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Theoretical mixture design method for mastic asphalt

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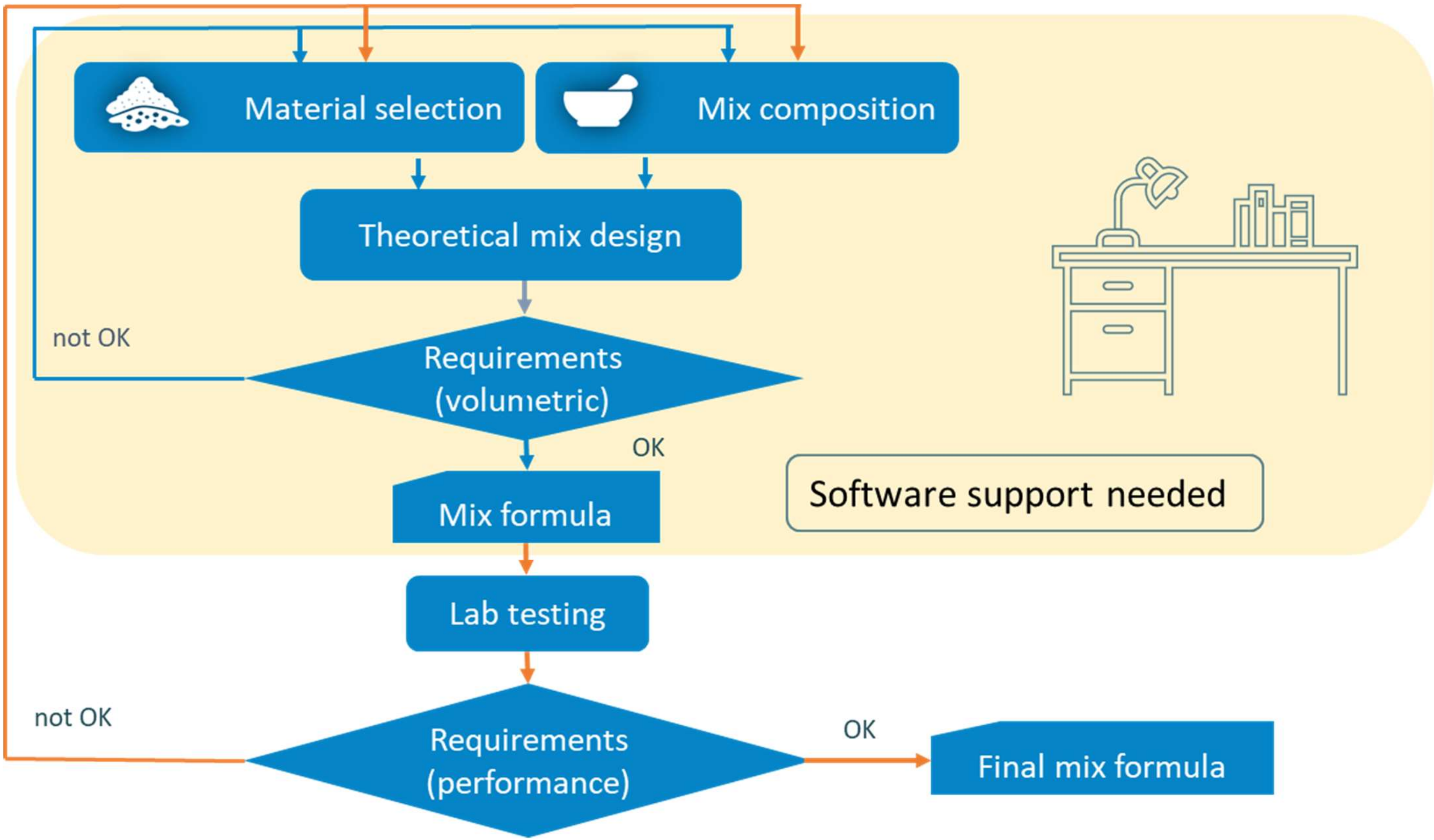
- Theoretical mixture design method
- Results of BRRC research project:
  - Application of mixture design to mastic asphalt – particularities
  - Comparison with performance characteristics
  - Case study 1: Impact of type of filler
  - Case study 2: Impact of type of sand
- Conclusions

Introduction – Why do we need well-designed mixtures?

A good mixture design

- Reduces the risk of damages
- Lowers costs
  (economic, social, environmental)
- Increases the service lifetime

Introduction – What is mixture design?



Introduction - Advantages of mixture design

Reduction of lab tests for a new mixture

Lower risk of mixtures with poor performance

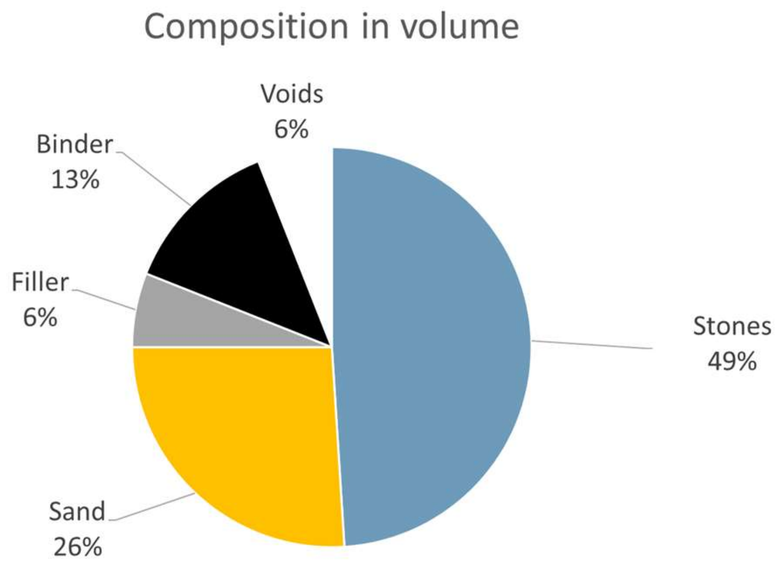
React quickly on changes in material characteristics

