FOAM

Duurzame funderingen door in situ recycling met schuimbitumentechnologie

PART II:

Market Potential for BSM in Flanders

EMIB
Energy & Materials in Infrastructure & Buildings
University of Antwerp

Odisee
DE CO-HOGESCHOOL

Opzoekingscentrum voor de Wegenbouw
Samen voor duurzame wegen

AGENTSCHAP INNOVEREN & ONDERNEMEN
Vlaanderen is ondernemen

Project "Duurzame funderingen door in-situ recycling met schuimbitumentechnologie"
"FOAM-project"

Title report: Part II Market Potential for BSM in Flanders

Version and date: 03-02-2023 v.1
Status report: Final

Project Coördinator : Wim Van den bergh; wim.vandenbergh@uantwerpen.be ; +32 486 79 86 86

Reporting : Ecem Nur Barisoglu; ecemnur.barisoglu@uantwerpen.be
Karolien Couscheir; karolien.couscheir@uantwerpen.be
Hosam Almalehy

Acknowledgements:

We are grateful for the help provided by Loudon International, who supported us in completing our project.

Project funded by VLAIO – Flemish Government (Grant HBC.2020.2094) and in collaboration with industry

Project Team Partners: UAntwerpen, BRRC and Odisee

Project Sector Partners: Agentschap Wegen en Verkeer, stad Antwerpen, North Sea Port, Lareco, COPRO, Topcon, VlaWeBo, Cementbouw, Ingevity, BESIX, Viabuild, Colas, Willemen Infra, DIBEC, Wirtgen Group, De Bruycker-kemp, Bomag

1 Introduction

1.1 Project Description

The Tetra project HBC.2020.2094 "Sustainable base layers through in-situ recycling with foamed bitumen technology" - referred to as the "FOAM project"- has the overall objective of technically, economically, and ecologically testing and evaluating foamed bitumen technology for base layers, leading to a more sustainable base. The results are disseminated for further implementation. The project started on November 1st, 2020 and was finalised on 31 October 2022. The project was carried out by the University of Antwerp, the Belgian Road and Research Centre, and Odisee University College. The project was funded by VLAIO.

To obtain sustainable road structures, attention should not only be paid to the asphalt pavement, but the base layer also plays a decisive role. Bitumen Stabilised Material "BSM" is a material in which the granulates - in this project 100 % reclaimed asphalt - are held together by maximum 3 % foamed bitumen or bitumen emulsion. The FOAM project tested the use of BSM as a base material, investigating its structural, environmental and economic impact. The project resulted in a method for mixture design and structural road design with BSM and was demonstrated through the construction of pilot sections. These trial sections are further followed up by a monitoring campaign.

The report of the FOAM project consists of 6 reports.

- PART I: Management report FOAM project
- PART II: Market Potential for BSM in Flanders
- PART III: Mix design of BSM
- PART IV: Structural design of pavements with BSM
- PART V: Sustainability Assessment of pavements with BSM
- PART VI: Synthesis report of test sections

This report, " PART II: Market Potential for BSM in Flanders" to provide an overview of the potential use of foamed bitumen technology in Flanders.

1.2 General

The world's human population is currently experiencing exponential growth. Development of the road construction links to this situation with the majority of the requisite capacity of pre-existing roads. Therefore, maintenance and rehabilitation of roads have become increasingly significant in pavement engineering to contribute towards a sustainable world.

Like many other countries, Belgium is looking for cost-effective, sustainable, and environmentally friendly solutions for pavement rehabilitation. In recent years, cold recycling has grown as one of the cost-effective and environmentally friendly technology over conventional road rehabilitation alternatives. In particular, cold recycling of existing pavements using either bitumen emulsion or foamed bitumen is gaining favour as a means of road rehabilitation. However, this technology is still not entirely accepted in the Flanders road industry. Some researchers have undertaken significant studies at the laboratory level, as well as full-scale testing of pavements. However, the cited investigations may not always represent the circumstances and materials utilised in Belgium roadways. Consequently, pavement designers in Belgium trying to employ foamed bitumen technology in rehabilitation projects face major challenges due to a lack of data on the performance of bitumen-stabilised materials (BSM). Since More and more Green Public Procurement (GPP) will be defined, also the base structure will be part of that GPP. In this FOAM-study LCA and LCCA calculations are made.

Cement-treated base layer has the highest environmental/economic impact (64 €/m² NPV en 65,5 GWP pavement structure)where BSM covered by one asphalt surface layer is best option (39,2 €/m² NPV and 39,2 GWP). With these figures, the contractor and/or pavement manager can calculate different scenarios and the benefit of using BSM. This deliverable intends to provide an overview of the potential use of foamed bitumen technology in Flanders.

1.3 Asphalt Recycling

The flexible pavement is the most common type of pavement used in road infrastructure around the world. The term "bituminous mixture" or "asphalt mixture" is used to describe a composite material made of bitumen, different fractions of aggregates, and filler that is used in flexible pavement applications. There are several types of asphalt mixes, which are largely divided by their design into dense-graded combinations, like asphalt concrete (AC), gap-graded mixtures, like stone mastic asphalt (SMA), and open-graded mixtures, like porous asphalt (PA). A well-functioning road system is unquestionably important for a world's social and economic development. A proper design and a constant supply of high-quality raw materials, such as aggregates and bitumen, are thus necessary for sustaining and expanding such a road network. Raw materials have high prices; therefore reclaimed asphalt pavement material (RAP) was introduced to reduce the material cost in road construction projects. In the road construction sector, RAP induces considerable economic and ecological benefits; therefore, it is a crucial factor in achieving sustainable pavements.

