KONFERENCJA - Nowoczesne nawierzchnie drogowe

Recykling w konstrukcjach nawierzchni drogowych

CONFERENCE - Modern Road Pavements

Recycling in road pavement structures

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Investigation of Tertiary Flow Behavior of Bitumen Stabilised Materials with bitumen emulsion

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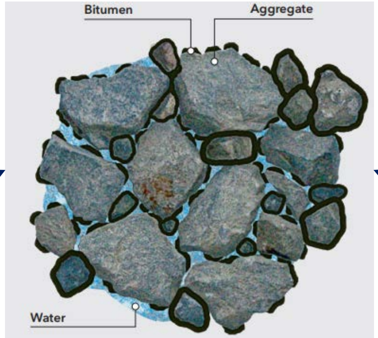
Drawing courtesy of Freepik.com

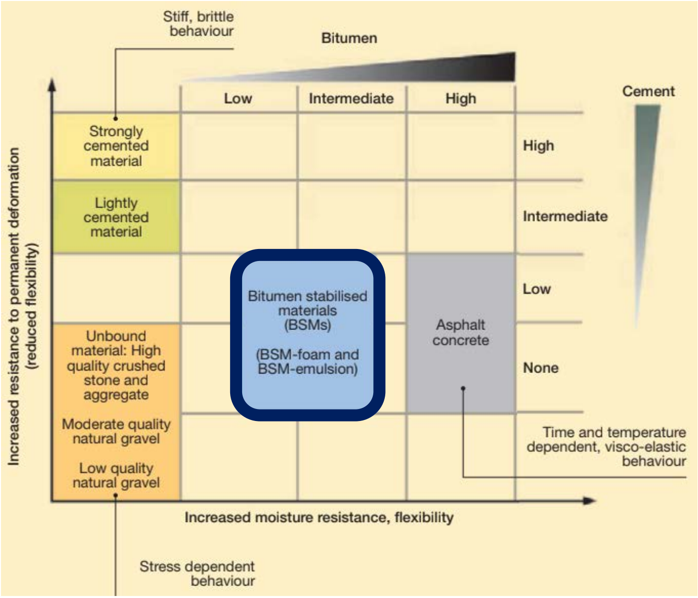
Bitumen Stabilised Materials (BSMs)

Cold recycling mixtures for base courses:

Reclaimed Asphalt Pavement (RAP) – **up to 100%,**
virgin aggregates, bitumen emulsion, cement **(<1%)**, water



Non-continuously bound



Source: Asphalt Academy Technical Guide
Wirtgen. Cold Recycling Technology Manual

Permanent deformation performance of BSMs

Granular material approach

widely described

- Non-linear elasticity, stress-dependency
- Dynamic triaxial testing
- Well-recognized and applied stress-ratio based evaluation parameters (e.g. Deviator Stress Ratio - DSR)
- Dependence of the chosen DSR on shear properties of individual mixtures

Viscoelastic material approach

briefly addressed

- Time- and temperature dependency
- Wheel Tracking (WTT) and Flow Number (FN) tests – single cases of application
- Necessity to adapt the testing parameters and condtions to reliably capture the BSMs' permanent deformation reponse

Research aim and motivation

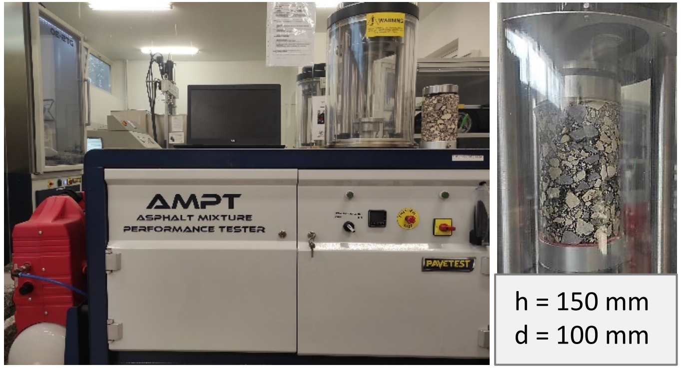
- Adaptation of the **AASHTO T378 Flow Number** testing method, commonly used for HMA and WMA, to **characterize the tertiary flow behaviour of BSMs**.
- Evaluation of permanent deformation characteristics of BSMs – identification of the influence of the material factors (i.e. RAP, bitumen emulsion, air void content).

