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

4. – Mix type selection

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Manual 24 Elements

- Design Situation
- Design Objectives
- Mix Type Selection
- Constituents and Proportioning
- Lab Design Procedure

You are here

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Mix type selection

- Performance of an asphalt layer - ***closely related to the structure of all aggregates in the mix***
- Determines
  - Mechanical properties
    - Resistance to fatigue
    - Resistance to permanent deformation
  - Permeability
  - Durability
  - Compactability

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First steps

- A ***Clear understanding*** of interaction between ***aggregate structure and mix performance is essential*** for optimal mix proportions
- This is the ***starting point*** of any ***new mix*** design (~~adopting a grading type or, worse, a grading envelope~~)

WRONG!

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First steps

- Using ***gradings*** as a starting point has the distinct disadvantage of having ***little*** or no evident ***bearing*** on ***performance characteristics***
- Mixes with the same (mass-based) grading could display significantly different behaviour

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Use of gradings

- Gradings are useful where mix types have been ***established and standardised*** for particular sources & applications

- ***Gradings*** are key to ***quality assurance*** procedures:
  - Why?
    - Mixes laid are representative of the materials used during the laboratory design process to ensure designed behaviour is achieved

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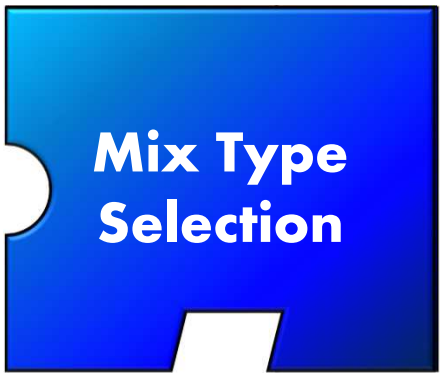
Mix type selection



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Mix Classification

First critical choice

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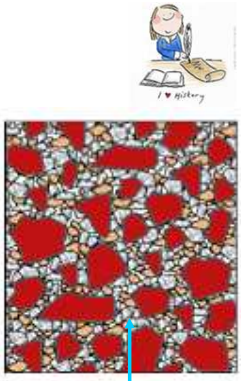
Sand skeleton mixes

- Loads are mainly ***carried*** by the ***finer aggregate (FA)*** fraction
- ***Larger aggregate*** provide ***bulk*** (volume filling by replacement of FA)
- ***Little contact*** between the individual ***larger aggregate (CA)*** particles
  - Semi-gap graded asphalt
  - Gap-graded asphalt
  - Medium/fine continuously graded asphalt.



Continuous matrix of fine aggregate

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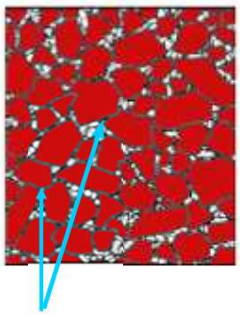
Stone skeleton mixes

- Loads ***carried*** by an ***interlocking matrix of the coarser aggregate***
- Contact between the coarser aggregate achieved by ***ensuring that the finer fractions*** (mastic) ***do not overfill the air spaces*** available between the larger aggregate



Contact between coarse aggregate

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Methods

- Number of analytical methods to analyse and define aggregate structure
- Sabita Manual 35 recommends the ***Bailey Method***
  - Systematic technique to ***establish which aggregate fraction – coarse or fine – is in control of the aggregate structure***.

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Bailey principles

- Brief introduction here
- ***Courses*** presented by ***AsAc***
- Evaluates ***packing characteristics***
- Determines what is "***coarse***" and "***fine***"
- Evaluates individual aggregates and blends by volume and weight
- Optimises composition for function and constructability

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Coarse and Fine

- ***CA - Coarse*** aggregate ***create voids***
- ***FA - Fine*** aggregates ***fill the voids***

- You therefore need to estimate void size by determining the break between coarse and fine