The material derived from the road milling process and classified according to EN 13108-8 is called RAP. The European Asphalt Pavement Association (EAPA) publishes a yearly report called Asphalt in Figures. According to the figures of 2018, in Europe, almost 50 million tonnes of RAP were available, of which around 60% was reused in hot or warm mix production, while the US generated roughly 92 million tonnes of RAP and recycled 90.5% in hot and warm asphalt production [1]. RAP has one of the highest recycling rates in the construction industry, according to EAPA and Eurobitume. Figure 1, from the PhD dissertation of Margaritis A., which shows the evolution of asphalt production along with the use of RAP from 2008 to 2019 as reported by COPRO, shows how Belgium regularly exhibits strong recycling rates (COntrol of PROducts, a Belgian impartial certification body in the Belgian construction sector).

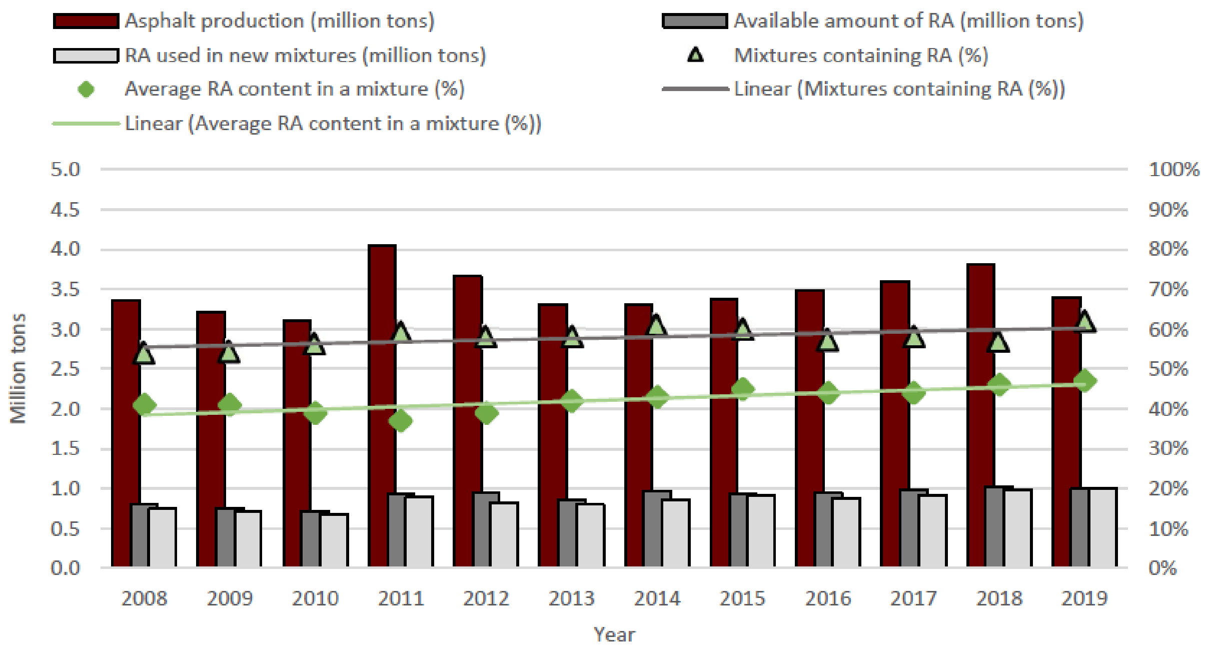


Figure 1. Asphalt production and recycling progress in Belgium, based on annual reports published by COPRO (2008-2019) [1]

The standard road regulations SB250, provided and revised by the Flemish Road Agency (FRA), must be followed when producing asphalt mixes for public works in Flanders. According to these regulations, no restrictions are imposed for base layer mixtures except for AVS mixtures. For these mixtures, RAP can only replace up to 20% of the binder content of the mix. Even though no restrictions are imposed for using RA in base layers, the current average still does not exceed the 40% RAP rate.

It is important to note that the terms "Recycling" and "reusing" can be confused. Reuse of RAP is the process of reincorporating RAP into the pavement, with the aggregates and the used bituminous binder continuing to serve the same purpose as before (i.e. back into the same product or application). This is independent of manufacturing temperature, road layer, etc. Hence, it would include, for example, the manufacturing of cold-mix asphalt from former warm or hot-mix asphalt. Recycling of RAP is an operation by which RAP is used as ingredients in new products such as foamed bitumen stabilised material (BSM) to be used as new pavement foundation, fill or road material. The recovered aggregate and bitumen perform a lesser (or alternative engineering) function than in the original application. Pavement "RAP" recycling is a series of pavement rehabilitation techniques that can be used to rehabilitate a deteriorated asphalt pavement effectively while reducing costs and environmental impacts and improving performance. There are currently different recycling options available to address particular pavement degradation and structural requirements.

- Hot mix asphalt recycling
- Hot in-place recycling
- Cold in-place recycling
- Cold central plant recycling
- Full depth recycling

One of these promising recycling technologies currently has a global increase in Cold Recycling (In-Situ or In-Plant), using the technology of foamed-bitumen stabilised materials (BSMs).

