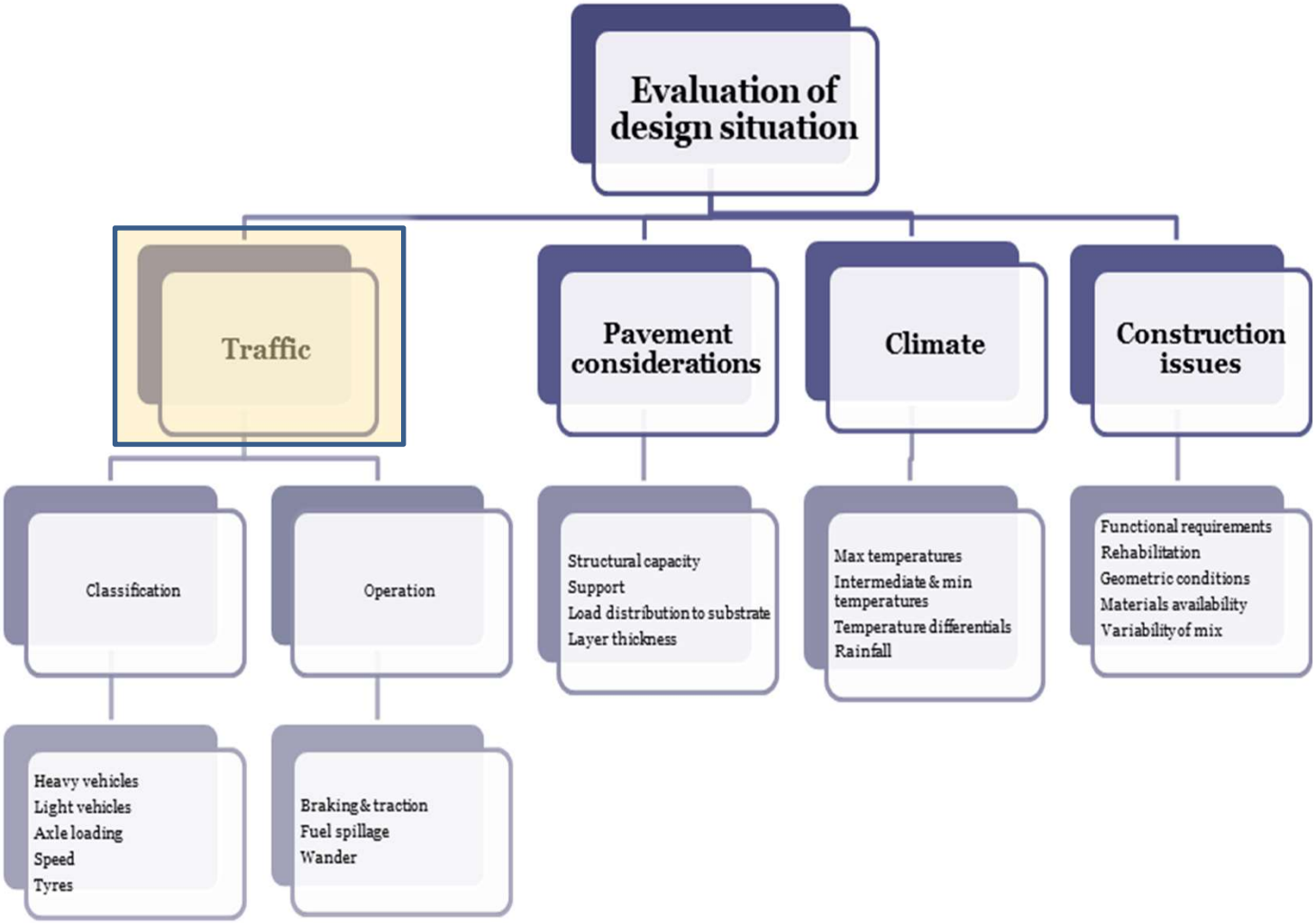
Evaluation of design situation



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Mix Design Inputs

- Traffic
- Pavement Considerations
- Climate
- Construction Issues

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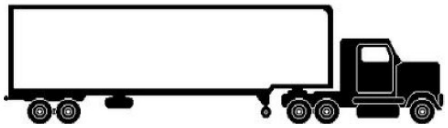
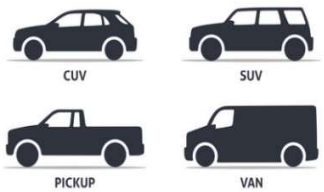
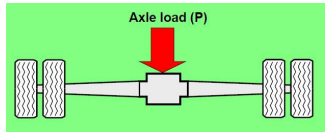
Design Situation

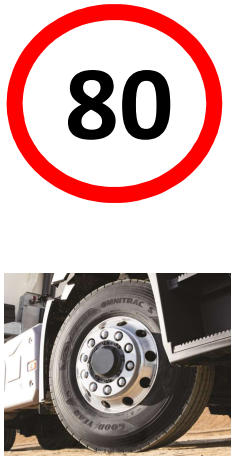
Traffic → Classification →







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



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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.

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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

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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

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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

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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.

