



# Belgisch **Wegen**congres Congrès belge de la **Route**

LEUVEN · 4-7.04.2022

## Matériaux stabilisés au bitume: une nouvelle approche des fondations durables en Flandre

Wim Van den bergh - UAntwerpen



Opzoekingscentrum voor de Wegenbouw  
Samen voor duurzame wegen





Belgisch Wegencongres  
Congrès belge de la Route  
LEUVEN 4-7.04.2022

# Innovations dans la construction routière



# FOAM

Fondations durables par recyclage in-situ avec la technologie de la mousse de bitume

Tetra project HBC.2020.2094 FOAM



Wim Van den bergh  
Universiteit Antwerpen



# Contenu

Contexte du projet

Matériaux stabilisés au bitume

Mise en œuvre

Pré-étude: formulation du mélange

Dimensionnement de la route

Structures-types

Les phases suivantes... et en route



**Fondations durables par recyclage in-situ  
avec la technologie de la mousse de bitume**

Tetra project HBC.2020.2094 FOAM

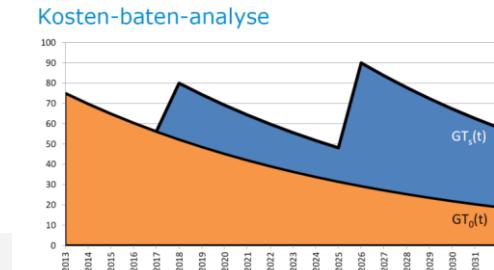


 **WIRTGEN GROUP**  **DE BRUYCKER-KEMP**  **BOMAG** PAINT GROUP

# Contexte du projet



- Utilisation durable des matériaux dans la construction routière
- Routes en asphalte: réutilisation des Agrégats d'enrobés bitumineux (AEB) (60%)
- En cas de rénovation: prise en compte de la réutilisation de l'AEB dans l'asphalte ou une autre application.
- Point de vue économique-écologique:
  - Coût de base/référence
  - Transport de l'AEB
  - Énergie en cas de réutilisation
  - Entièrement/partiellement remplacé par de nouvelles matières premières

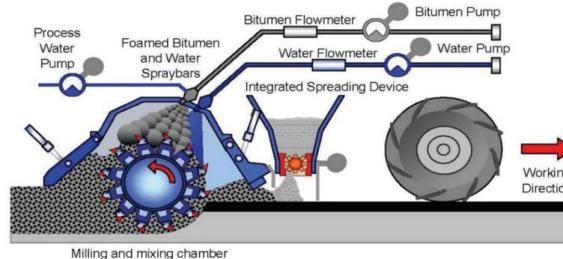


# Sustainability



Critères de succès: augmentation de l'utilisation durable de l'AEB

- moins de transport vers/depuis le site/obstructions
- moins d'utilisation de matériaux primaires
- moins de consommation d'énergie/CO<sub>2</sub>
- matériau de base qualitatif (solide)