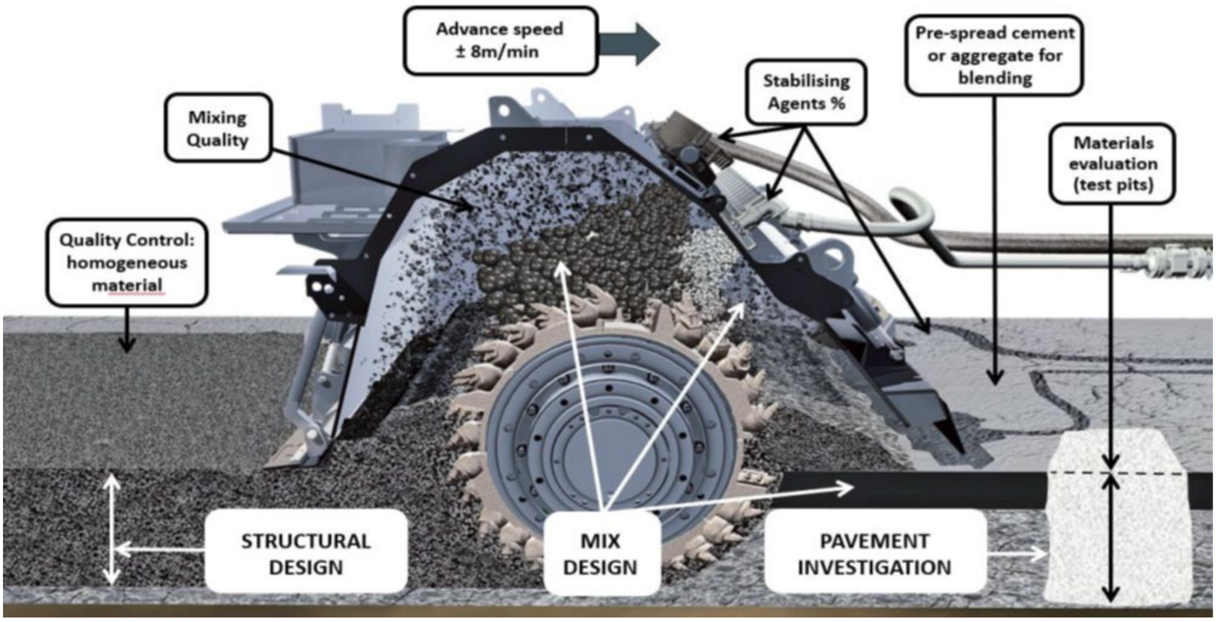


Figure 2. In-situ cold recycling process

Figure 3. In-plant cold recycling (production)

1.4 The global market of RAP reclaiming

The global market for RAP reclaiming (reusing+recycling) has been divided into submarkets based on type. Based on the Type, the global Recycled Asphalt market has been categorised into Hot reusing and Cold recycling.
According to "Recycled Asphalt Market Analysis Report to 2030" by Straits research, the hot reusing segment was the highest contributor to the market, growing at a Compound Annual Growth Rate (CAGR) of 6.3% during the forecast period. There are two distinct methods for carrying out hot reusing: recycled hot mix and hot in-place recycling. The technique of heater scarification repaving and remixing is used in hot in-place recycling. In this process, the surface is first heated, then sacrificed using teeth that do not rotate. After this step, the binder viscosity is improved by adding additives that give it a new lease on life. During repaving, the top layer is entirely removed. Remixing is adding aggregate to a road to improve its strength and stability. Because the hot recycling method is straightforward and can be completed on-site, it reduces logistics costs, acting as a market driver.
The second-largest segment is the cold recycling segment is expected to reach around USD 5,060.07 million by 2030 at a CAGR of 5.9% during the forecast period. The processes are known as cold plant mix and cold in-place recycling, both examples of cold recycling. The pavement structure is pulverised during the cold, in-place recycling process, and a binding agent is also added. The mixture used for cold recycling is frequently used as a stabilised base for the reconstructed pavement. One type of cold in-place recycling is called "full-depth reclamation." This type of recycling involves pulverising and recycling the entire pavement structure. The process of transporting the reclaimed aggregate to a nearby plant or facility, where it is processed, and then transporting it back to the site is another component of the cold recycling process.

1.5 European market of RAP reclaiming

The European Asphalt Pavement Association (EAPA) publishes a report every year on the key data of the European asphalt industry. According to the report published in 2020, 46.4 Mt reclaimed asphalt is available in Europe. However, it is important to note that the following seventeen European countries are considered in this report: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Norway, Romania, Slovakia, Slovenia, Spain and Turkey. Additionally, data from Italy was not provided this year, but it was estimated as the value supplied in 2019: 9,5 Mt (20%). Germany (11,6 Mt, 25% of total), France (6,0 Mt, 13%) and Great Britain (5,0 Mt, 11%) are the leading countries. Figure 4 demonstrates the percentage of available RAP which was re-used for the manufacture of new mixes (including HMA, WMA, Half-WMA and CMA), recycled as unbound road layers and other civil Engineering applications, and utilised in other unknown applications or put to landfill. For the calculation of these values, only countries providing full data (total amount and use percentages) were considered. These fourteen European countries were Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Norway, Romania, Slovakia, Slovenia, Spain and Turkey. In these countries, a total of 27,4 Mt of reclaimed asphalt were available, out of which, 64% were re-used, 33% were recycled and only 3% were used on unknown applications or put to landfill.