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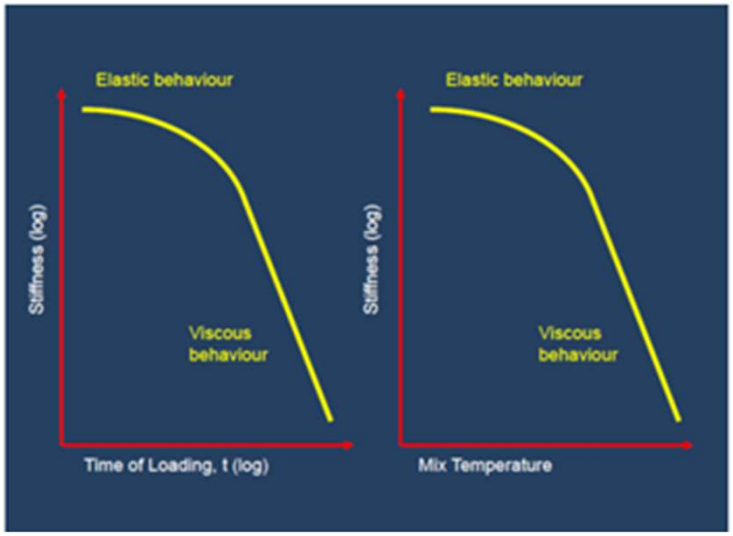
Visco-elastic behaviour



- 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***

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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

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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

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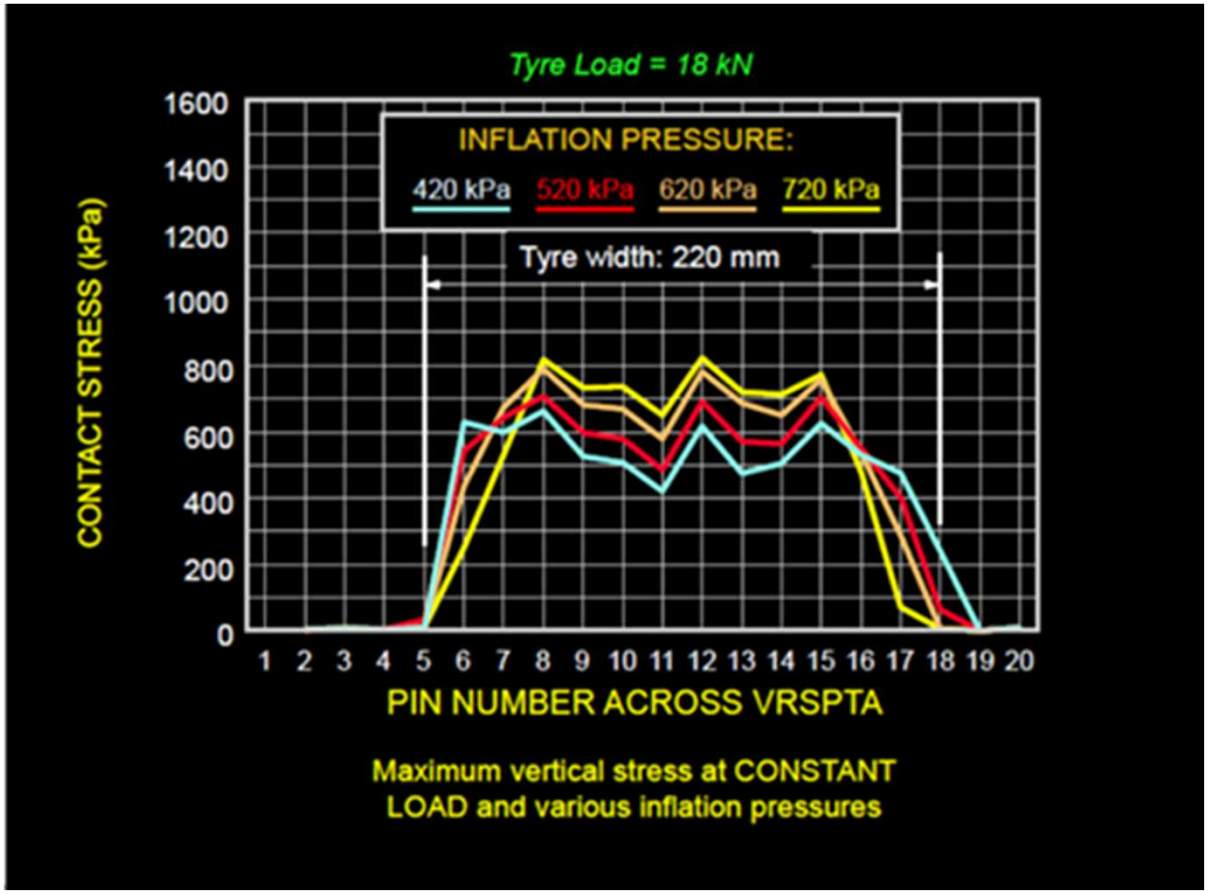
Effect of tyre pressure



