



**DANISH  
TECHNOLOGICAL  
INSTITUTE**

1st International Workshop on  
Asphalt Recycling Technologies

9th and 10th September 2024  
RWTH Aachen | Germany



APT 2024



# **DANISH EXPERIENCE WITH BSM *FROM INTRODUCTION TO FULL IMPLEMENTATION IN 5 YEARS***

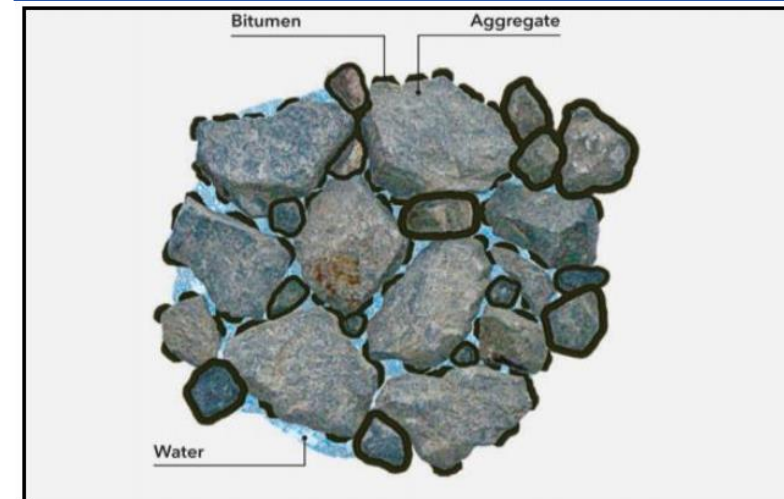
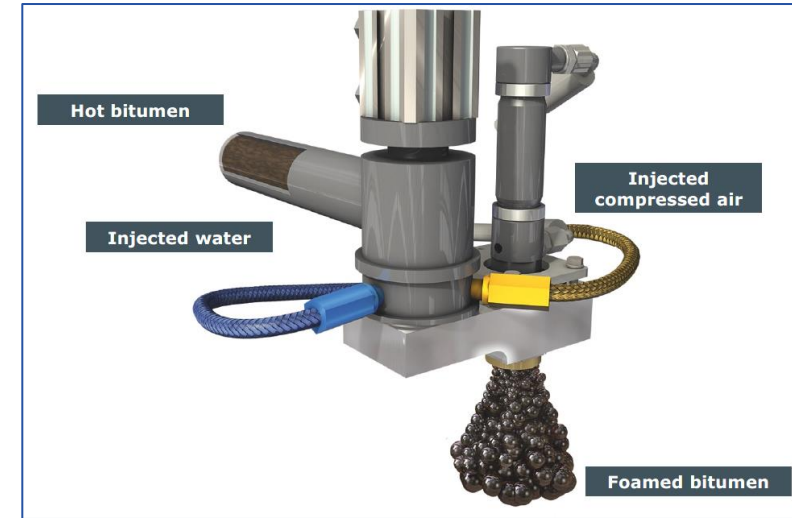
Ole Grann Andersson,  
Senior Specialist, Roads&Asphalt, DTI, Denmark

09-10 Sep 2024

# BSM – BITUMEN STABILIZED MATERIAL

## INTRO - WHAT IS BSM?

- Stabilised base layer for roads (may replace HMA-base layer)
- "Cold" mixing procedure, local materials: CO2-savings
- Normally based on reclaimed asphalt 0/16 - 0/32 mm (RAP)
- < 1% cement added as "active filler"
- Small amount of water added for compactability (from Proctor)
- Only 2-2,5% foamed bitumen 40/60 (or 70/100) added (alternatively bitumen emulsion)
- Final product a "point bound" base layer (see figure, right)
- Normally covered with a HMA-wearing course on top (some cases with heavy trafficked roads maybe also ABB binder layer)
- Two methods of production: In mobile mixing plant ("KMA") or in situ with special milling/stabilising machines ("WR" or "CRi")