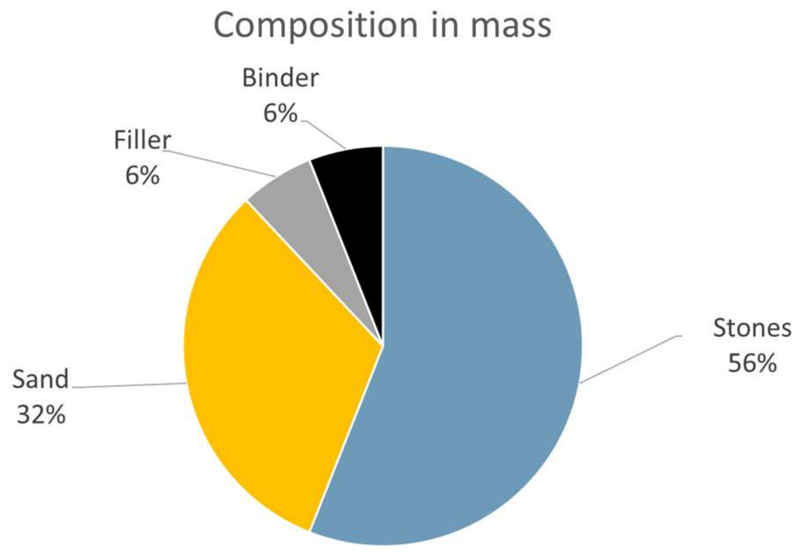
Design mixtures with unknown materials, e.g. new type of fillers

No trial and error

Calculation of a new mixture with software: ≤ 10 minutes

Theoretical mixture design method - Basic principles

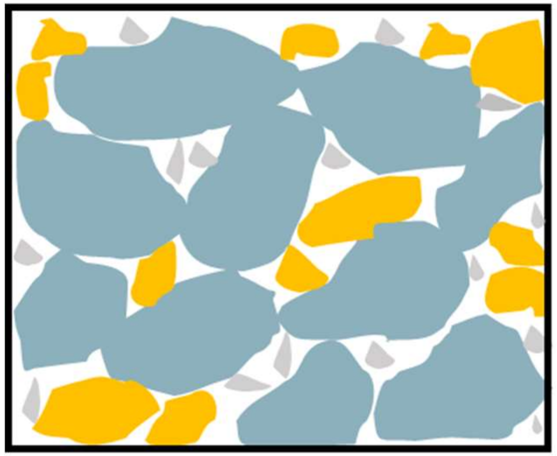




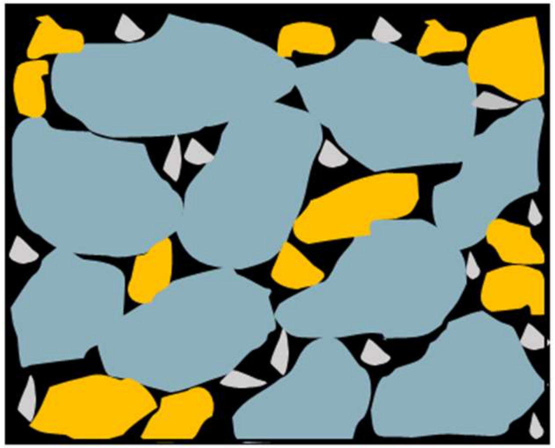
Example: Asphalt concrete

- Volumetric formulation is necessary for the calculation
- In practice (after calculation): Composition in mass for weighing

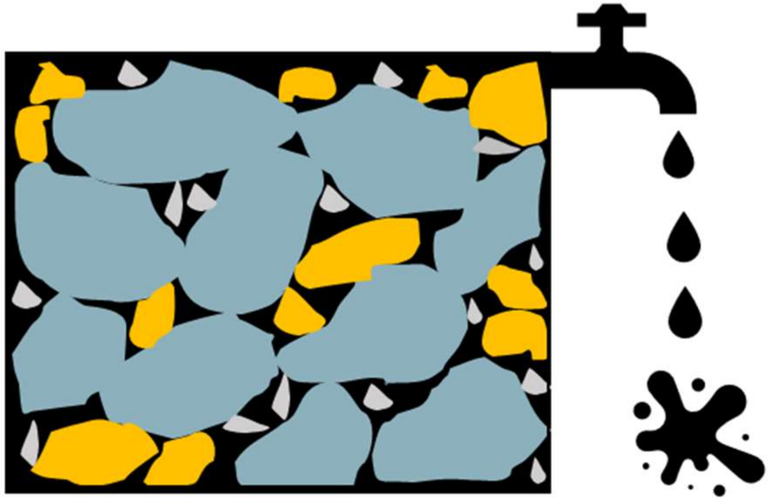
Theoretical mixture design method – Particularities for mastic asphalt



Mineral aggregates



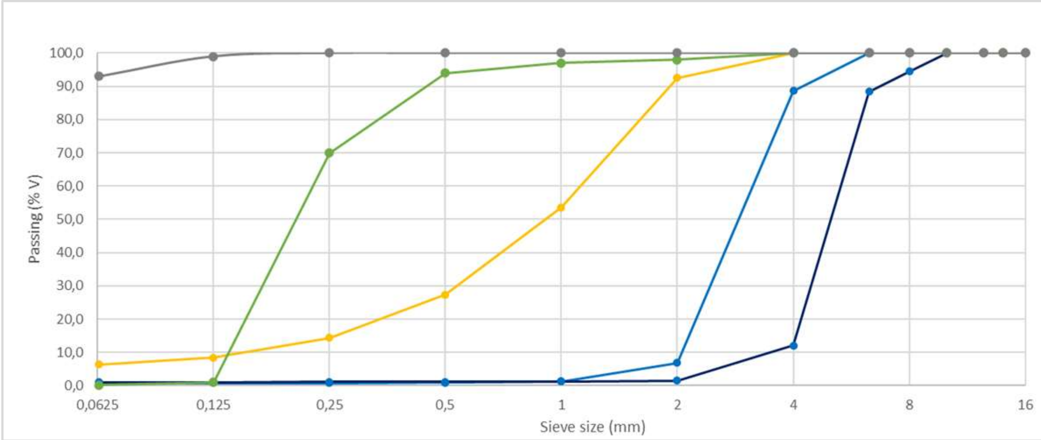
Mastic asphalt at ambient temperature: low or no voids or light binder surplus



Mastic asphalt at production temperature: binder surplus

Calculation of mixture composition – What is needed?