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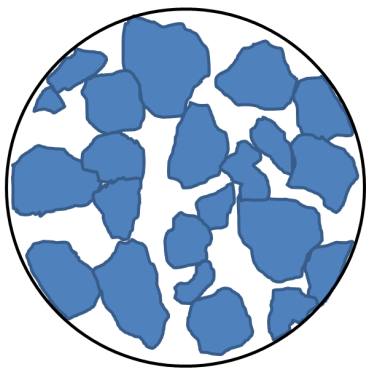
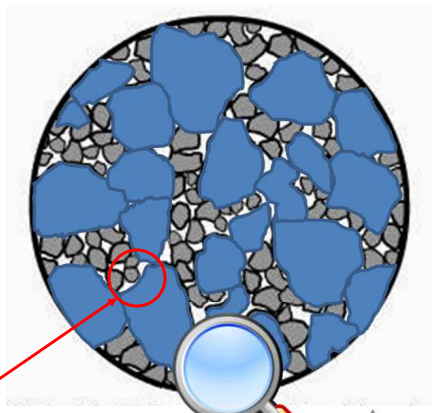
Aggregate matrix in Mix



CA Creates Voids

FA Fills Voids



Void Size???

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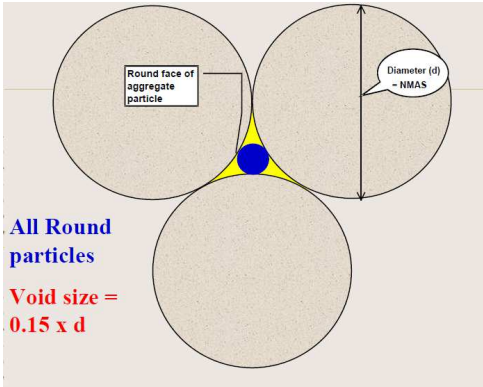
Volumetric cases for Void Size



Case 1 of 4: void size of ***three round particles*** touching
Void size is ***0.15 of particle size diameter*** (NMAS)

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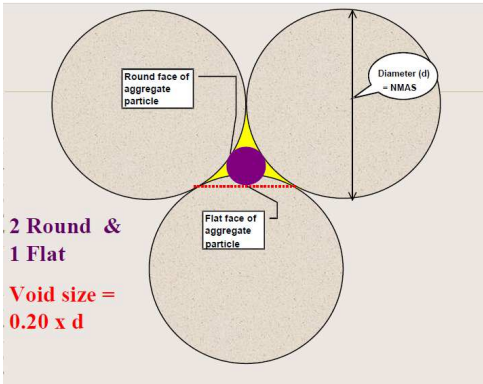
Volumetric cases for Void Size



Case 2 of 4: void size of ***2 round & 1 flat face particles*** touching
Void size is ***0.20 of particle size diameter*** (NMAS)

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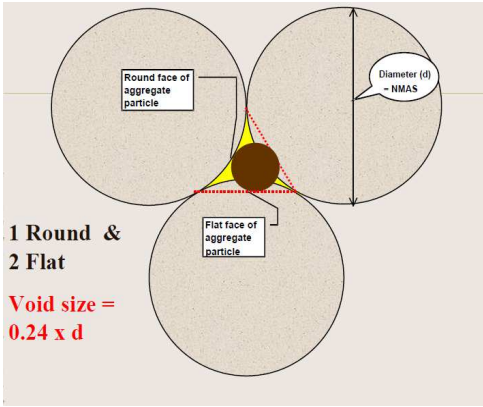
Volumetric cases for Void Size



Case 3 of 4: void size of ***1 round & 2 flat face particles*** touching
Void size is ***0.24 of particle size diameter*** (NMAS)

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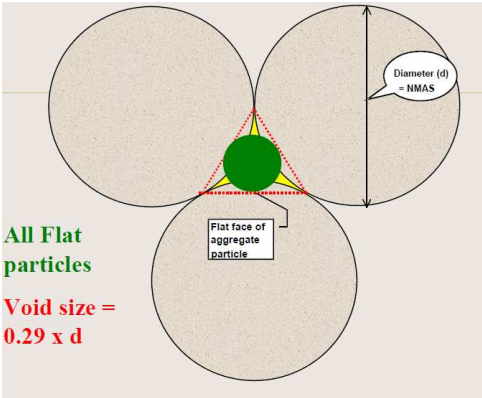
Volumetric cases for Void Size



Case 4 of 4: void size of ***3 flat face particles*** touching
Void size is ***0.29 of particle size diameter*** (NMAS)