In situ



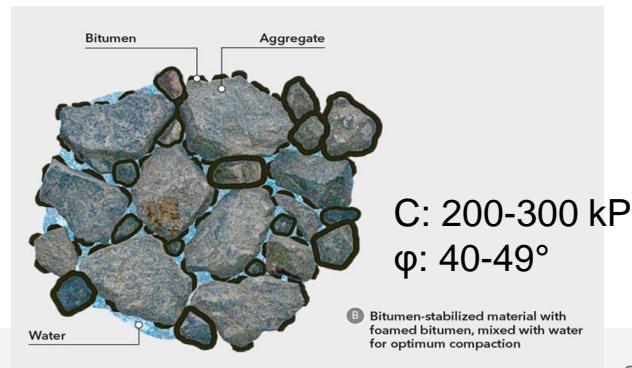
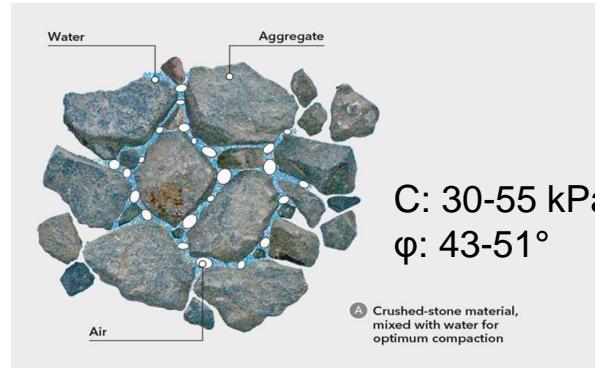
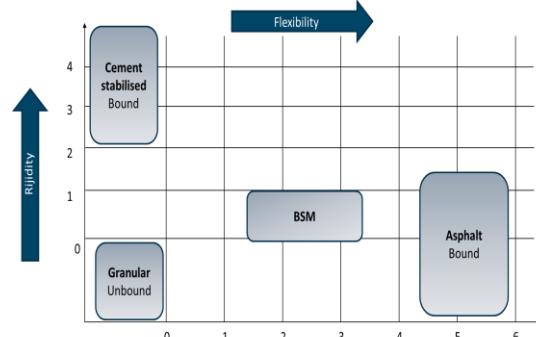
KMA



# Bitumen Stabilised Material



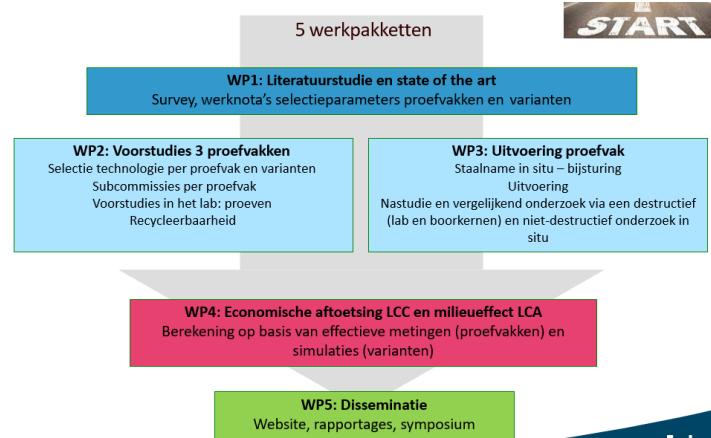
- Matériaux de base: au lieu de non lié/lié
- Granulats d'asphalte + ciment (1-2%) + éventuellement de nouveaux granulats, maintenus ensemble par une petite quantité de bitume (2-3%).
- Traitement à froid → dispersion du bitume par
  - Mousse de bitume
  - émulsions de bitume



# Réalisation du projet



- Démonstration avec 3 planches d'essai
  - In situ (mousse de bitume)
  - In situ (émulsion)
  - KMA (mousse de bitume)
- Etude préliminaire du mélange: laboratoire
- Surveillance de l'exécution
- Post-étude des échantillons: labo versus in situ