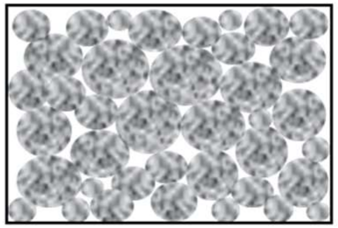
Grading of mineral components



Density of all components

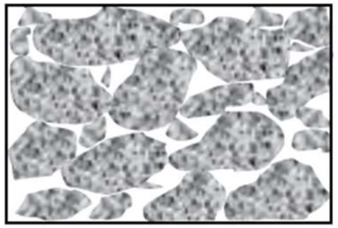
Angularity stones & sand (crushed, round)

Round



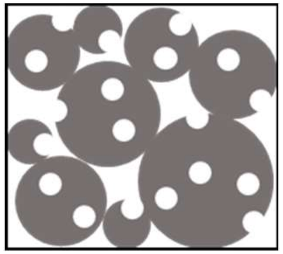
Lower % of voids

Angular

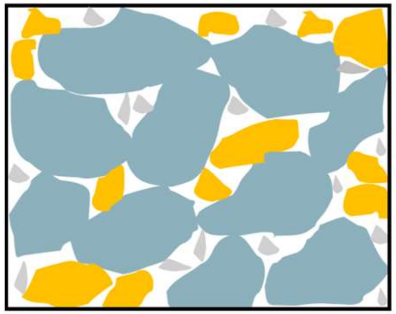


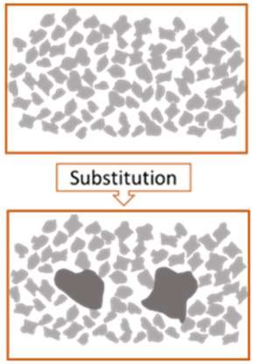
Higher % of voids

% of voids in the filler (Rigden voids)

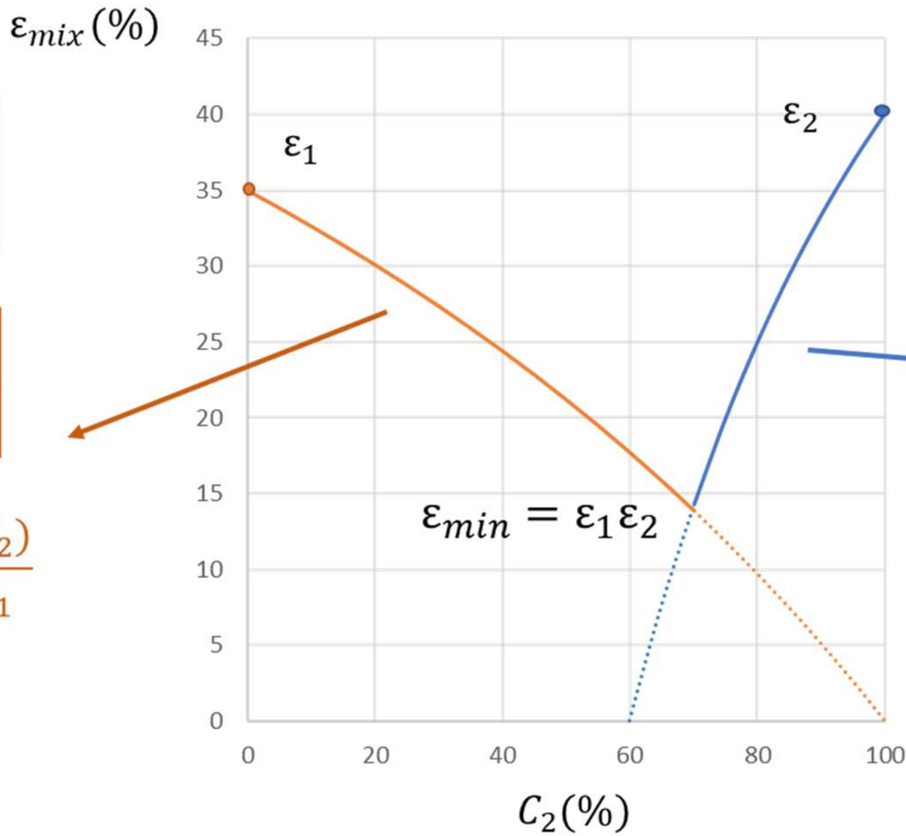


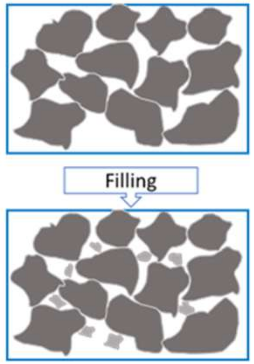
Theoretical parameters –
Voids in mineral aggregate (VMA)