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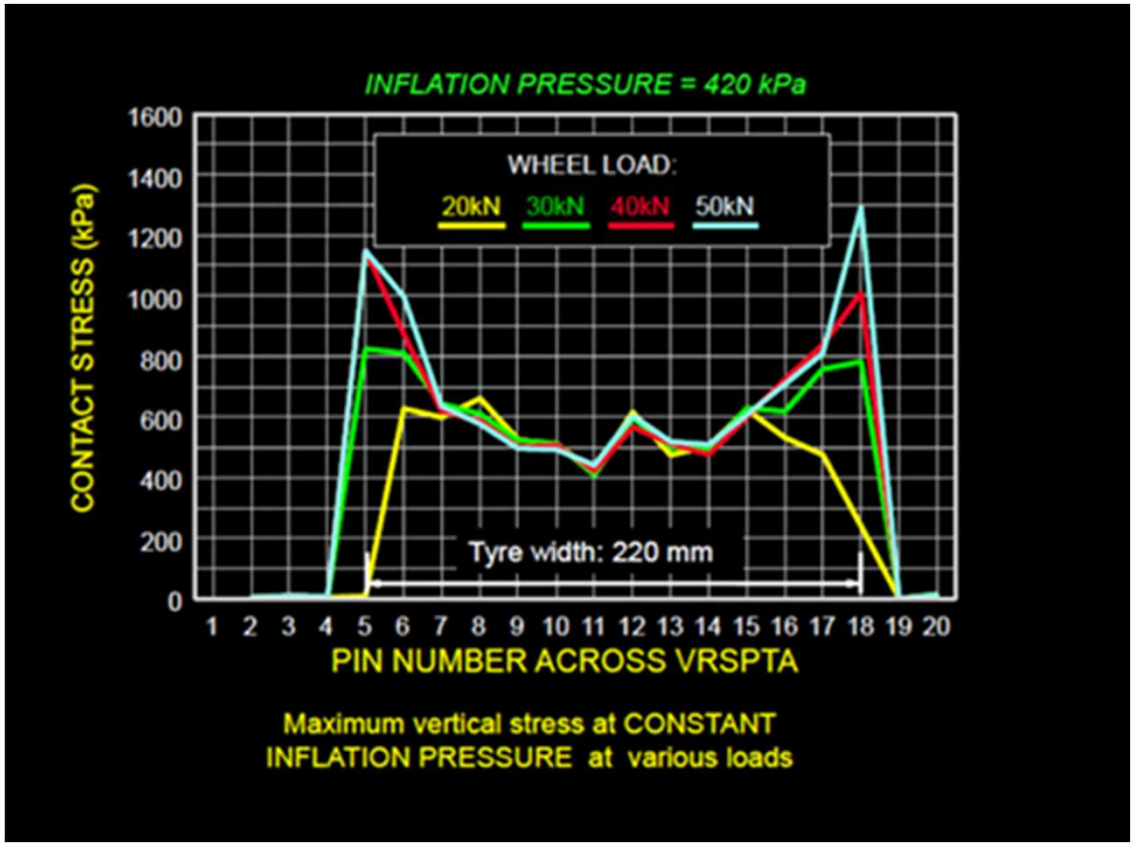
Effect of wheel load



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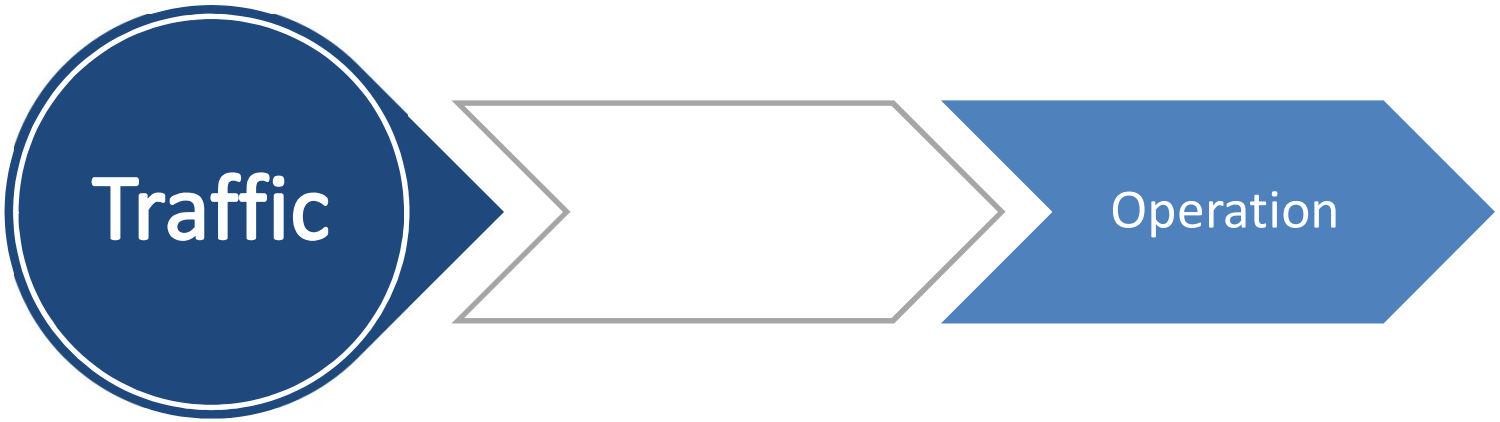
Design Situation