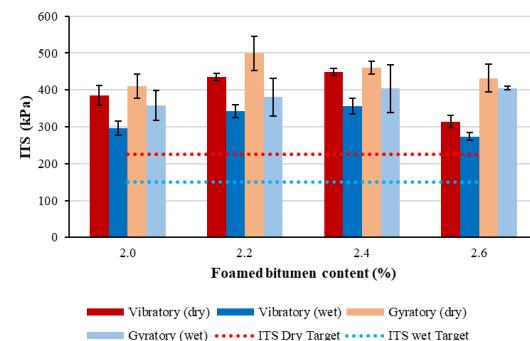
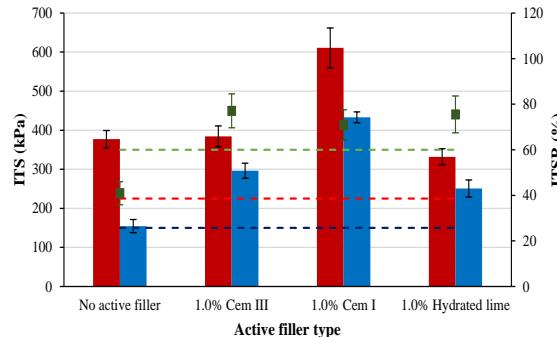
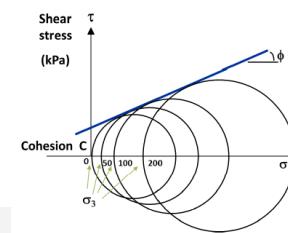
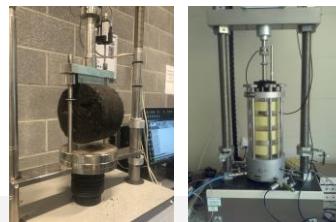
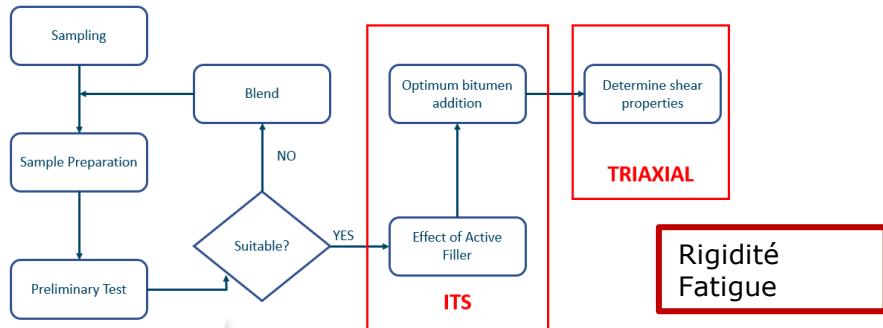
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# Etude préliminaire: formulation du mélange



- Conversion de la formulation du mélange en BE via TG2 (Afrique du Sud)



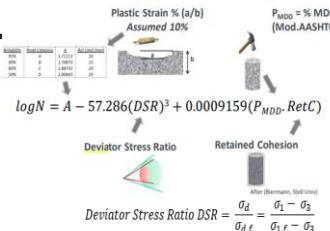


# Dimensionnement

Layer	Material	Design parameter	Response location	Failure mode (Terminal condition)	Transfer function
AC layers	Bitumen mix	Horizontal tensile strain $\varepsilon_h$ "m/m"	Bottom	fatigue cracking @ %20 lane area cracked	$N = \left( \frac{0.0016}{\varepsilon_h} \right)^{4.76}$
	Bitumen mix with high stiffness AVS	Horizontal tensile strain $\varepsilon_h$ "m/m"	Bottom	fatigue cracking @ %20 lane area cracked	$N = \left( \frac{0.0081}{\varepsilon_h} \right)^{7.39}$
Base layer	Cement stabilised material	Horizontal tensile strain $\varepsilon_h$ "m/m"	Bottom	fatigue cracking @ %20 lane area cracked	$\log N = 12 - 8000 * \varepsilon_h$
	Lean concrete (gravel)	Horizontal tensile stress $\sigma_h$ "MPa"	Bottom	fatigue cracking @ %20 lane area cracked	$\log N = 14 * \left( 1 - \frac{\sigma_h}{1.20} \right)$
	Lean concrete (gravel-bitumen)	Horizontal Tensile strain $\varepsilon_h$ "m/m"	Bottom	fatigue cracking @ %20 lane area cracked	$N_f = \left( \frac{0.00111}{\varepsilon_h} \right)^5$
Foam-BSM / Emulsion-BSM Stabilized material	Deviator Stress Ratio DSR	Roughly at top 1/4 depth in BSM	shear permanent deformation @ 10mm rut-depth with Reliability 90%	Stellenbosch BSM Design Function (1):	$\log N = A - 57.286(DSR)^3 + 0.0009159(P_{MDD}, RetC)$
Subgrade	Sand/clay ...	Compressive vertical strain $\varepsilon_v$ "m/m"	Top	permanent deformation @ 12.5mm rut-depth	$\frac{1}{N} = \left( \frac{\varepsilon_v}{0.011} \right)^{1/0.23}$