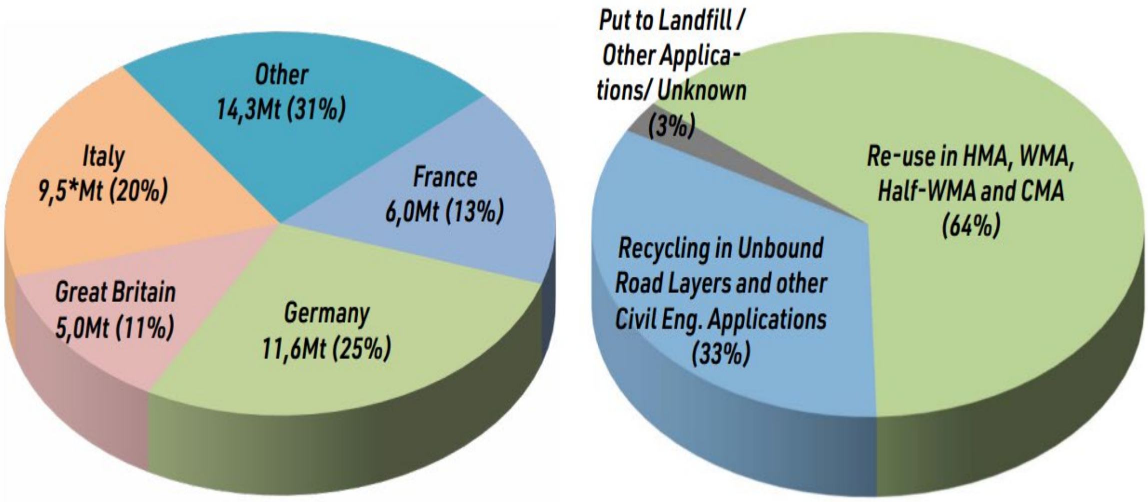


Figure 4. Total amount of reclaimed asphalt available in seventeen European countries providing data in 2020 (left) and the application of reclaimed asphalt in fourteen European countries providing data (right) [3]

Figure 5 and Figure 6 show the provisional figures from 2020 and 2021, respectively, from National Associations and some further estimations based on previous years' data.
Data from the aforementioned countries indicate that until 2017, Cold mix asphalt (CMA) output was almost steady, at about 3 Mt year. Production has since decreased to 2,2 Mt. The percentage of CMA production to total asphalt production also decreased to 2,3% in 2020. Figure 7 shows the data for CMA mixtures in tones.

Country	Total amount of site-won asphalt generated in 2020 in tonnes	Amount of reclaimed asphalt available to be used by the asphalt industry in 2020 in tonnes	% of available reclaimed asphalt used in							Applied area in m2 of hot reuse of existing asphalt pavement material in-situ / on the road (Remixing, Repaving, Reshaping, Road Train etc.)	The amount of "only" reheated (reused) asphalt material in-situ / on the road (Remixing, Repaving, Reshaping, Road Train etc.) in metric tonnes
			Hot and Warm Mix Asphalt Production	Half Warm Mix Asphalt Production	On-Site Cold Recycling[1]	Plant Cold Recycling[1]	Unbound Road Layers	Other Civil Engineering Applications	Put to Landfill / Other Applications/ Unknown		
Austria	1.800.000	1.260.000	70	30						no data	no data
Belgium	no data	1.981.500	47	no data	no data	no data	no data	no data	no data	no data	no data
Croatia	280.000	240.000	33	0	0	2	no data	no data	no data	no data	no data
Czech Republic	2.700.000	2.500.000	15	no data	25	no data	25	7	28	no data	no data
Denmark	1.410.000	1.160.000	85	no data	no data	no data	15	no data	no data	no data	no data
Finland	1.600.000	no data	100	0	0	0	0	0	0	12.000.000	no data
France	8.056.000	6.042.000	76	10	no data	no data	no data	no data	no data	1.171.000[2]	0
Germany	13.800.000	11.600.000	84	0	0	0	16	0	0	no data	no data
Great Britain	5.525.673	4.973.106	37	0	0	0	63		no data	no data	no data
Hungary	200.000	140.000	95	0	0	3	2	0	0	no data	no data
Ireland	500.000	220.000	100	0	0	0	0	0	0	no data	no data
Italy	no data	9.500.000*	25*	75*						no data	no data
Norway	1.300.000	840.000	35	0	0	0	65	0	0	no data	no data
Romania	10.425	no data	0	0	100	0	0	0	0	279.910	120
Slovakia	no data	135.846	53	0	30	0	17	0	0	no data	no data
Slovenia	no data	170.000	29	0	10	1	25	10	25	no data	no data
Spain	2.400.000	1.900.000	72,7	0,2	0,2	0,0	24,0	3,0	0,0	no data	no data
Turkey	no data	2.143.354	2	0	0	0	98	0	0	no data	no data
USA	87.000.000	85.000.000	93,0	0	0,0	0,4	6,2	0,3	0	no data	no data

[1] Cold recycling includes stabilisation with bitumen emulsion, foamed bitumen and/or cement.
[2] Only remix and repave with bitumen emulsion

Figure 5. Re-use and recycling of reclaimed asphalt in 2020 [3]