- 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

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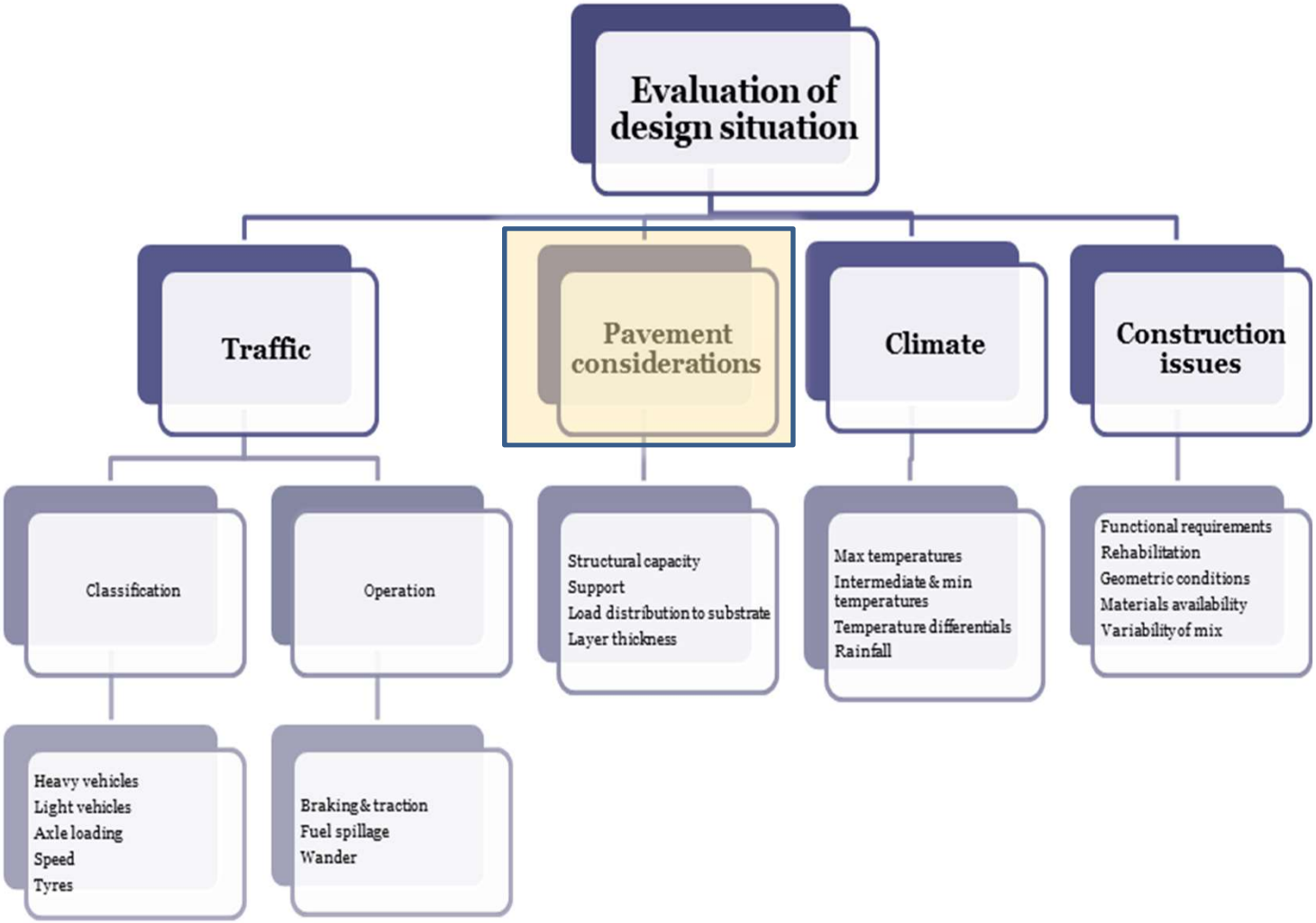
Evaluation of design situation



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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

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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

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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***.

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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

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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 ⚠