$$\varepsilon_{mix} = \frac{\varepsilon_1(1 - C_2)}{1 - C_2\varepsilon_1}$$





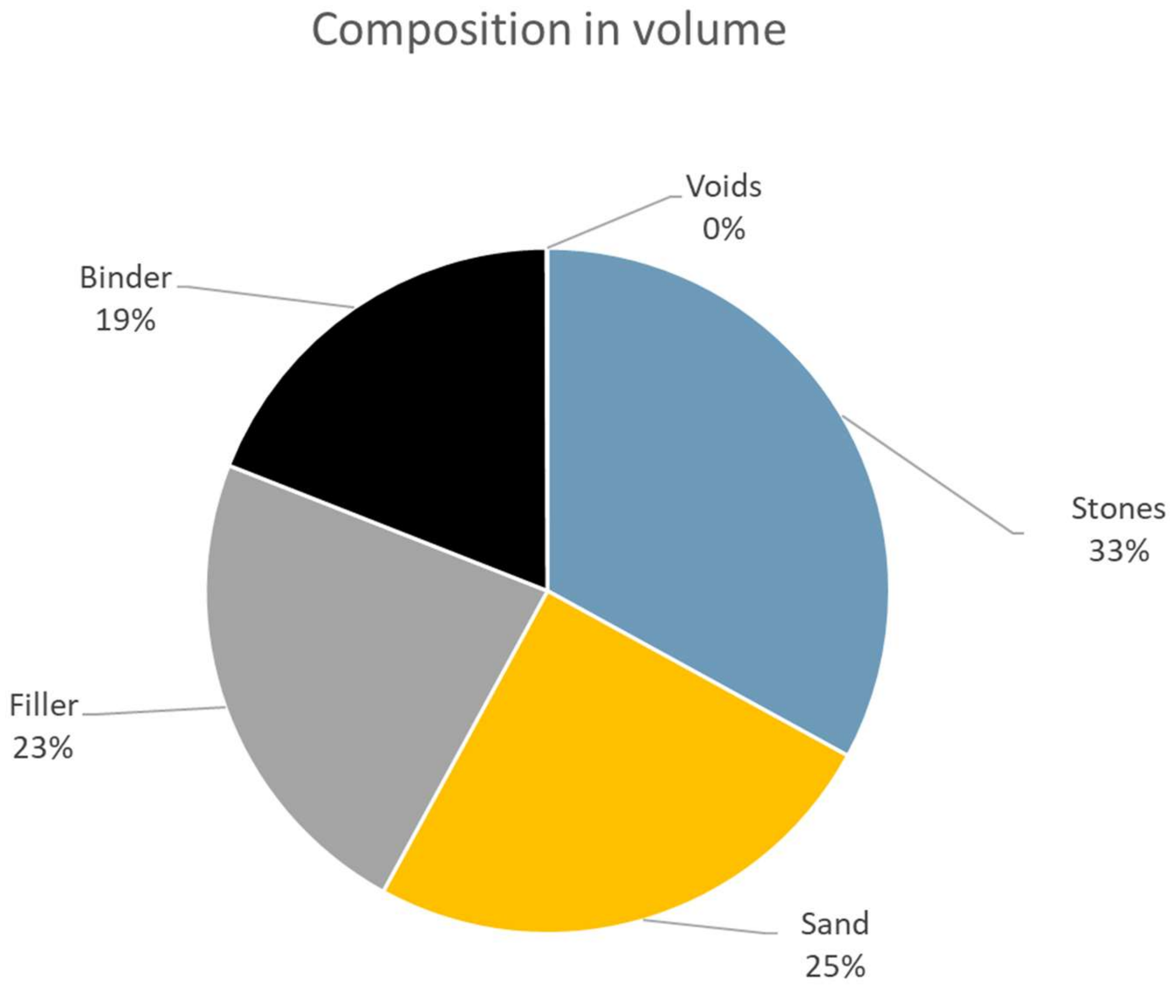
$$\varepsilon_{mix} = 1 - \frac{1 - \varepsilon_2}{C_2}$$

Binary mix

where $\frac{D_1}{D_2} \approx 0$

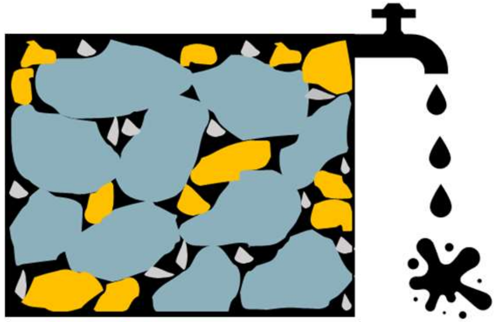
ε_1: porosity of fine aggregate; ε_2: porosity of coarse aggregate, C_2: concentration of coarse aggregate

Theoretical parameters - Voids in the bituminous mixture



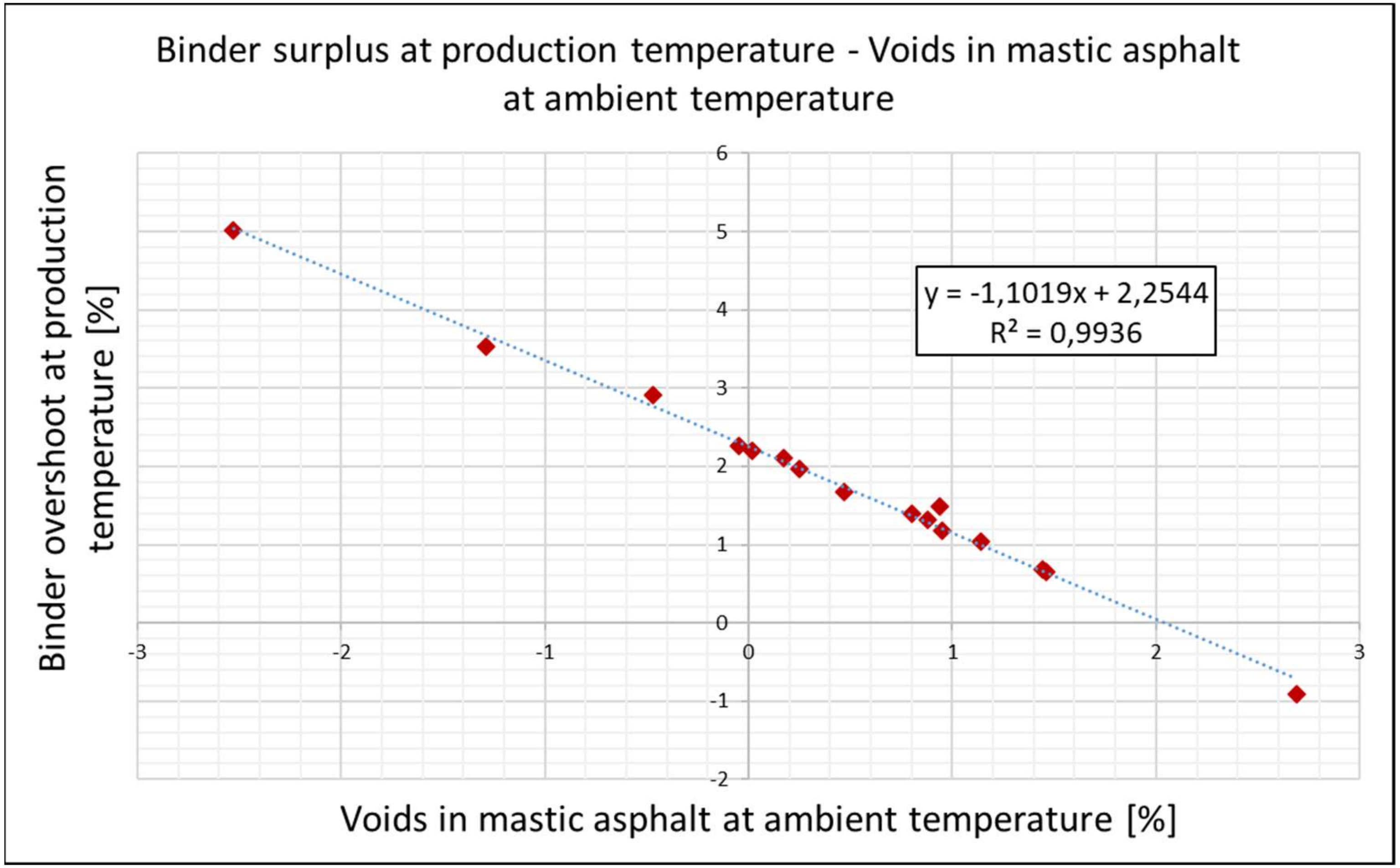
Example: Mastic asphalt at ambient temperature