# BSM PRODUCED AT KMA PLANT

- KMA mixing plant ('Kalt Misch Anlage'),
- BSM typically produced from crushed RAP, from near-by milling operation or from available stockpile.
- Cement, water and hot bitumen supplied by tankers. Ordinary asphalt pavers and rollers (pneumatic and steel wheel)



# BSM PRODUCED 'IN SITU' AT SITE

BSM produced in same operation as milling of old asphalt, directly at site

WR or CRi machines are used

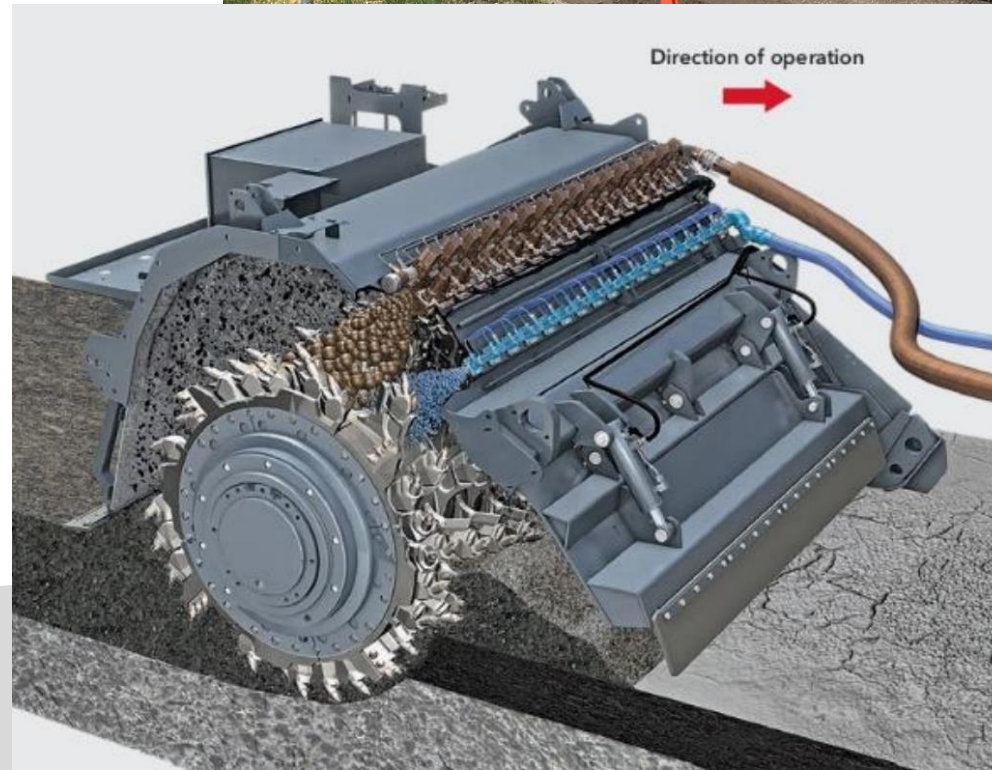
Cement, water and hot bitumen supplied by connected tankers ('train') and injected into milling chamber



Wirtgen CRi recycler



Wirtgen WR recycler



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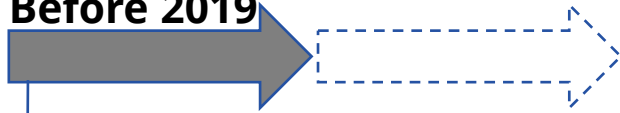
# BSM IN SITU - PAVING AND COMPACTION