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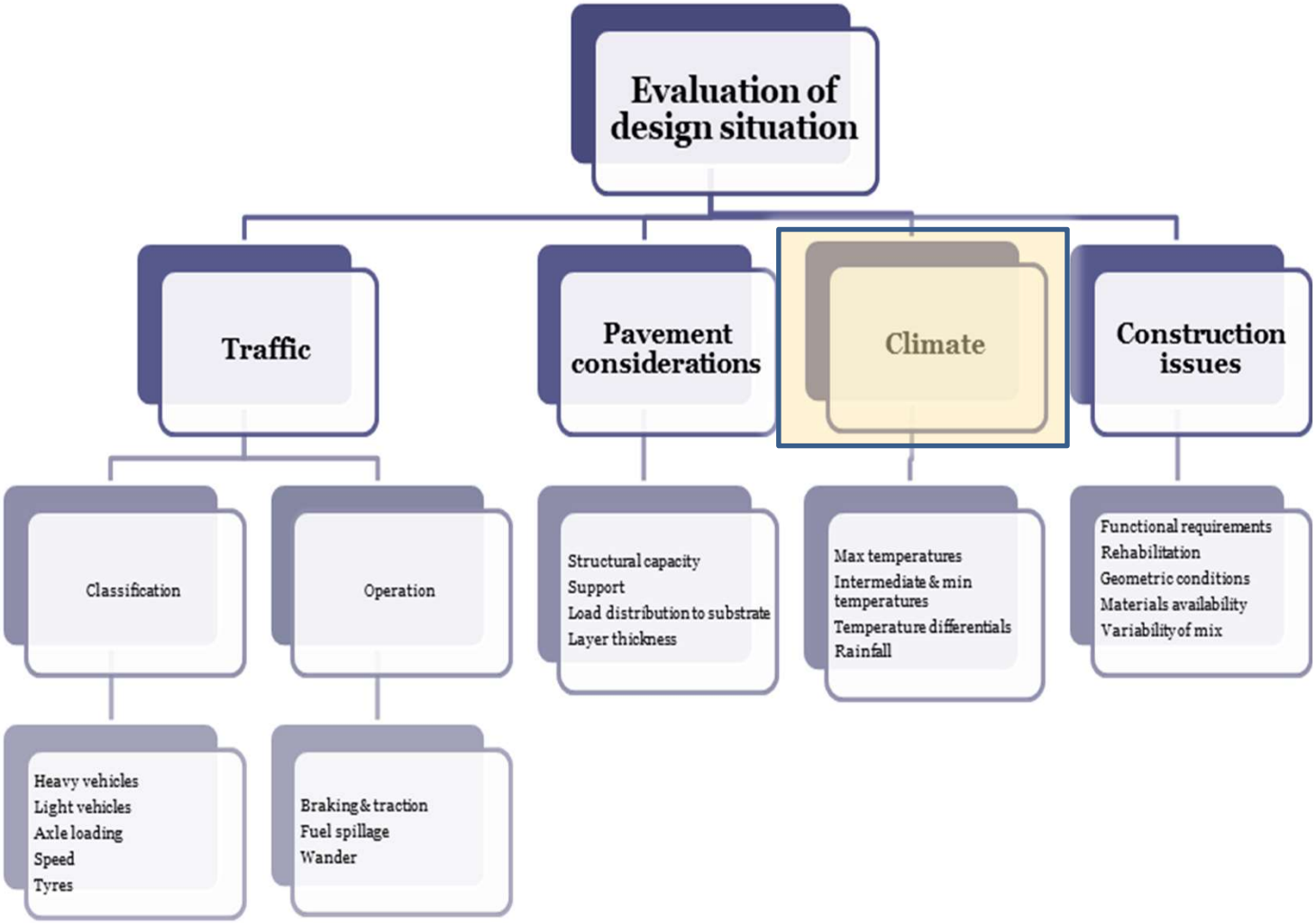
Evaluation of design situation



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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)

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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

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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)

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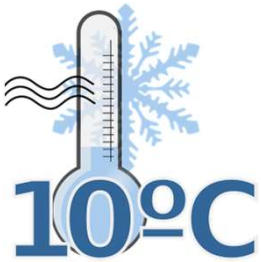
Low temperature

- 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

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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***