Provisional figures, latest update September 2022

Country	Total amount of site-won asphalt generated in 2020 in tonnes	Amount of reclaimed asphalt available to be used by the asphalt industry in 2020 in tonnes	% of available reclaimed asphalt used in							Total Re-use	Total Recycling	Total Landfill
			Hot and Warm Mix Asphalt Production	Half Warm Mix Asphalt Production	On-Site Cold Recycling**	Plant Cold Recycling**	Unbound Road Layers	Other Civil Engineering Applications	Put to Landfill /Other Applications/ Unknown			
Austria	1.850.000	900.000	85	0	5		10			90	10	0
Belgium	1.343.000	1.506.000	no data	no data	no data	no data	no data	no data	no data	71	no data	no data
Croatia	390.000	390.000	30	0	11	6	0	0	53	47	0	53
Czech Republic	2.700.000*	2.500.000*	15*	no data	25*	no data	25*	7*	28*	40*	32*	28*
Denmark	1.372.000*	1.172.000	85				15	no data	no data	85	15	no data
Finland	1.000.000	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
France	8.056.000*	6.042.000*	76*	10*	no data	no data	no data	no data	no data	86*	no data	no data
Germany	13.800.000*	11.600.000*	84*	0*	0*	0*	16*	0*	0*	84*	16*	0*
Great Britain	5.525.673*	4.973.106*	37*	no data	no data	no data	63*		no data	37*	63*	0*
Hungary	250.000*	160.000	98	0	0	0	2	0	0	98	2	0
Ireland	500.000*	500.000*	45*	no data	no data	no data	no data	no data	no data	45	no data	no data
Italy	11.000.000	no data	30	70						no data	no data	no data
Norway	1.129.512	1.172.618	46	0	0	1	54	0	0	46	54	0
Romania	10.425*	no data	0*	0*	100*	0*	0*	0*	0*	100*	0*	0*
Slovakia	82.134	70.946	63	0	29	0	8	0	0	92	8	0
Slovenia	200.000	79.000	40	0	3	2	5	18	32	45	23	32
Spain	3.050.000	2.495.000	61	0	6	0	15	18	0,01	66	34	0
Turkey	1.927.000	1.800.000	1	0	0	1	99	0	0	1	99	0

**Cold recycling includes stabilisation with bitumen emulsion, foamed bitumen and/or cement.

Figure 6. Re-use and recycling of reclaimed asphalt in 2021 [3]

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	20.000	20.000	30.000	no data	no data	no data	no data	no data	no data	no data
Belgium	33.000	27.000	30.000	no data	20.000	20.000	10.000	5.000	no data	no data
Croatia	21.000	23.000	32.000	no data	no data	no data	no data	no data	no data	no data
Czech Republic	9.907	4.421	9.570	40.000	5.400	5.000	4.000	4.000	6.000	6.000
France	1.600.000	1.460.000	1.550.000	1.418.000	1.808.000	1.858.000	1.977.000	1.975.000	1.622.000	1.741.000
Great Britain	no data	no data	no data	no data	<200.000	no data	no data	no data	no data	no data
Hungary	40.000	15.400	58.800	40.000	60.000	30.000	50.000	50.000	60.000	70.000
Iceland	no data	no data	no data	10.000	10.000	no data	no data	no data	no data	no data
Lithuania	no data	no data	no data	no data	no data	50.000	no data	no data	no data	no data
Luxembourg	0	2.000	10.000,00	no data	10.000	no data	no data	no data	no data	no data
Netherlands	no data	20.000	0	no data	no data	26.000	23.000	no data	no data	no data
Norway	37.000	6.000	20.000	30.000	no data	no data	no data	no data	no data	no data
Portugal	no data	no data	no data	no data	no data	no data	no data	no data	30.000	50.000
Romania	13.000	2.000	2.625	no data	no data	no data	no data	no data	8.000	109.000
Slovakia	3.000	0	no data	0	1.000	2.400	1.000	1.000	3.000	0
Slovenia	no data	no data	26.000	no data	no data	no data	no data	no data	no data	no data
Spain	200.000	92.400	86.700	150.000	94.000	190.000	80.000	100.000	110.000	110.000
Sweden	60.000	90.000	90.000	100.000	100.000	no data	no data	no data	no data	no data
Switzerland	740.000	710.000	830.000	25.000	no data	no data	no data	no data	no data	no data
Turkey	1.020.000	1.818.000	1.050.000	938.000	783.000	543.446	1.048.000	707.000	905.000	309.000

Figure 7. Cold bituminous mixtures (below 50ºc) in the period 2011 - 2020 (in tonnes) [3]

1.6 Belgian market of RAP reclaiming

acccording to the COPRO annual report 2021, The total amount of COPRO-certified RAP in Flanders is 13,410,198 tonnes.

Fixed site (TRA10) – total amount of RAP delivered 11,696,977 tonnes

Mobile installation (TRA11) – total production 6,466,051 tonnes, of which:

- produced at construction and demolition sites: 1,713,221 tonnes
- produced at other fixed sites (TRA 10): 4,752,830 tonnes

Where there was still a slight decrease in 2019 and 2020, in 2021 there was again a slight increase (+1%) in the amount of RAP delivered. The amount of recycled COPRO-approved agregates amounted to approximately 13.4 million tonnes. What stood out in 2021 is that more and more fixed locations are relying on certified mobile crushers. Belgium was already one of the leaders in Europe in the field of RAP, and will maintain this position in 2021.