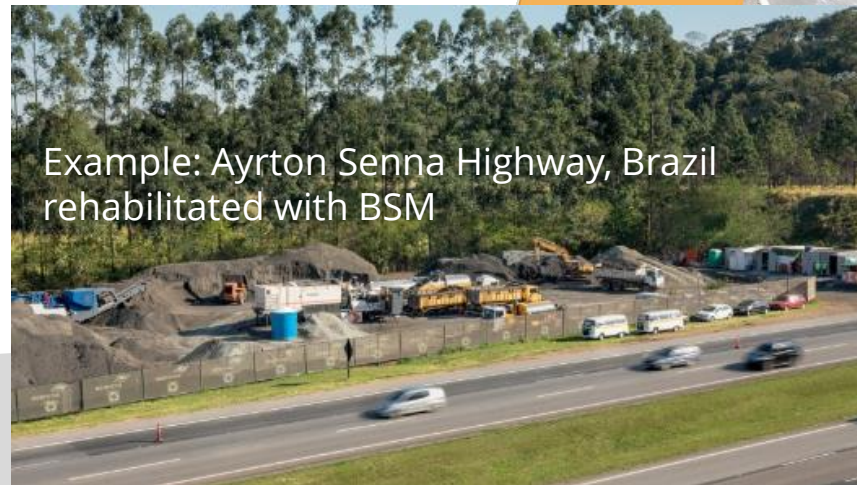
# BSM IN DK – FROM DEVELOPMENT STATE TO IMPLEMENTATION (0)

Implementation time line:

**Before 2019**



- Good experience with BSM from South Africa, Australia, America, Canada reported
- Equipment developed and produced by Wirtgen
- Cold stabilising technique low on CO2-emissions
- Limited experience in Europe



Example: Ayrton Senna Highway, Brazil rehabilitated with BSM



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# BSM IN DK – FROM INTRODUCTION TO FULL IMPLEMENTATION

2019

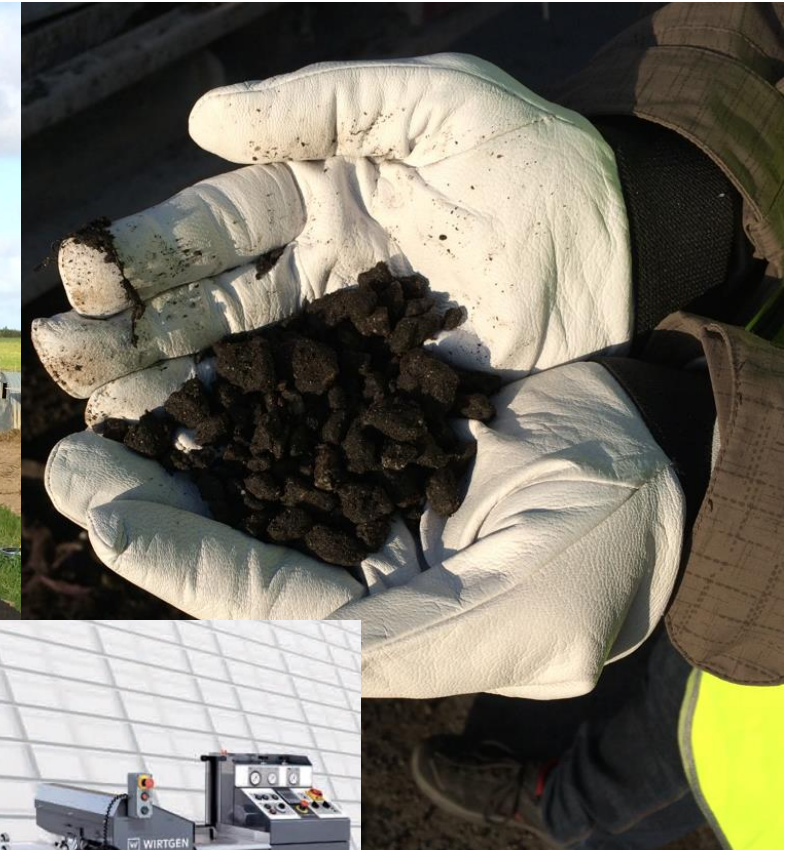
DRD strategic focus on CO<sub>2</sub>-savings

DRD Regulations group set out subgroup\* BSM

DRD contract to DTI for lab.test program 2019-22

DTI lab-tests document potential

First trial section on rural road



\*) With representatives from Municipalities, Contractors, DRD, DTI



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# BSM IN DK – FROM INTRODUCTION TO FULL IMPLEMENTATION

2020

7 full scale BSM test sections on municipality roads and motorway followed by DTI testing program

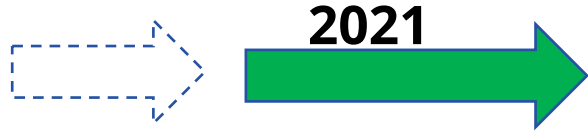
Supplementary lab.doc. of WTT, Triaxial test, TSRST crack resist. etc.