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Rainfall

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

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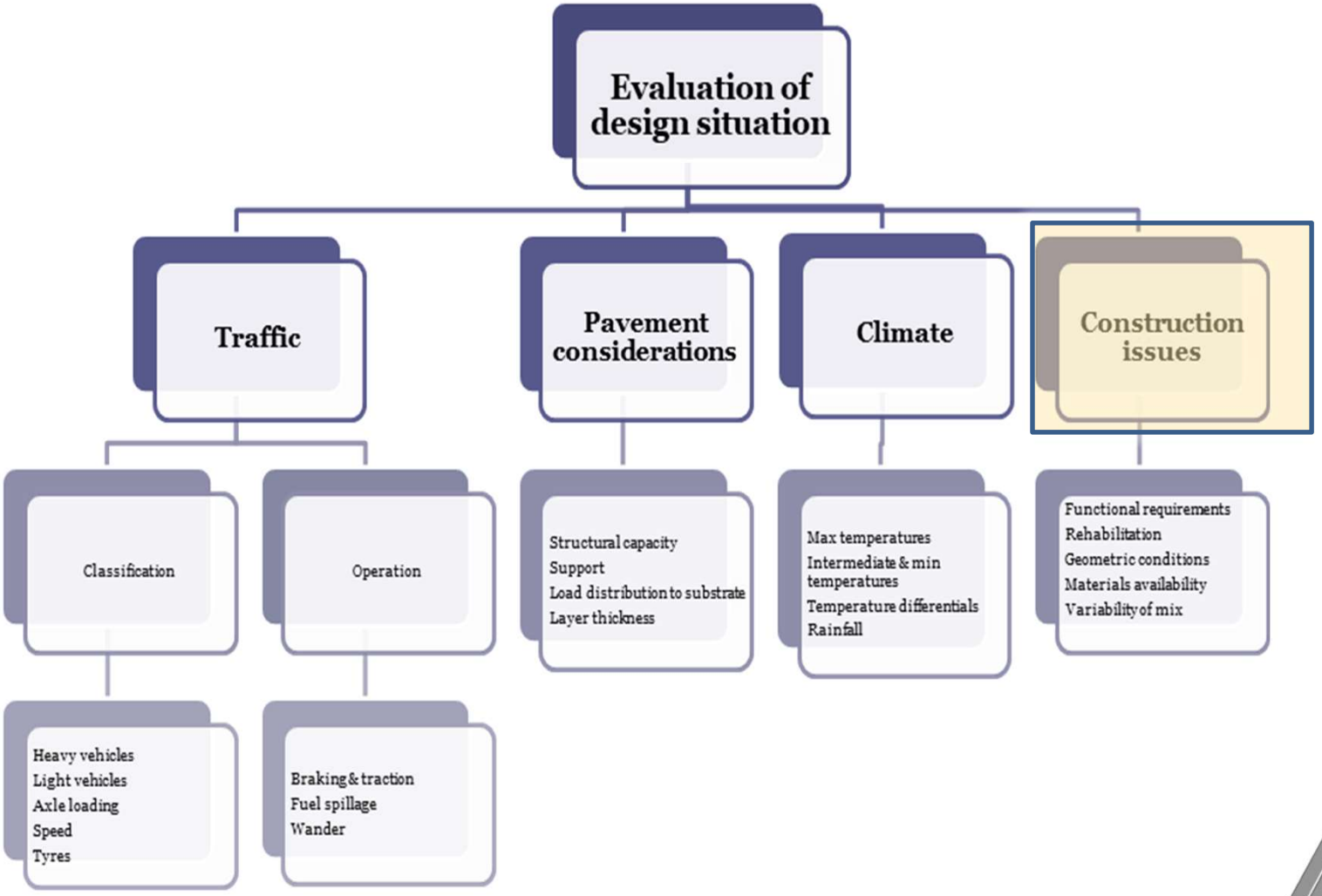
Evaluation of design situation



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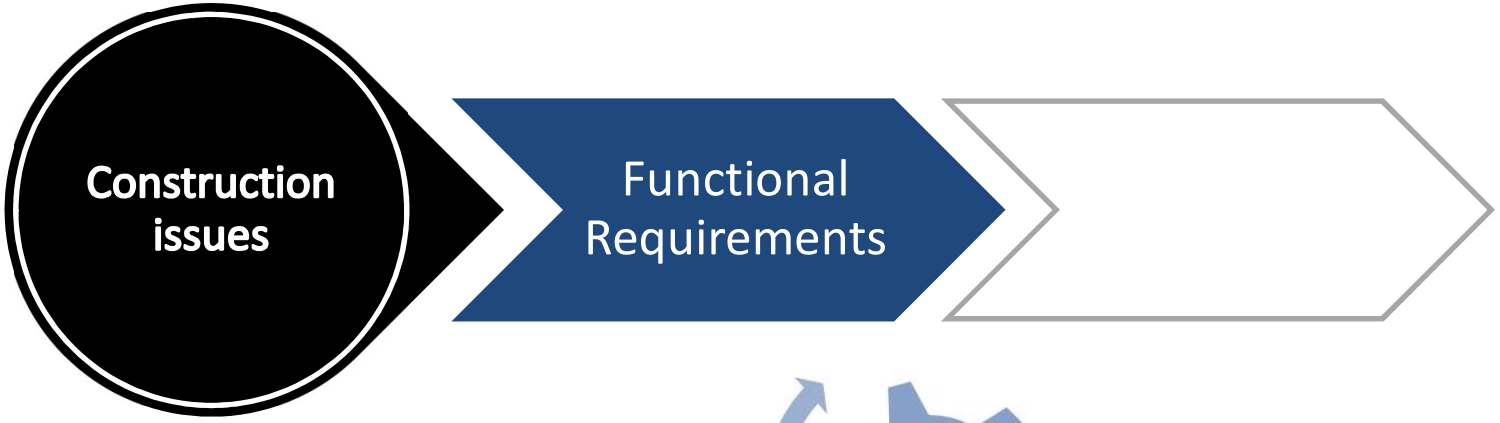
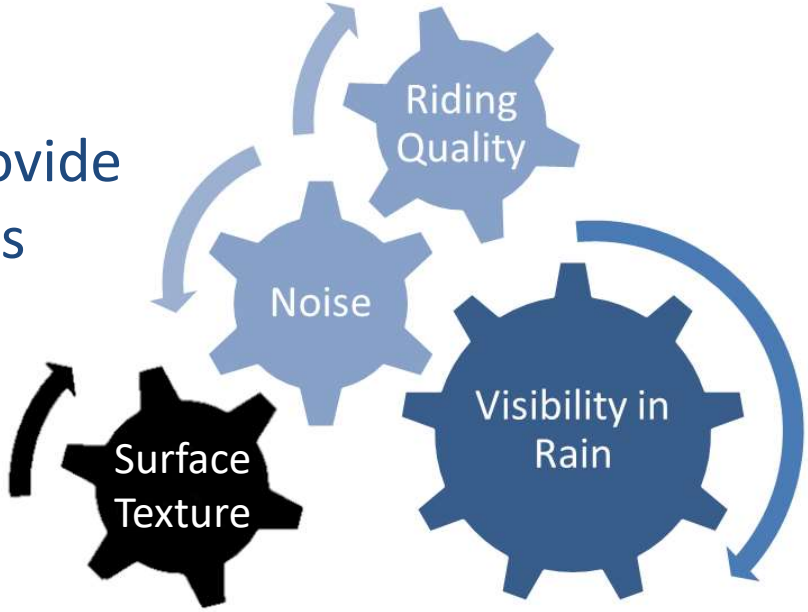
Design Situation