## Stellenbosch BSM function (NEW)

### New Mechanistic Empirical Structural Design Function



$$\sigma_{d,f} = \frac{(1 + \sin \theta) \cdot \sigma_3 + 2 \cdot C \cdot \cos \theta}{(1 - \sin \theta)}$$

DSR Deviator Stress Ratio

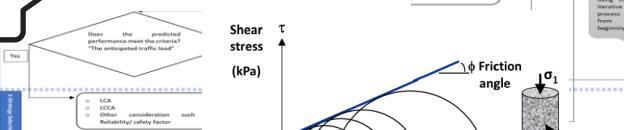
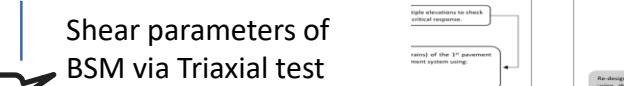
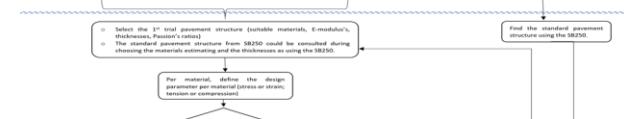
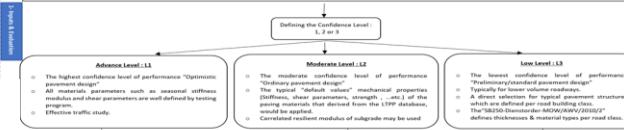
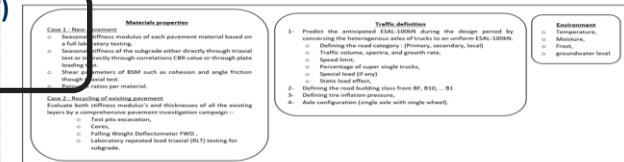
$\sigma_1$  Major principle stress in the layer (kPa)

$\sigma_3$  Minor principle stress in the layer (kPa)

$\sigma_{d,f}$  Major principle stress at failure from a triaxial test (kPa)

C Cohesion value of BSM from project mix design (kPa)