Further consolidation of lab.data plus FWD by DRD





# BSM IN DK – FROM INTRODUCTION TO FULL IMPLEMENTATION



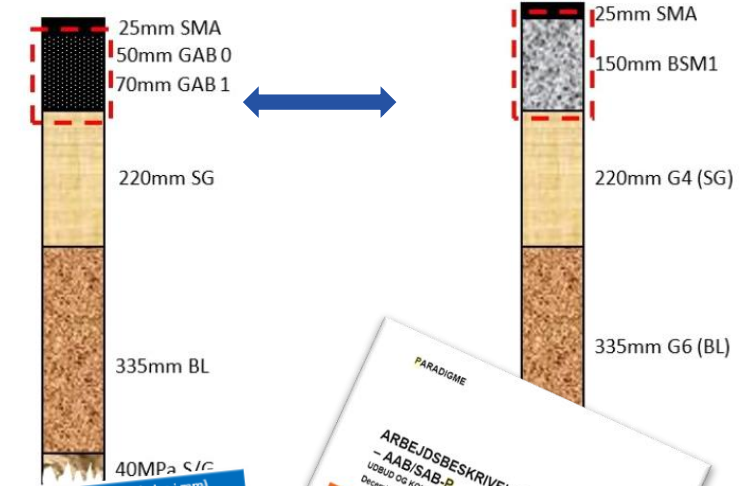
- DTI's LCA for SR-Gruppen documents ~50-75% CO<sub>2</sub> savings
- Cores from 2020 sections show fine data and increased stiffness modulus
- Further test sections performed
- DRD standard tender specifications for BSM-KMA published, plus 3 new BSM lab. test methods (foaming, mixing and specimen preparation)
- DRD design handbook revised to include BSM (incl. Catalogue)



Trafikklasse T4

STANDARD PAVEMENT FOR T4 TRAFFIC CLASS

ALTERNATIVE BSM PAVEMENT



Befæstelser med bitumenstabiliseret materiale til 20 års trafik (lagtykkelse i mm)						
Trafikklasse	T0	T1	T2	T3	T4	T5
Tunge køretøjer pr. døgn	Ingen	< 1	≤ 65	65-120	120-560	560-1.200
Æ10-belastning		0,5	0,5-20	20-50	50-200	200-500
	15 OB 500 125 BSM 100 SG 160 BL <sup>(2)</sup>	25 AB 1000 125 BSM 100 SG 150 BL <sup>(2)</sup>	30 AB 2000 <sup>(3)</sup> 150 BSM 100 SG 250 BL	35 AB 3000 <sup>(3)</sup> 160 BSM 150 SG 255 BL	40 AB 3000 <sup>(3)</sup> 190 BSM 200 SG 270 BL	30 AB 3000 40 ABB 3000 250 BSM 200 SG 220 BL
	25 PA 500 125 BSM 100 SG 150 BL <sup>(2)</sup>	25 SMA 1000 125 BSM 100 SG 150 BL <sup>(2)</sup>	30 SMA 3000 160 BSM 110 SG 200 BL	35 SMA 3000 160 BSM 150 SG 255 BL	40 SMA 3000 190 BSM 200 SG 270 BL	30 SMA 3000 40 ABB 3000 250 BSM 200 SG 220 BL