Where asphalt provide interface of wheels and pavement



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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

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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

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Surface texture

- 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*** recommend the practice of ***rolled-in-chips on continuously graded*** asphalt in view of adverse effect on mix performance in terms of durability and permeability

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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

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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

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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

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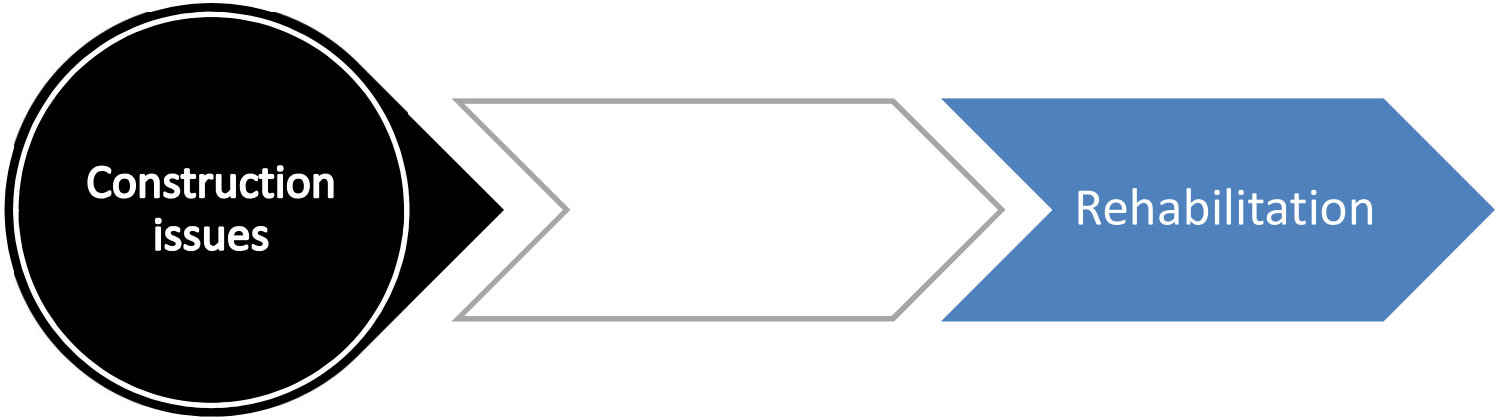
Design Situation



Designers to note:

- Joint construction and position
- Water ingress

Fewer joints, larger areas

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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

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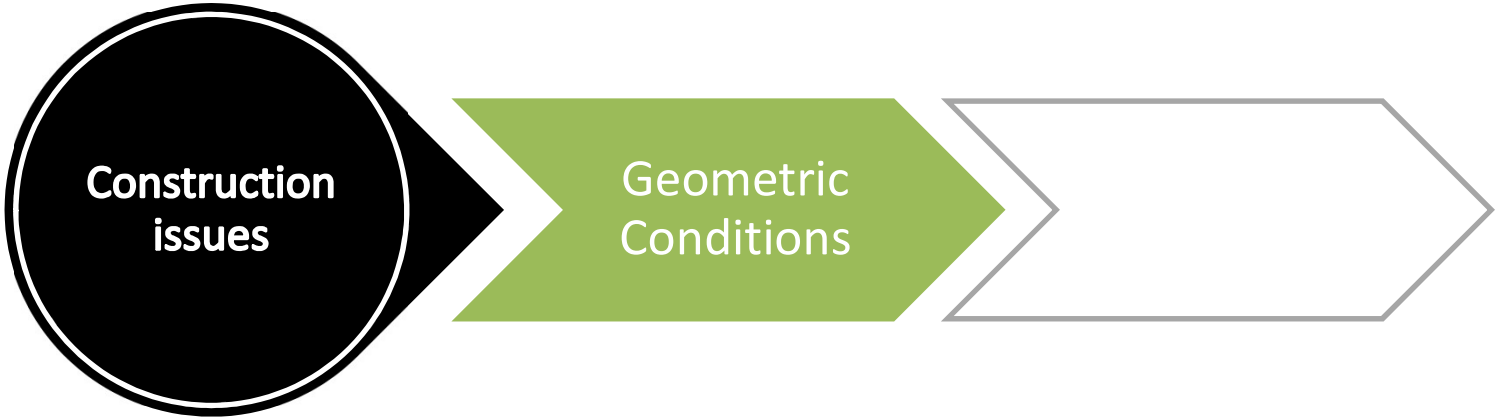
Design Situation