- Currently available research can only be considered a first step toward a more profound understanding of the permanent **deformation response of BSMs in terms of viscoelasticity.**
- Extensive study is needed to define unified BSM permanent deformation testing conditions.

Flow Number method adaptation

Dynamic creep and recovery testing methodology (AASHTO T378 standard):

- Asphalt Mixture Performance Tester (AMPT) device,
- stress-controlled mode under unconfined conditions,
- three-staged permanent strain response,
- Flow Number parameter - the load cycle number corresponding to the minimum rate of the permanent axial strain change,
- testing parameters: loading stress level, temperature,
- maximum test duration: 10 000 cycles.



h = 150 mm
d = 100 mm

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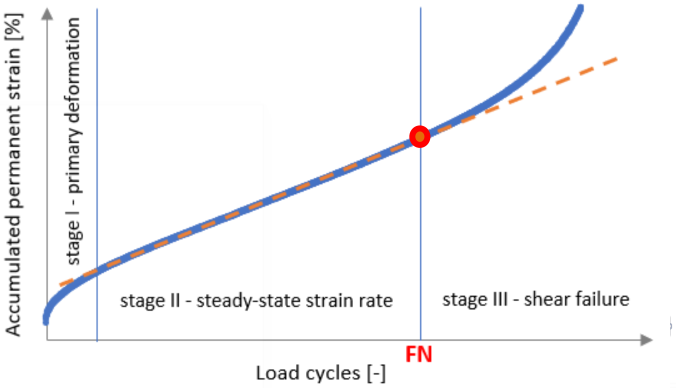


Flow Number method adaptation

	HMA	BSM
Test temperature	Adjusted PG temperature	**40°C, 60°C**
Repeated axial stress level	600 kPa	*low* *intermediate* *high* **140 kPa, 400 kPa, 600 kPa at 40°C** **200 kPa, 400 kPa, 600 kPa at 60°C**
Target air void content	(7±0.5) %	within the range of relevant CRM requirements
Minimum average FN requirement	50 – 740 cycles	to be verified
FN determination	Smooth central difference algorithm/Francken model	

FN estimation method

1. Data fitting to the **Francken model**

$$\varepsilon_p(N) = AN^B + C(e^{DN} - 1)$$

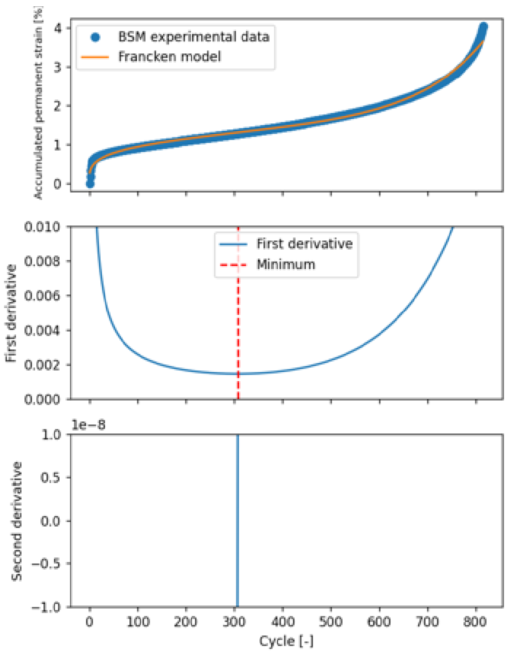
- determination of regression coefficients using Python programming script

2. Statistical analysis - goodness-of-fit evaluation: **R^2, QQ plots**

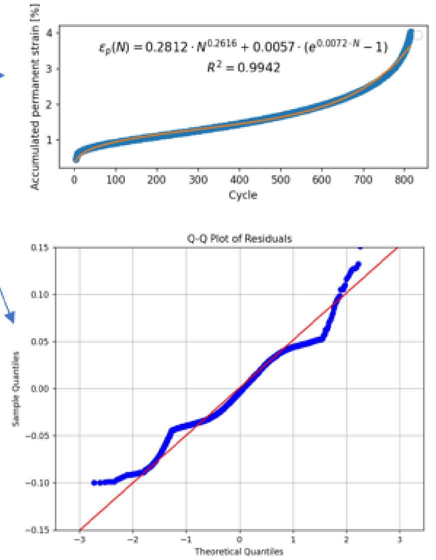
3. Flow Number determination:

$$\dot{\varepsilon_p}(N) = \frac{d\varepsilon_p(N)}{dN}$$

Francken model fitting and FN determination

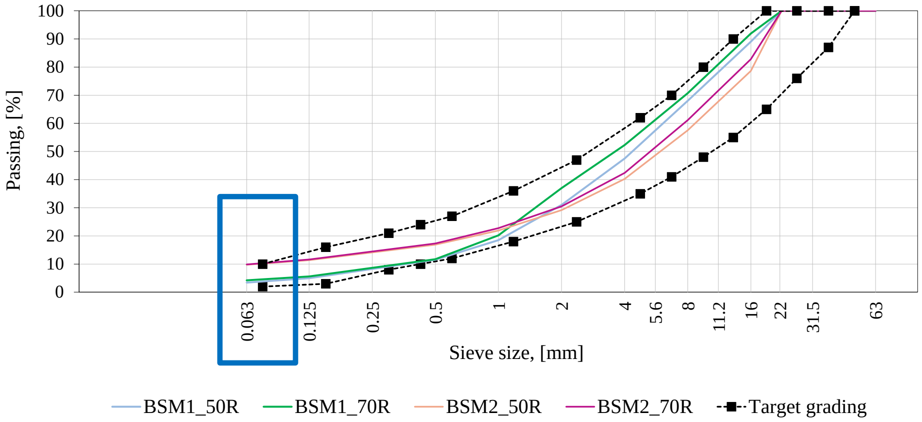


Statistical analysis of the model fitting accuracy



BSM mixtures

	BSM1	BSM2
RAP content	**50%, 70%**	
BE content	4.5% - 5.2%	6.0% - 6.4%
Air void content	**18%-20%**	**10%-12%**
Cement content	1%	



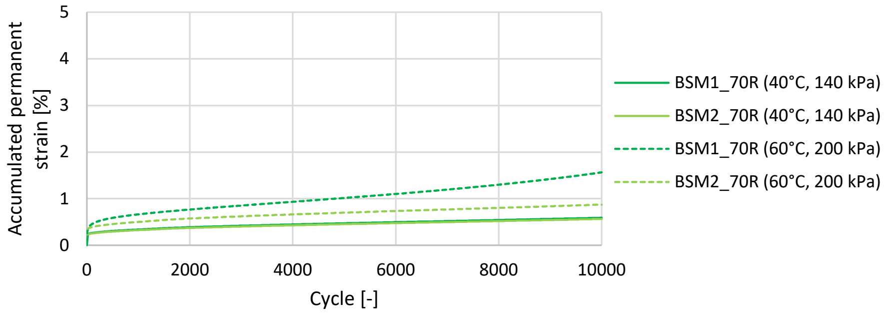
Specimen conditioning – oven drying at 40°C, for min. of 3 days, until reaching constant mass.

Results

Low loading stress levels (140 kPa at 40°C, 200 kPa at 60°C)

- Flow Number **not reached** within the limited number of load cycles, independently of the mix composition (RAP content), air voids content and applied test temperature.

- Insufficient data fitting accuracy for BSM mixtures with accumulated permanent strain curves presenting a prolonged secondary stage.



Low loading stresses are not recommended to be adopted in BSM tertiary flow testing.

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Results

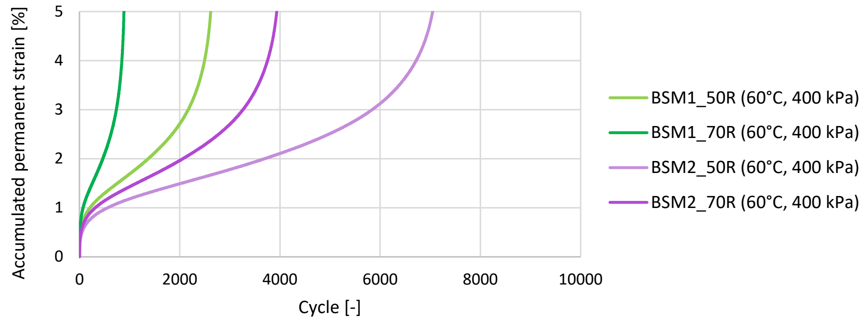
Intermediate loading stress level (400 kPa, 40°C and 60°C)