# BSM IN DK – FROM INTRODUCTION TO FULL IMPLEMENTATION

2022



Public tender BSM contracts on state road and airport TWY

Further tests leading to DRD specification for BSM in situ

Test section with waste ignition slag based BSM in Copenhagen Harbour



Motorway widening  
Funen



Taxiway reconstructed  
Roskilde Airport

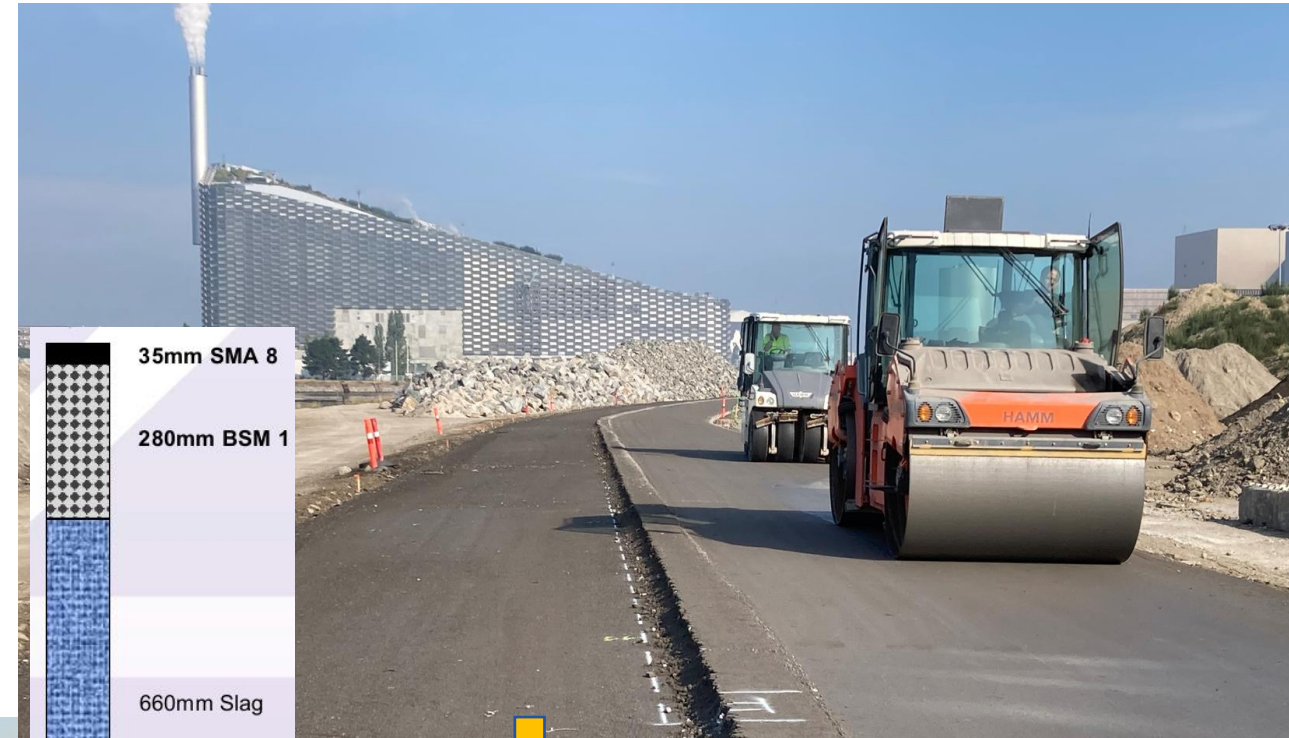


State-road Viborg,  
Jutland reconstructed



# BSM IN DK – FROM INTRODUCTION TO FULL IMPLEMENTATION

- BSM normally based on crushed RAP 0/16 or 0/32 mm (KMA) – or fresh milled material (in situ)
- New BSM type based on household waste ignition slag 0/32 mm from Afatek, Copenhagen.
- Demonstration section with slag-BSM on part of new heavy trafficked road in Copenhagen harbour area.
- Slag used as subbase, gravel base and for BSM – part section only covered with 35 mm SMA.
- Monitored with built-in sensors and also followed by DRD with FWD-measurements