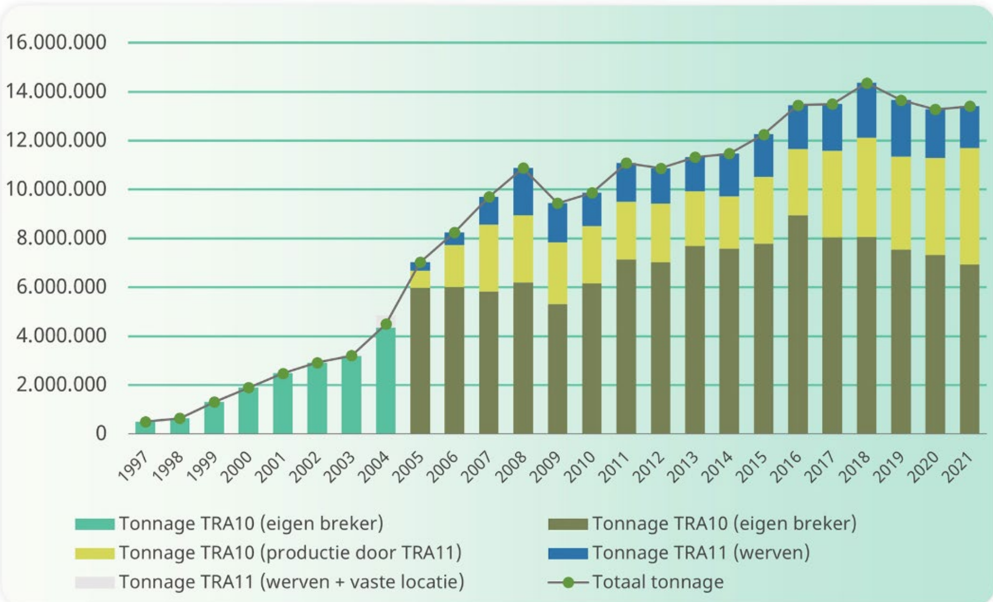


Figure 8. Total amount of RAP in Flanders [2]

	Vaste locatie	%	Mobiele installatie (totaal)	%	Mobiele installatie (werven)	%
Betongranulaat Waaronder hoogwaardig betongranulaat	4.281.779 ton 29.468 ton	37 < 1	3.010.151 ton 0 ton	46 -	1.058.174 ton 0 ton	62 -
Menggranulaat Waaronder hoogwaardig menggranulaat	4.494.538 ton 346 ton	38 < 1	2.099.831 ton 0 ton	32 -	356.358 ton 0 ton	21 -
Metselwerkgranulaat	194.211 ton	2	39.263 ton	1	7.055 ton	< 1
Niet-teerhoudend asfaltgranulaat	571.517 ton	5	376.881 ton	6	67.722 ton	4
Brekerzeefzand (ophogingen, aanvullingen, steens-lag voor zandcement/granulaatcement, conform NBN EN 13242)	2.007.678 ton	17	859.189 ton	13	211.232 ton	12
Brekerzeefzand asfaltgranulaat	5.628 ton	< 1	33.924 ton	1	3.999 ton	< 1
Brekerzand	40.167 ton	< 1	0 ton	-	0 ton	-
Beton- en asfaltgranulaat	27.346 ton	< 1	25.139 ton	< 1	4.290 ton	< 1
Asfalt- en menggranulaat	20.718 ton	< 1	17.854 ton	< 1	572 ton	< 1
Sorteerzeefzand	53.280 ton	< 1	0 ton	-	0 ton	-
Sorteerzeefgranulaten	0 ton	-	0 ton	-	0 ton	-
Gerecycleerde brokken puin	115 ton	< 1	0 ton	-	0 ton	-

Figure 9. Totals of the types of RAP produced [2]

2 Benefits of Cold Recycling Technology

Cold recycling is ultimately beneficial to the environment based on some factors:

2.1 Environmental benefits

It is a novel, promising, and ecologically beneficial technology that seeks to recycle/stabilise up to 100% of RAP. The reclaimed asphalt pavement consists of binder and aggregates when used. As a result, less binder and aggregate are required to produce asphalt from recycled materials. This results in a reduction in the use of virgin materials, which further reduces the strain that is placed on the earth's natural resources. In addition to this, the amount of water and energy that is consumed is decreased, which further lessens the strain that is placed on natural resources.

Moreover, asphalt that has been recycled is utilised in rehabilitating roads, which prevents the rehabilitated roads from being dumped in landfills. Furthermore, there are significant Carbon savings from cold recycling technology :

- Direct emissions reduction: there is potential to reduce direct burner emissions in comparison to hot mix processes by employing reduced temperature techniques when incorporating recycled asphalt. Estimates and experience to date suggest that these are in the region of 30 to 50% of direct emissions.
- Non-Direct emissions reduction: where embodied in raw materials – the potential to 'save' all of the embodied carbon in the raw materials (aggregate and binder) when they are recycled. This is approximately 40% of the cradle-to-gate carbon of new asphalt, so 10% inclusion of RA would recover 4%, but 50% RA content would recover 20% of embodied carbon.

- Transport CO2 reduction: Cold recycling technology has two approaches either in-situ or ex-situ (portable plant near to construction site). Both approaches seem locally planed and thus they will reduce emissions from transporting materials by trucks.

2.2 Economic benefits

The binders utilised in asphalt production are both pricey and associated with a high variable cost. It is estimated that utilising RAP will reduce costs by up to 35 percent. This is because RAP contains a high percentage of the binder. The increase in strength associated with bitumen stabilisation allows a BSM to replace alternative high-quality materials in the upper pavement. For example, either bitumen emulsion BSM or foamed BSM can be used in place of an asphalt base, offering significant cost savings.