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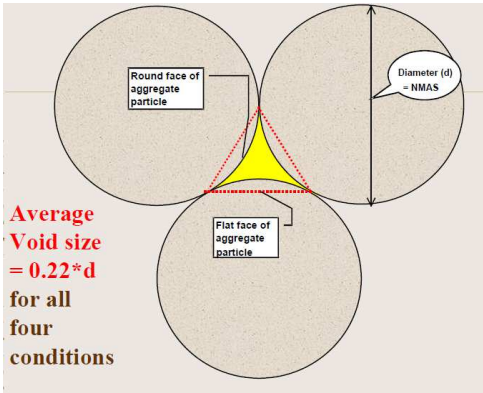
Volumetrics – average situation



Average case : Void size is ***0.22 of particle size diameter*** (NMAS) i.e. ***Primary Control Sieve (PCS) = 0.22 x NMAS***

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Bailey method parameters

- Only ***some parameters*** introduced
- ***Primary control sieve*** (PCS) define the ***division between coarse and fine aggregate*** of a <u>specific</u> mix
- 0.22 x NMAS

NMPS (mm)	PCS (mm)
37.5	10
28	7.1
20	5
14	2
10	2
7.1	1

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Aggregate packing

- Control ***volumes*** of ***coarse*** and ***fine*** aggregate according to ***mix type***
- ***Design by volume***
- Determine unit weights
- Calculate volume of solids in coarse fraction
- Calculate volume of voids it contains

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Unit weights

- ***Loose*** unit weight (***LUW***)
- ***Rodded*** unit weight (***RUW***)
- ***Chosen*** unit weight (***CUW***)
- LUW & RUW - according to ***AASHTO T 19***
  - ***Specific mould volumes!!!***

Designation: C 29/C 29M – 97

Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

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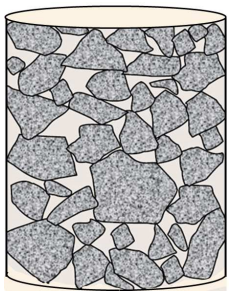
Loose unit weight (LUW)

- ***No compactive effort***
- ***Start*** of ***particle-to-particle contact***
- Shovelling procedure to fill mould
- Strike off level (no compaction)
- Determine ***LUW (kg / m³)***
- Determine ***volume of voids***



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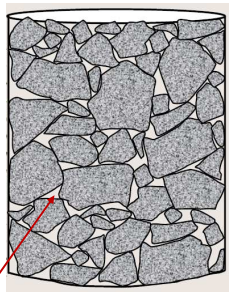
Rodded unit weight (RUW)

- With ***compactive effort*** applied – 3 equal lifts
- ***Increased particle-to particle contact***
- Determine ***RUW (kg/m³)***
- Determine ***volume of voids***



Less voids

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Unit weight and mix type

- *Sand skeleton*
  - CA volume ***< 80% LUW***
  - Little or ***no particle-to-particle contact in CA***
  - ***Large aggregates float*** in matrix of fine aggregate
- *Stone skeleton* ***(general but be careful !!!!)***
  - CA volume between LUW and RUW ***(95 – 105% LUW)***
  - Significant ***particle-to-particle contact in CA***
- Stone skeleton (***Stone mastic asphalt SMA***)
  - CA volume ***110 – 125% RUW***
  - ***Comprehensive particle-to-particle contact*** in CA

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- Mixes, with ***CUW 80% - 95% of LUW can be problematic*** - should be avoided:
  - Possible risk factors:
    - tenderness
    - Segregate susceptibility
    - Can present compaction issues and
    - gradings of these mixes – are often close to the maximum density line which can limit achievement of both:
      - sufficient binder
      - adequate air voids.

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Fine aggregate

- ***Similar principles applied to FA***, depending on mix type
- Not dealt with here
- ***Course on Bailey method AsAc***

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Mix classification

- Stone skeleton (Coarse graded): ***> 50 %*** aggregate ***retained on the PCS*** (i.e. < 50% passes the PCS
- Sand skeleton (Fine graded) : ***≤ 50 %*** aggregate ***retained on the PCS*** (i.e. ≥ 50% passes the PCS.