Theoretical parameters – Mastic asphalt
Binder surplus at production temperature

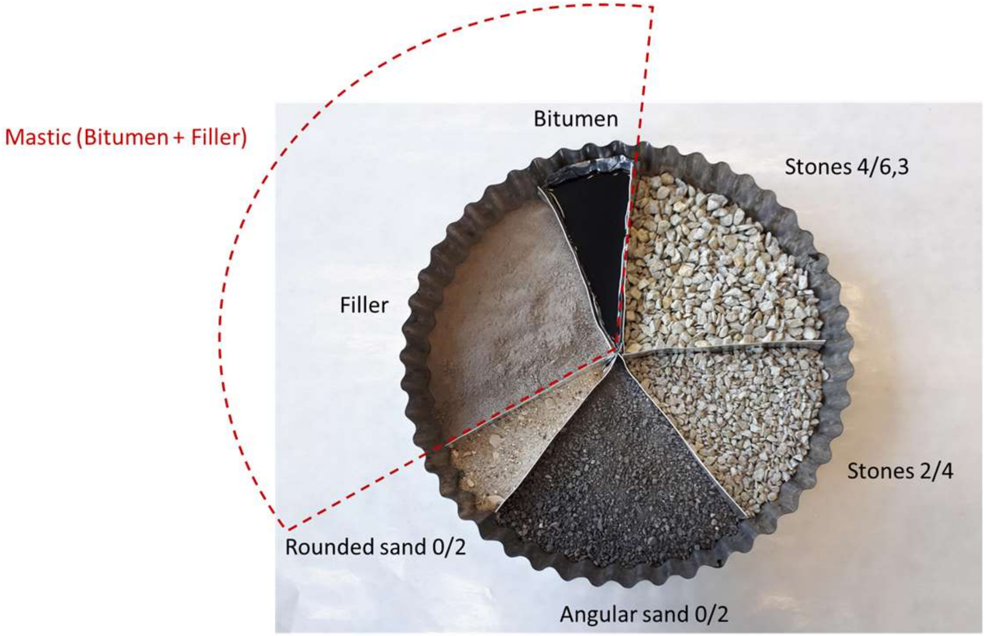


Correlated to voids in bituminous mixture

Results BRRC project (series of mastic asphalts MA 6,3 – protection layer for waterproofings):



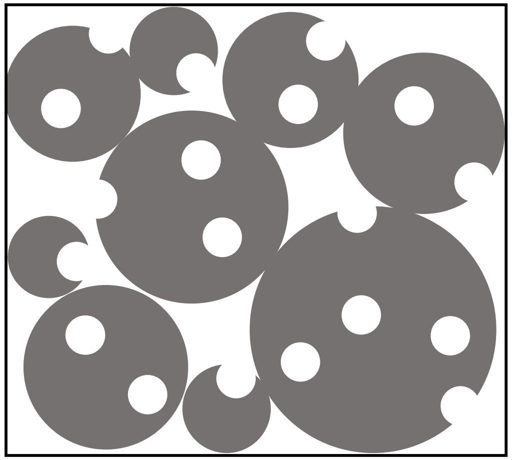
Theoretical parameters - Mastic stiffness indicator (MSI)



Function of

- Voids in the filler (Rigden voids) and
- Ratio volume filler/volume bitumen

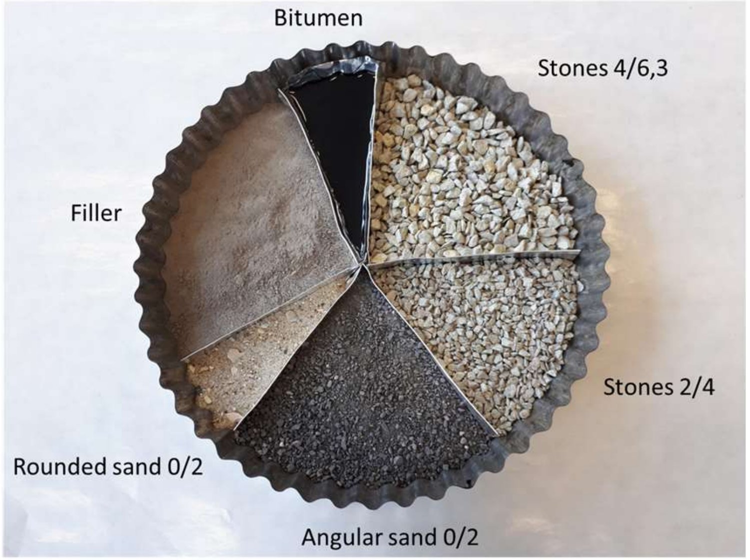
For bitumen it corresponds to:
Results of 'Delta Ring and Ball Test' on bitumen/filler mixture
(EN 13179-1)



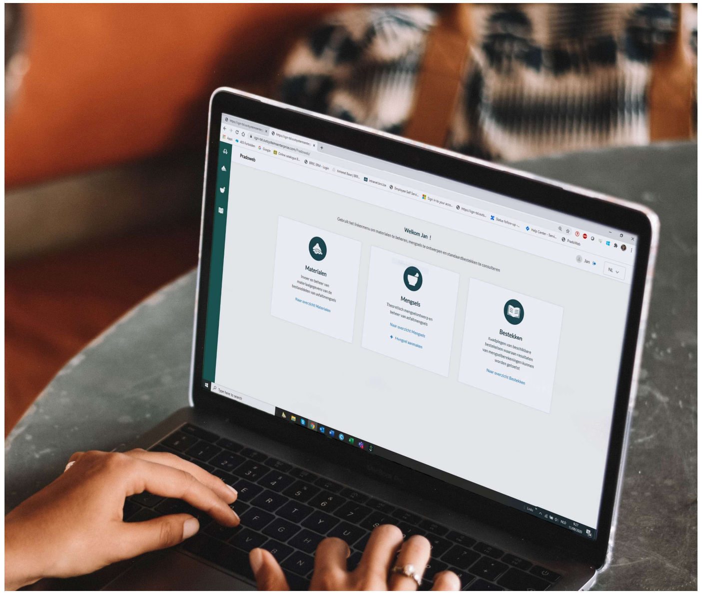
Calculation of mixture composition

Calculation of mixture composition and theoretical parameters needs software support