2.3 Minimising traffic disruption

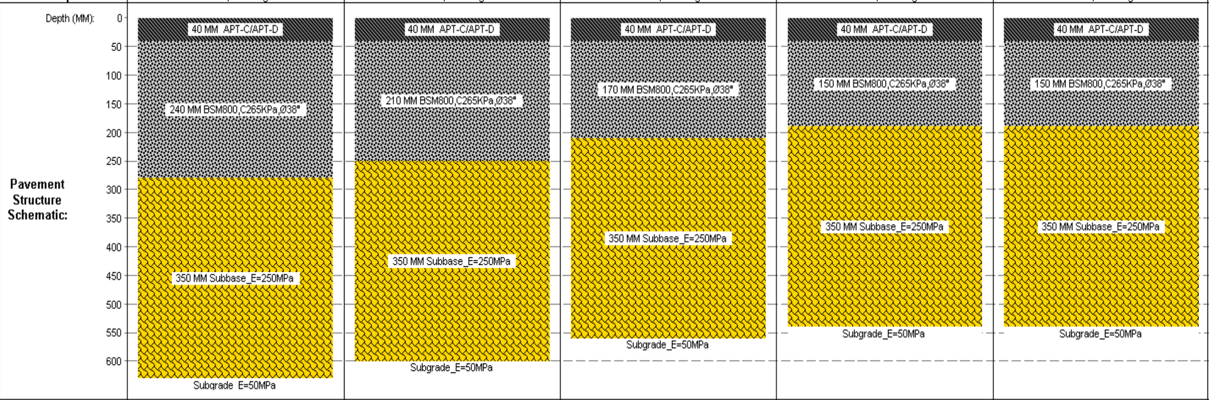
In both approaches: ISCR or IPCR, the road treated with Foam BSM can be used immediately by traffic, once the BSM base has been compacted thoroughly. Because foamed-BSM achieves a significant increase in cohesive strength as soon as it is compacted. This provides the new layer with sufficient structural strength to withstand traffic loads immediately after construction, although protection from the raveling action of tires is required.

2.4 Increasing the quality of paving material

Bitumen stabilisation improves the shear strength of a material and significantly Improved resistance to moisture damage due to the finer particles being encapsulated in bitumen and, therefore, immobilised (i.e better durability). Therefore, BSMs are best suited to top pavement layers because strength & durability as benefits are costly, where stresses from applied loads are highest and moisture infiltration owing to surfacing cracks is most likely to occur. Consequently, a BSM can replace other high-quality materials on the top pavement. For instance, replacing an asphalt base with a high quality foamed-BSM can result in significant cost savings. Figure 8 below shows that BSM base which is covered by a thin HMW layer could bear millions ESALs. A structural design study done in the context of Foam project shows that BSM covered with 4cm HMA would safe for low road classes from B10 =0,25 MESAL to B6 =4 MESAL at maximum. Moreover, The failure condition of a BSM is permanent deformation. This implies that the pavement will require far less effort to rehabilitate when the terminal condition is reached compared with a material that fails due to full-depth cracking.

Pavement Name	B6	B7	B8	B9	B10
Description	E-BSM=800MPa ; E-subgrade=50MPa	E-BSM=800MPa ; E-subgrade=50MPa	E-BSM=800MPa ; E-subgrade=50MPa	E-BSM=800MPa ; E-subgrade=50MPa	E-BSM=800MPa ; E-subgrade=50MPa

Pavement Structure Schematic:



	B6	B7	B8	B9	B10
Total pavement thickness "cover" mm	630	600	560	540	540
Structural Capacity MESAL-100kN (applied loading is a super single wheel 50kN/wheel; Inflation pressure 700KPa)	N = 3,95 MESAL-100kN (Subgrade)	N = 2,46 MESAL-100kN (Subgrade)	N = 1,24 MESAL-100kN (Subgrade)	N = 0,86 MESAL-100kN (Subgrade)	N = 0,86 MESAL-100kN (Subgrade)
Verification by The South African mechanistic pavement design method (SAMDM) ; (ref: SAPEM guideline,2014 + TG2 guideline,2020)	BSM 23CM _Critical layer is Subbase (4,6 MESAL)	BSM 21CM _Critical layer is Subbase (2,7 MESAL)	BSM 19CM _Critical layer is Subbase (1,6 MESAL)	BSM 16CM _Critical layer is Subbase (0,82 MESAL)	BSM 14CM _Critical layer is Subbase (0,52 MESAL)
NOTES					

Figure 10. Pavement structure with BSM base with only HMA thin layer 4cm

Material quality: Lower quality aggregates can often be successfully used as a base layer. Unlike asphalt, BSMs are not overly sensitive materials and small variations in both the amount of bitumen added as well as the properties of the untreated material will not significantly change the strength achieved through treatment. Random variability in the recycled material is, therefore, less critical than in asphalt.

Temperature susceptibility: Unlike hot mix asphalt, BSMs are relatively thermally insensitive. This is because the bitumen phase is not continuous throughout the mix.

3 Challenges with Cold Recycling

The BSM's technology in Belgium/Flanders will face some concerns/limitations/restrictions as follow:

- Each project using cold recycling and BSM's is individual. No two projects are same because each existing road has different paved materials/layers; and, therefore, different mechanical properties for all layers (subgrade, subbase, foundation, AC base, AC wearing). So, each project shall have a unique mix design to determine the job mix formula (optimum amounts/grading ..etc). Moreover, shear properties of BSM's shall be measured laboratory because they are key inputs in the pavement structural design of BSM pavement. Consequently, a professional engineer who has good experience should be consulted.
- Temperature challenge is one of the key factors that influence the BSM production process. Foamed bitumen will not disperse if the temperature of the material RAP is too low <15°C. In general, foamed bitumen is not recommended when the temperature of the material being treated is below 15°C. In Belgium, the desired temperature >15 °C could be only achieved in the summer season (June-September). Therefore, the weather forecast in foaming/recycling day(s) should be checked beforehand.
- If an existing road needs to be rehabilitated, adding materials (foamed bitumen + active filler or emulsion bitumen) during the stabilisation process will increase the volume of the mixture and, as a result, raise the elevation of the finalised road surface. As a result, it is expected that there

will be drainage issues and access issues to private residences. Pre-milling a few centimeters (4cm-6cm) might easily fix this issue. This might not be a problem, however, if the elevation is uncontrolled on an existing rural road. Furthermore, height isn't a concern with new roads.