Quick check
But Bailey Analysis will help confirm behaviour

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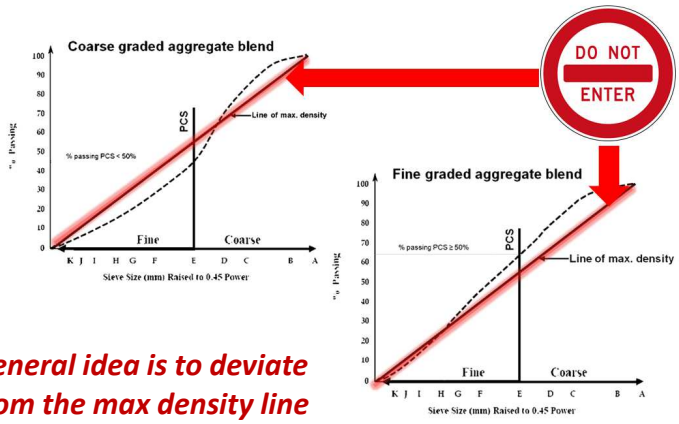
Mix classification



General idea is to deviate from the max density line

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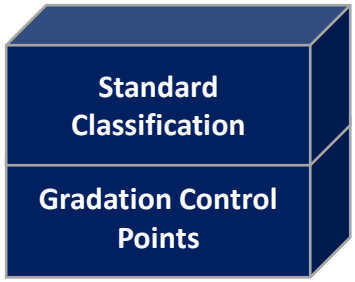
Mix Gradations



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Limitations of grading

- Traditionally mixes were classified in terms of their gradings
- Practice has been ***discontinued in Manual 35:***
  - change in aggregate shape over the years due to advances in crushing technology
  - traditional gradings used for decades do not necessarily guarantee optimal designs today
  - increased heavy traffic loads that occur early in the life of the layer

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Limitations of grading

- ***Examination of the aggregate packing*** is now the ***primary step*** in the design of asphalt
- ***Gradings*** have a crucial role in ***quality assurance***

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Grading terminology

Continuously graded

- ***Near maximum density line***. Many mixes used in SA have this type of gradation, sometimes with ***unacceptably low VMA***

Gap Graded

- ***Low proportion*** of particles in the ***mid-size range***
- Coarse stone plums in sand matrix
- Considered where ***permeability of the mix is a critical*** requirement
- Require some ***texturing*** to improve skid resistance

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Grading terminology

Open Graded

- Small proportion of fine aggregates
- ***High air voids***
- Used for porous asphalt and thin friction courses.

Uniformly Graded

- Particles are ***single sized***
- Applies to ***aggregate fractions***

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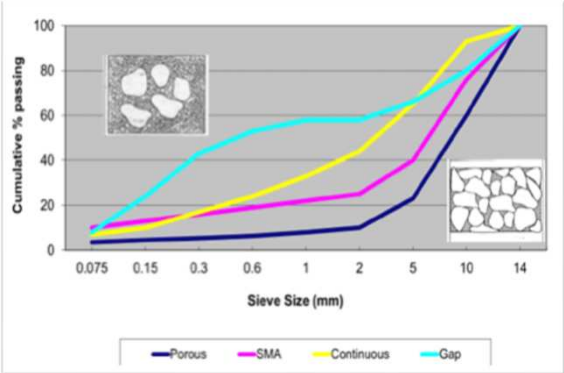
Grading types

- Sand-skeleton mix types e.g. **Gap graded** quite distinct from stone-skeleton types such as **"SMA"** and **"Porous"**
- Note that **continuously graded** mixes could be ***either type!*** (***limitation of using grading to characterise mix behaviour***)



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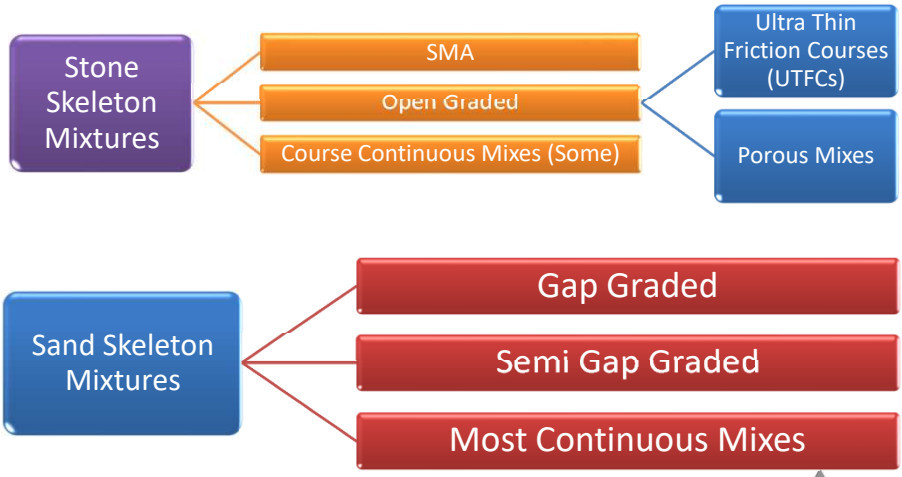
Standard classification