BRRC developped PradoWeb software (Program for Road Asphalt Design and Optimisation) based on long-term research



- Precise
- Fast
- User-friendly



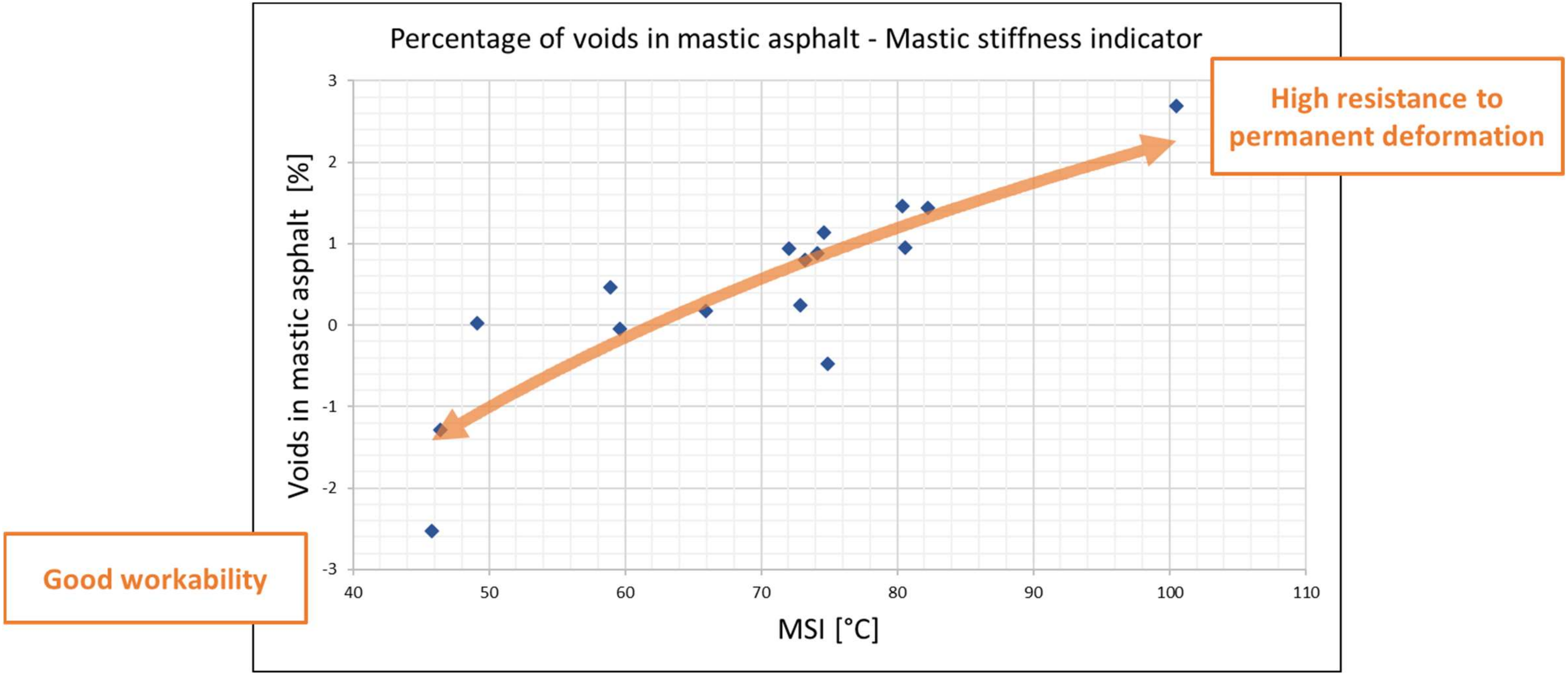
Comparison with performance characteristics

Project of the Belgian Road Research Centre (funded by the Belgian Bureau for Standardisation):

- Series of mastic asphalts MA 6,3 (protection layer for waterproofings)
  - Theoretical parameters of the mixtures
    - VMA
    - Voids in mastic asphalt
    - MSI
  - Performance of the mixtures
    - Workability
    - Resistance to permanent deformation

Comparison with performance characteristics

Results of BRRC study (mixtures with neat bitumen, no additives/PmB):