- **FN values** of BSM mixtures influenced by:
  - ✓ **air void content** for corresponding %RAP,
  - ✓ **RAP content** for corresponding air void content,
  - ✓ **test temperature.**

40°C

Mixture designation	Air void content [%]	Test conditions 40°C, 400 kPa	
		Average [-]	COV [%]
BSM1_50R	18 – 20	4165	12.1
BSM2_50R	10 – 12	*No FN*	-
BSM1_70R	18 – 20	2818	10.3
BSM2_70R	10 – 12	*No FN*	-

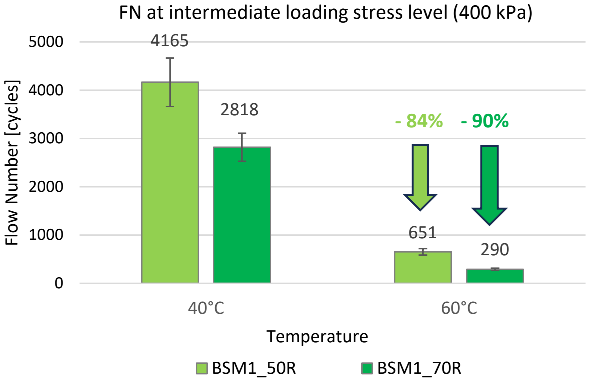
60°C



Results

Intermediate loading stress level (400 kPa)

40°C vs. 60°C



- Different temperature sensitivity of BSM mixtures depending on the RAP content.

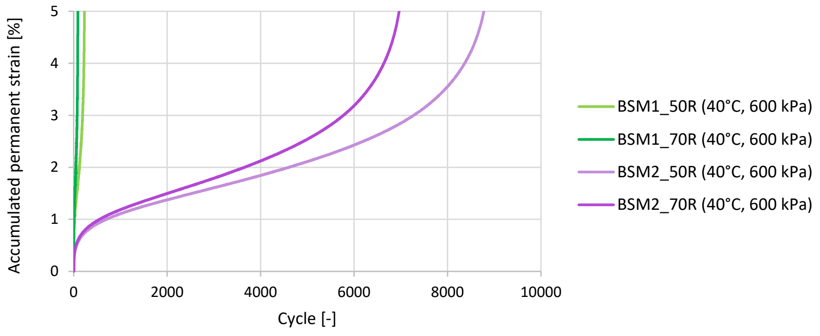
Intermediate loading stress levels are suitable for BSMs with high air void content.

Investigation of Tertiary Flow Behavior of Bitumen Stabilised Materials with bitumen emulsion

Results

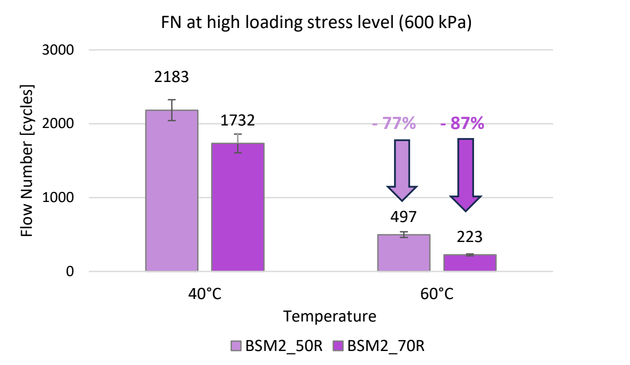
High loading stress level (600 kPa)

Influence of air void and RAP content



Temperature sensitivity of BSM mixtures

Mixture designation	Temperature [°C]	Loading stress [kPa] 600 kPa	
		Average [-]	COV [%]
BSM1_50R	40	57	14.1
BSM1_70R	40	22	16.9
BSM1_50R	60	21	12.7
BSM1_70R	60	9	42.1



High loading stress levels are more suitable for BSMs with dense internal structure - lower air void content and high fine particle share.

Conclusions

- Application of the **AASHTO T378 Flow Number** testing methodology for evaluating tertiary flow behaviour of Bitumen Stabilised Materials was **positively verified.**

- BSMs' permanent deformation characteristics (FN values) depend on the applied **loading stress level** and **test temperature.**

- Selection of the FN test parameters requires **an individual approach** depending on the properties of the BSM mixture, as the mix composition and air void content highly influenced the obtained FN values for specific test conditions.

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Discussion & questions

Thank you for your attention!

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