# BSM IN DK – FROM INTRODUCTION TO FULL IMPLEMENTATION (5)

FULL IMPLEMENTATION IN 5 YEARS

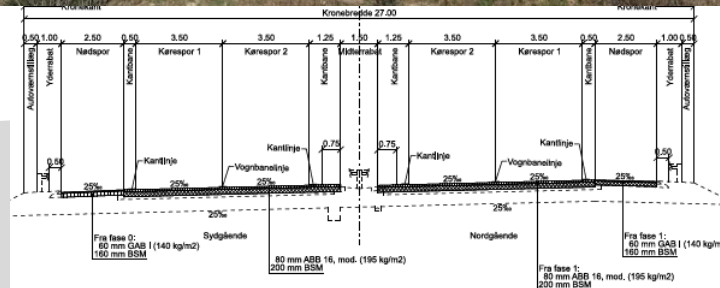
2023

- First large size public tender of motorway total rehabilitation: BSM with 8 cm AC binder course ('ABB')
- Further work on optimization of structural design and parameters
- Follow-up check on older BSM sections



## 7 km of M E45 reconstructed

- Exist. asphalt cracked bottom-top => milled off
- 20 cm BSM-KMA
- 80 mm ACB (+SMA later)
- Emergency lanes BSM in-situ + 60 mm AC base + AC wear.
- Traffic: ADT 55.000 in 2021, expected 75.000 in 2030



# DANISH BSM – 2023 PERFORMANCE FOLLOW-UP



- In 2021 and 2023 re-visited four BSM sections paved in 2020 Cores sampled for evaluation of stiffness modulus development (initial tests 2020 contra cores 2021). (see no. 2, 3, 5 and 8/6 on map)



# BSM DEVELOPMENT WITH TIME (CORES)

## STIFFNESS MODULUS

### ITSM @ 20°C:

- Average 2020 production tests: 1.100 MPa
- Average 2021 cores: 1.640 MPa
- Average 2023 cores: 1.700 MPa

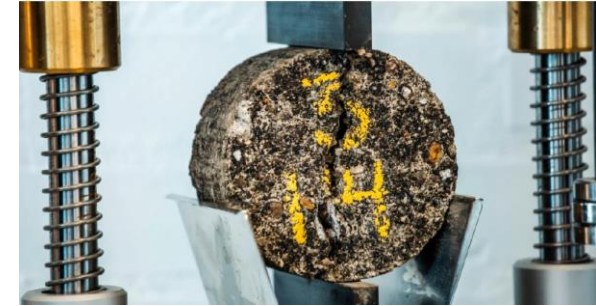
### ITSM @ 10°C:

- Average 2021 cores: 2.700 MPa
- Average 2023 cores: 2.840 MPa

DRD standard specifications BSM:  $\geq 1.000$  MPa @20°C

### **Indirect tensile strength (ITS), 25°C, example:**

- ITS dry, 2020: 140 kPa
- ITS dry, 2021 cores: 300 kPa
- ITS dry, 2023 cores: 400 kPa



### **Conclusions:**

- Stiffness increase with time
- Indirect tensile strength also increasing with time
- Bearing capacity of BSM's seems higher than initially estimated
- (Challenge to sample cores ideally)

# BSM STIFFNESS / BEARING CAPACITY

A bit like a bumble bee:

*'Theoretically being too heavy to fly – but it doesn't know'*

BSM:

*Much stronger than you would expect!*



# TO SUMMARIZE:

- BSM fully implemented in Danish road construction in < 5 years
- Full tender specifications for BSM works issued by DRD. Based on work from full sector-represented task-group and comprehensive test program.
- Cold procedure, local recycled materials: Up to 75% CO2-savings (LCA), and saved costs.
- BSM may substitute AC base layers with proper design (~ +25% thickness)
- BSM point-bound: Normally finish with a traditional wearing course
- Good experience: BSM is strong and stable – increased stiffness with time





# QUESTIONS?



Ole Grann Andersson  
Danish Technological Institute

**Thank you!**