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

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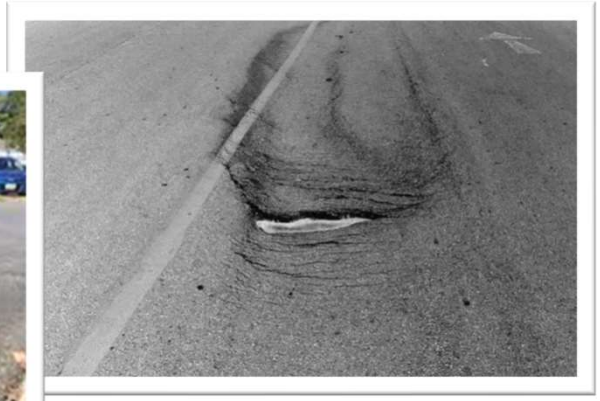
Geometric considerations

- 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***

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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

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Wander

- In the latter situation, channelisation is increased and consequently rutting resistance should take account of the increased concentration of loading.

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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)

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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)

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Materials availability

- If available aggregates are unlikely to provide sufficient deformation resistance a ***high viscosity or modified binder*** should be considered

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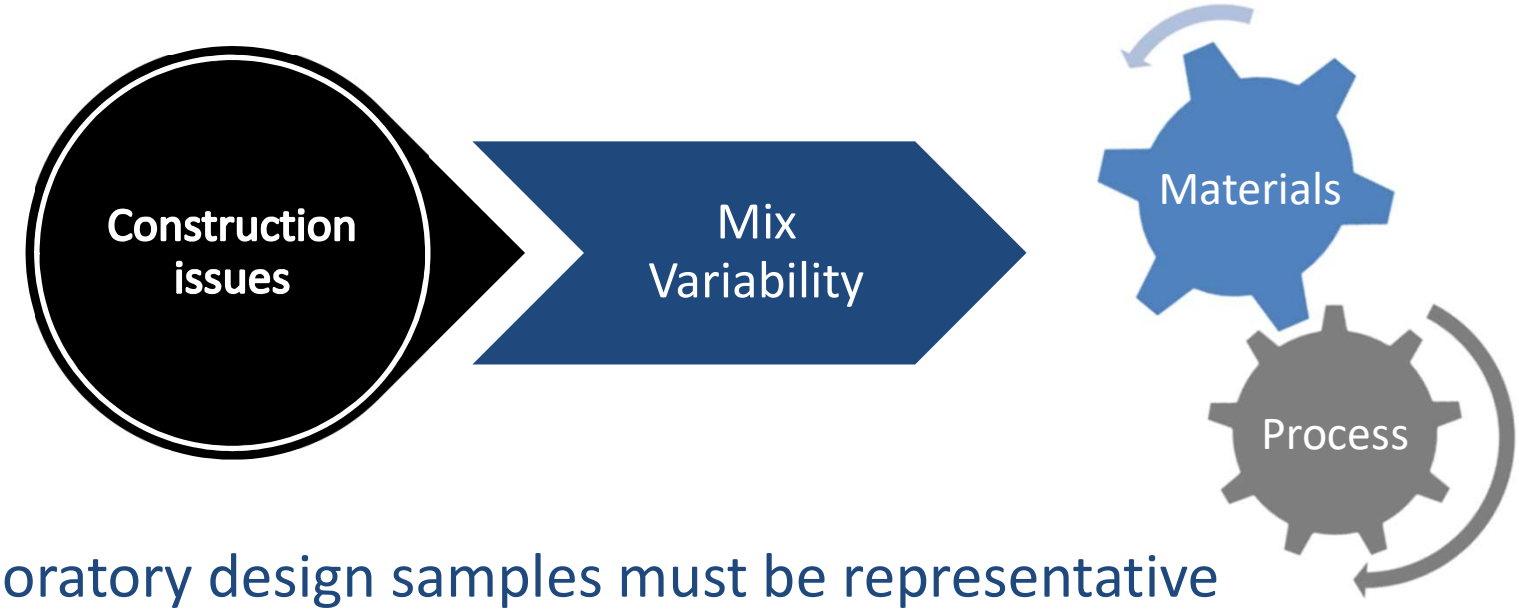
Design Situation



- 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

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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

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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.

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Component materials

- 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

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Component materials - RA

- ***Reclaimed asphalt*** is now increasingly being used as a significant component of asphalt mixes
- Consultation of Manual 36 (TRH21): *Use of reclaimed asphalt in the production of asphalt is recommended*.

Sabita Manual 36 / TRH 21

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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

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Construction process

- 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

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THAT WAS MODULE 2

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POP QUIZ - Module 2

2 Why is it important to establish a link between the pavement design and the mix design?

3 Which two factors are used to define and evaluate and determine the mix properties?

4 Which two factors of loading significantly influences the visco-elastic behaviour of the asphalt layer?

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