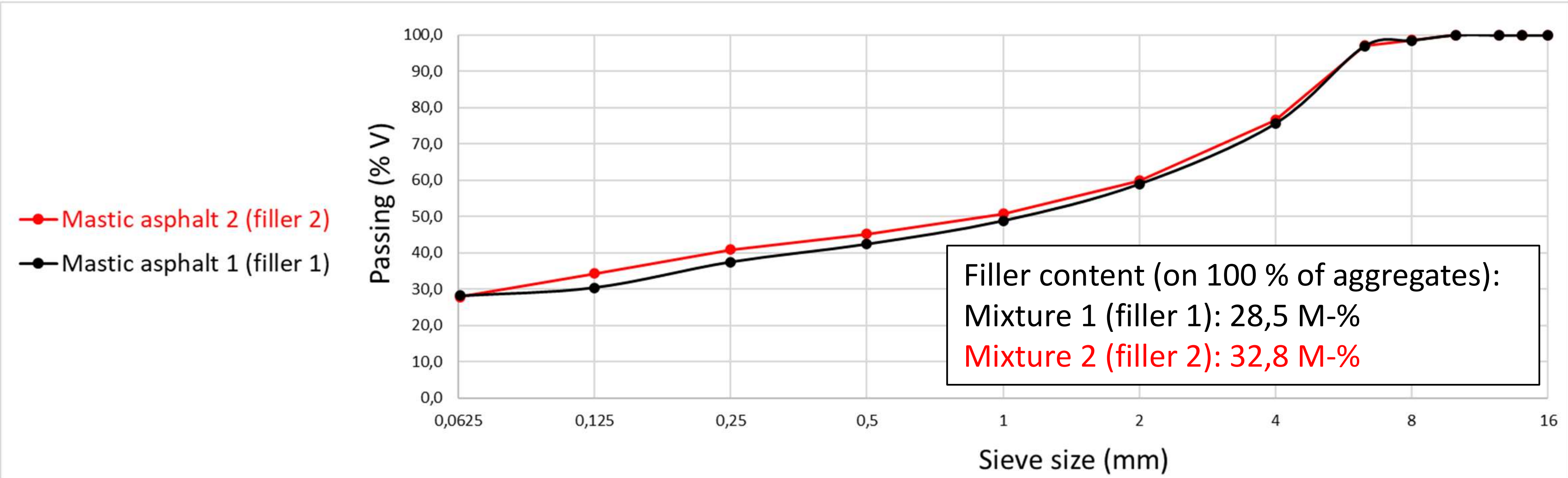


Compromise has to be found between:
Workability and resistance to permanent deformation

Case study 1: Exchange of the filler

Limestone filler	Rigden voids [%]	Percentage passing by mass		
		Sieve 0,25 mm	Sieve 0,125 mm	Sieve 0,063 mm
1	36	100	99	93
2	**32**	**100**	**98**	**80**

Grading curves of the two mastic asphalts (same target curve):



Case study 1:
Exchange of the filler

	Theoretical parameters			Measurements: Indentation		
Mastic asphalt with filler	VMA [%]	Voids in mixture [%]	MSI [°C]	30 ' [mm]	60 ' [mm]	Δ [mm]
1	19,9	0,8	73,2	3,9	4,8	0,9
2	**18,2**	**-1,3**	**46,4**	**4,6**	**5,9**	**1,3**

Lower percentage of voids (+ binder surplus) + low MSI: ⇨ Less resistant against deformation

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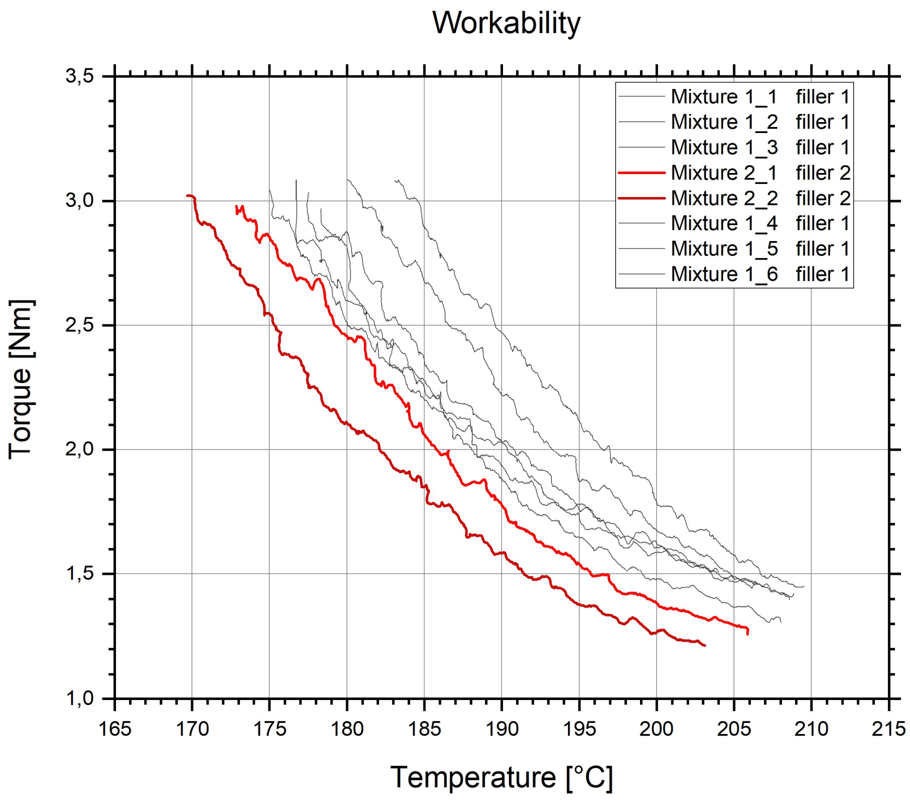
Case study 1: Exchange of the filler



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Case study 2: Composition of the sand fraction

		Theoretical parameters		
Mixture	Sand fraction	VMA [%]	Voids in mixture [%]	MSI [°C]
Reference A	75 % angular (0/2) 25 % round (0/2)	20,0	0,9	72,0
Variant with round sand	**76 % round (0/4)** **24 % round (0/2)**	**18,8**	**-0,5**	**74,9**