$\theta$  Friction Angle of BSM from project mix design



# Dimensionnement: Structure-type



Standard structure for Road class B4 <b>[Refined]</b>		Structure with BSM base (1 AC layer=40mm)		Structure with BSM base (1 AC layer=50mm)		Structure with BSM base (2 AC layer cover)	
40mm Top AC layer = SMA-C $E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$	$E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$	40mm Top AC layer = APT $E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$	$E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$	50mm Top AC layer = APT $E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$	$E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$	40mm AC underlayer = APO-A $E_{30c} = 5000\text{MPa};$ $E_{15c} = 10000\text{MPa};$ $E_{0c} = 20000\text{MPa}$	$E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$
70mm AC underlayer = APO-A $E_{30c} = 5000\text{MPa};$ $E_{15c} = 10000\text{MPa};$ $E_{0c} = 20000\text{MPa}$	$E_{30c} = 5000\text{MPa};$ $E_{15c} = 10000\text{MPa};$ $E_{0c} = 20000\text{MPa}$	300mm Base layer =Foam-BSM (B2,2% , F1%) $E = 800\text{MPa}$	$E = 800\text{MPa}$	300mm Base layer =Foam-BSM (B2,2% , F1%) $E = 800\text{MPa}$	$E = 800\text{MPa}$	60mm AC underlayer = APO-A $E_{30c} = 5000\text{MPa};$ $E_{15c} = 10000\text{MPa};$ $E_{0c} = 20000\text{MPa}$	$E_{30c} = 4000\text{MPa};$ $E_{15c} = 8000\text{MPa};$ $E_{0c} = 16000\text{MPa}$
300mm Base layer = cemented stabilized crushed aggregates $E = 4000\text{MPa}$	$E = 4000\text{MPa}$	450mm Subbase = Sand type I $E = 250\text{MPa}$	$E = 250\text{MPa}$	450mm Subbase = Sand type I $E = 250\text{MPa}$	$E = 250\text{MPa}$	250mm Base layer =Foam-BSM (B2,2% , F1%) $E = 800\text{MPa}$	$E = 800\text{MPa}$
300mm Subbase = Sand type I $E = 250\text{MPa}$	$E = 250\text{MPa}$	450mm Subgrade = Sand $E = 50\text{MPa}$	$E = 50\text{MPa}$	450mm Subgrade = Sand $E = 50\text{MPa}$	$E = 50\text{MPa}$	300mm Subbase = Sand type I $E = 250\text{MPa}$	$E = 250\text{MPa}$
Subgrade = Sand $E = 50\text{MPa}$	$E = 50\text{MPa}$	Subgrade = Sand $E = 50\text{MPa}$	$E = 50\text{MPa}$	Subgrade = Sand $E = 50\text{MPa}$	$E = 50\text{MPa}$	Subgrade = Sand $E = 50\text{MPa}$	$E = 50\text{MPa}$
Lowest N = base layer = CSM $N_{20} = 11.226.854$ ESAL-100kN	$N_{20} = 8.423.034$ ESAL-100kN	Lowest N = base layer = BSM $N_{20} = 3.823.014$ ESAL-100kN (AC layer APT)	Lowest N = AC layer = APT $N_{20} = 3.823.014$ ESAL-100kN (AC layer APT)	Lowest N = AC layer $N_{20} = 2.297.501$ ESAL-100kN (AC layer)	Lowest N= AC layer $N_{20} = 2.297.501$ ESAL-100kN (AC layer)	CSM layer is the critical layer $N_{20} = 11.226.854$ ESAL-100kN	CSM layer is the critical layer $N_{20} = 8.423.034$ ESAL-100kN
CSM layer is the critical layer $N_{20} = 11.226.854$ ESAL-100kN	CSM layer is the critical layer $N_{20} = 8.423.034$ ESAL-100kN	(OFFICIALLY; BSM layer is the critical layer) $N_{20} = 13.344.089$ ESAL-100kN (BSM)	(OFFICIALLY; BSM layer is the critical layer) $N_{20} = 13.344.089$ ESAL-100kN (BSM)	(OFFICIALLY; Subgrade layer is the critical layer) $N_{20} = 10.878.875$ ESAL-100kN (subgrade)	(OFFICIALLY; Subgrade layer is the critical layer) $N_{20} = 10.878.875$ ESAL-100kN (subgrade)	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}
Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}	Structurally and economically feasible/acceptable for B4 that has a range of {8MESAL to 16MESAL}

Table 18: Recommended standard structures based on AWV Standards according to the Flemish AWV Agency (MOW/AWV/2017/4)

Bitumineuze verharding op een steenslagfundering dikte van de lagen in cm										
bouwklasse	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
verharding	-	-	-	25	23	20	18	16	14	12
fundering	-	-	-	40	35	35	30	25	25	20

Bitumineuze verharding op een behandelde steenslagfundering dikte van de lagen in cm										
bouwklasse	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
verharding	-	-	-	23	21	19	16	14	12	11
fundering	-	-	-	35	30	25	25	20	20	20

Bitumineuze verharding op een gestabiliseerde steenslagfundering dikte van de lagen in cm										
bouwklasse	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
verharding	23	22	20	19	17	16	15	14	13	12
fundering	25	25	25	25	25	25	25	25	25	25

Bitumineuze verharding op een schraalbetonfundering dikte van de lagen in cm										
bouwklasse	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
verharding	20	19	18	17	16	15	14	13	12	11
fundering	25	25	25	25	25	25	25	25	25	25



## Les phases suivantes

- Sélection des trois planches d'essai : Site Viabuild, Alost
- Études préliminaires
- Mesures réelles pendant l'exécution: coût énergétique, transport
- Échantillonnage pour comparaison en laboratoire et sur site
- Comparaison LCA et LCCA avec des fondations conventionnelles
- Séminaires, formation, publications





# Merci beaucoup pour votre attention

<https://www.uantwerpen.be/en/research-groups/emib/rers/>

<https://www.uantwerpen.be/en/research-groups/emib/rers/activities/ais/>





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## UNE ORGANISATION



**ABR**

Association  
Belge de la Route



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