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Max density gradations

1960s - FHWA introduced the standard gradation graph widely used in the asphalt industry today - where the exponent of n = 0.45 was adopted, i.e.:

$$p_i = \left(\frac{d_i}{D}\right)^{0.45}$$

Graph - different than other gradation graphs because it uses the ***sieve size raised to the power 0.45 as the x-axis units***

Note: Gradings close to these maximum density lines ***limits the space available*** for ***adequate binder volumes*** while providing ***sufficient voids***.

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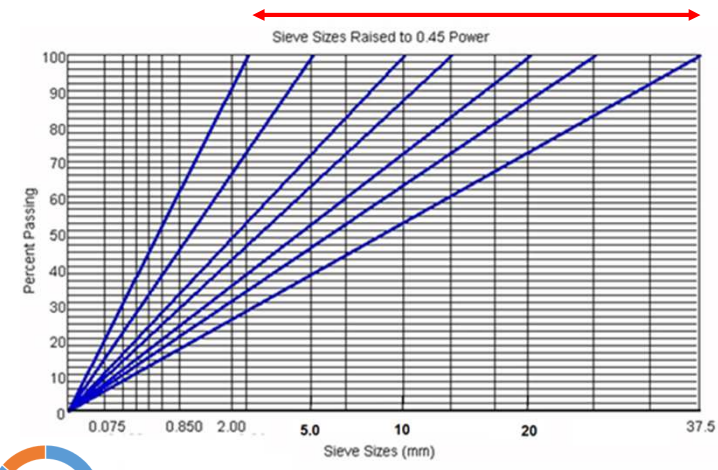
Max density lines (n = 0.45)



Note: The max. dens. Line moves as mix size changes!

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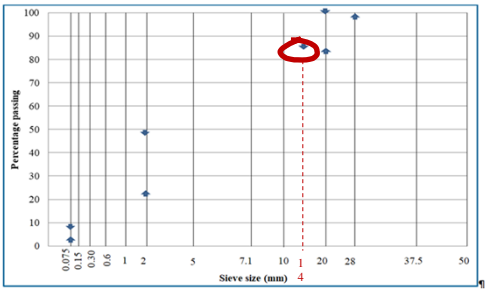
Grading control points

- Manual 35 – Suggested control points for ***sand skeleton mixes (ONLY)***
- Note: Aids with keeping mix size relevant!
- E.g. For 20 mm NMPS:



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- Control points - ***guidelines only ONLY relevant to sand skeleton types*** (For Stone skeleton – Speciality manuals)
- Gradation of (continuously graded) sand skeleton mixes ***should not be too close to the 0.45 power maximum density curve***
  - VMA is likely to be too low leading to low binder content to attain minimum voids in the mix
- To ***optimise aggregate proportions***, use the ***Bailey method***, (used with success in SA).

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Mix type selection

Selection guidelines

- Take into account all ***key elements*** of the ***design situation*** (section 3.1)
- ***Informed decision*** on the selection of the ***mix type***
  - ***Application;***
  - ***Type;***
  - ***Size; etc.***

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Selection considerations

Selected *mix type determines the grading*

- ***Friction and noise - opposing dynamics*** (except open-graded asphalt and purpose designed friction courses)
- Thin layer asphalts ***for low speed, light to moderate traffic*** in residential areas - typically ***sand-skeleton mixes***
- ***Stone-skeleton*** mixes preferred for ***high traffic volumes*** where ***friction & rut resistance*** are key considerations

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Selection considerations

Selected *mix type determines the grading*

- ***Continuous gradings that ensure sand-skeletons*** are frequently selected for ***general use***
- The term "***continuously graded asphalt***" has ***little specific meaning***
- For adequate ***skid resistance of gap- & semi gap-graded*** wearing courses, ***pre-coated chippings*** are usually applied prior to rolling -> be vigilant of permeability and durability!
- Refer Table 7 in Manual 35

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We are HERE in the process

Questions?

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