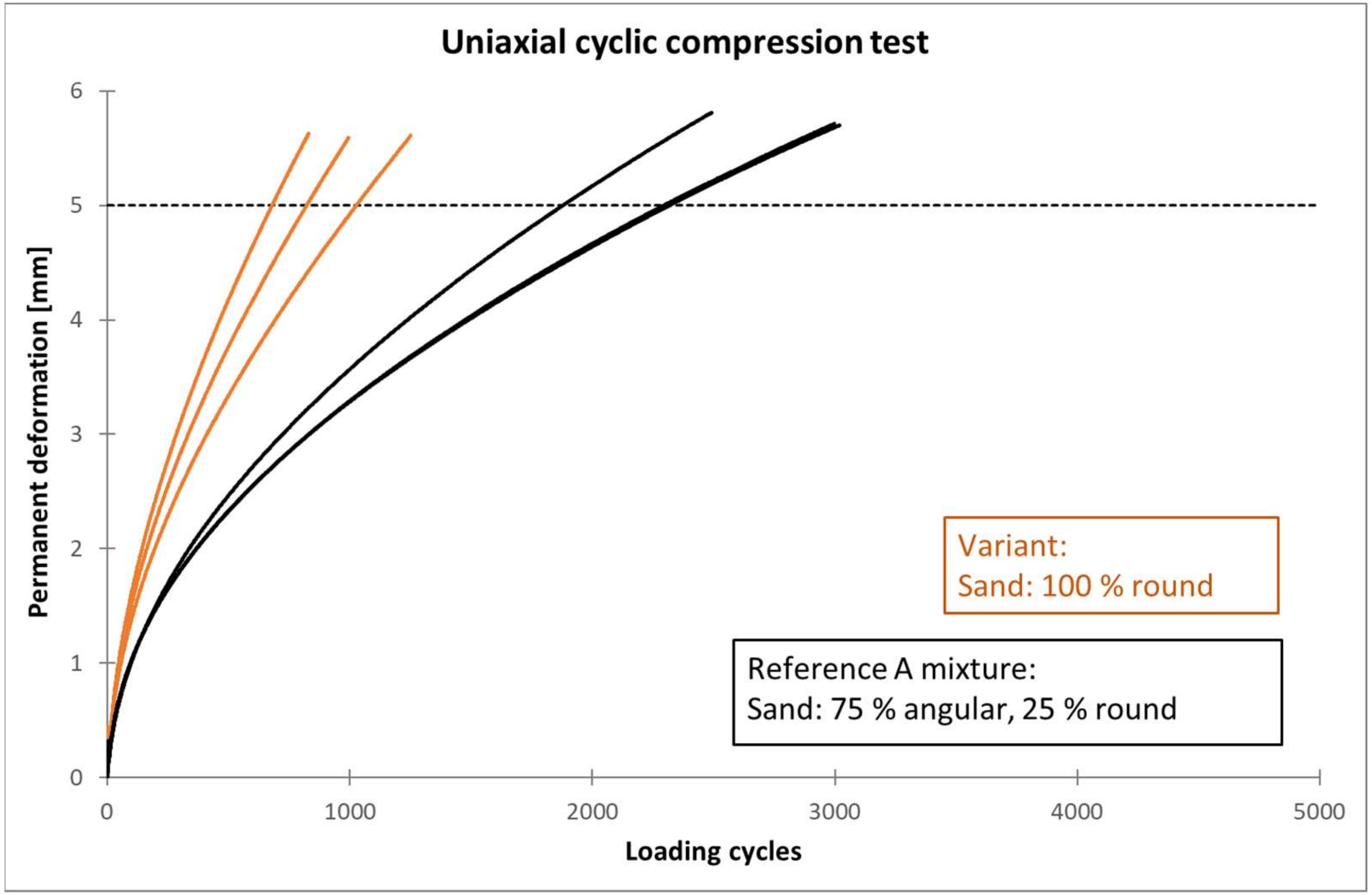
- Same target grading curve for the two mixtures
- Small differences in % of filler, same bitumen content (→ almost identical MSI)
- Differences in VMA and voids in mixture

Case study 2:
Composition of the sand fraction

	Theoretical parameters			Measurements: Indentation		
Mixture	VMA [%]	Voids in mixture [%]	MSI [°C]	30 ' [mm]	60 ' [mm]	Δ [mm]
Reference A	20,0	0,9	72,0	2,5	2,9	0,4
Variant with round sand	**18,8**	**-0,5**	**74,9**	**2,9**	**3,3**	**0,4**

Lower percentage of voids (+ binder surplus): ⇨ Less resistant against deformation

Case study 2: Composition of the sand fraction



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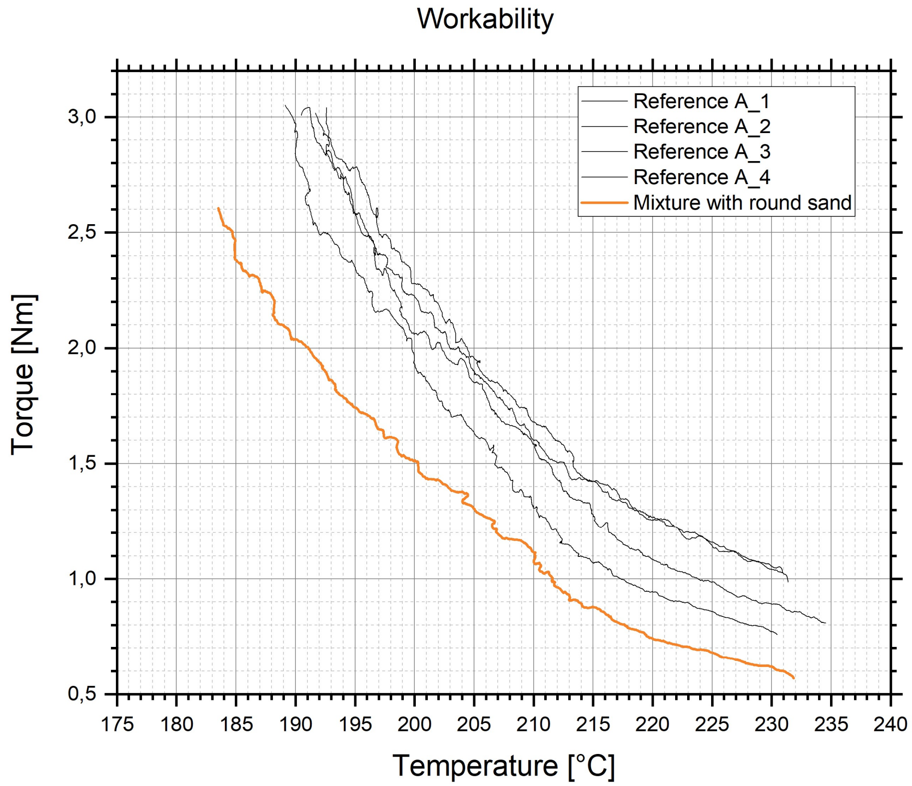

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Lower percentage of voids (+ binder surplus): ⇨ Better workability

Conclusions 'Theoretical mixture design method'

- Lowering of costs
- Preselection of promising mixture candidates without tests
- Reduction of lab tests
- Exchange of components becomes easier
- Better quality of mixtures and lower risks for contractors and road owners

Limitations of the theoretical method:

- Impact of additives/PmB not yet studied (complex task)
- Assesses the impact of granular materials and composition but not yet the binder type

More information

BRRC Code of good practice for the design of bituminous mixtures (mastic asphalt not yet included in detail):

- French: https://brrc.be/sites/default/files/2022-12/R105.pdf
- Dutch: https://brrc.be/sites/default/files/2022-12/A105.pdf

PradoWeb software (Program for Road Asphalt Design and Optimisation):

- https://brrc.be/en/innovation/innovation-overview/pradoweb

Thank you for your attention ☺