- The existence of manholes is often seen to be one of the biggest obstacles facing in-situ cold recycling by recyclers directly. This issue is less common on rural roads.
- On the day of the construction of BSM, the moisture content of the RAP material either in the stockpile or on the existing road, shall be similar to the RAP sample that was imported to the lab for mix design. Any change in the moisture content in situ will result in an unfavorable mixture and sooner-than-expected damage. For instance, if the existing road get extra moisture due to rainfall or less moisture due to very hot days, then both mix design and structural design shall be repeated with a new moisture content. RAP Stockpile shall be covered once the sample is collected and delivered to the lab for mix design purposes, as shown below.

Figure 11. Non-protected stockpile (left) vs protected stockpile (right)

- Quality and Homogeneity of RAP Aggregates: Generally, the removed asphalt concrete presents a high content of fine particles, due to the milling operations of the pavement layers and/or to the crushing processes to reduce the aggregates size, especially when the material comes from a full-depth pavement demolition. The amount of fine particles may limit the maximum RAP content because the gradation requirements of the final mix might not be met. Furthermore, the finer particles contain higher amount of aged binder, due to their higher surface area. Still, finer particles tend to retain moisture; the RAP material itself does not drain as virgin aggregates do. All these aspects must be taken into account for correct RAP management, mix design and production of asphalt concretes containing RAP. Milled aggregates from a single and traceable source can be very consistent and, sometimes, no further crushing and/or screening operations are needed to use the material in new asphalt concretes. However, the quality of the removed asphalt materials from pavements depends on the milling machine, its speed and milling depth; in particular, the latter factor is important as the material from a single layer has homogeneous properties (i.e., aggregate type and grading curve, bitumen characteristics and content)A good milling operation guarantees a high quality of the removed asphalt. As a result, keeping millings of specific projects in separate stockpiles and ensuring that the removed asphalt concrete is not contaminated.

- Professional operators are needed to achieve the target grading in the case of the ISCR approach by the recycler. The drum speed of the recycler plays a leading role in finding the desired grading.

There is a lack of awareness among road builders and contractors in several emerging economies about the use and benefits of recycled asphalt. The advantages of using recycled asphalt in construction road pavements outweigh the costs. However, contractors and road builders in emerging economies do not consider these factors because they are concerned with lowering the cost of materials and construction. This factor is estimated to challenge the market growth.

4 Conclusion

The FOAM project developed an experience with foamed bitumen technology in the Road Engineering Research Section at the University of Antwerp. This team constitutes the first Flemish group that could be consulted in the context of BSM mix design, BSM structural design and feasibility studies. The helpful opportunity will surely encourage the market players to take steps in cold recycling technology. When the Belgian government's emphasis on Cold recycling initiatives and investments in utilising (RAP) can be used to reconstruct worn highway surfaces and repair damaged roads will further expand the future growth of the recycled asphalt market. Further optimalisation is still ongoing to offer high-quality BSM's materials, for instance, by adding new additives, might be driven forward by extend profitable opportunities to the market players in the forecast period.

There are two competitive players in the European market who offer to supply the needed machines to cold recycling technology. Both are purchasing recyclers, stabilisers, etc.; as well. Moreover, they have good operators for implementing the process of stabilisation. Furthermore, they organise periodic training and workshops to demonstrate this technology. Those technology suppliers are Wirtgen Group and Bomag Group, both are German global leaders in cold recycling. Some of the large infrastructure companies prefer to purchase already recyclers, and thus they have own trained operators to implement cold recycling. For instance, the Dutch company (Freesmij) purchased recyclers from Wirtgen.

5 References

[1] A. Margaritis, “Maximising asphalt recycling: challenges and variability in fatigue and healing”, PhD thesis, University of Antwerp, 2020.

[2] COPRO, “Annual report”, 2021.

[3] EAPA, “Asphalt in Figures” 2021.

APPENDIX I

Questionary results

Ten different companies in Flanders attended this Survey, namely companies C1 to C12.

Q1. In which of the following years have you renovated existing roads, including the foundation?

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
2021	x	x	x		x	x	x	x	x		x	x
2020		x	x	x	x		x		x			x
2019		x	x	x	x		x		x	x		x
2018		x	x		x		x		x	x		x

Q2. Rehabilitation project details

	The size (m²)	Sewer covers or other obstacles on existing road	The original road construction (before rehabilitation)
C1	13000	Yes	mosaic cobblestone, wedge bed in sand 4cm, foundation lean concrete 20cm
C2	10000	Yes	Gravel 20 cm en 5 cm asphalt
C3	500	Yes	15cm crushed stone foundation and 8cm asphalt
C3	650	Yes	crushed stone foundation and 8cm asphalt
C3	3000	No	15cm crushed stone and 4-8cm asphalt
C3	15000	No	sand foundation + 10cm asphalt
C3	500	Yes	15cm crushed stone foundation, 6cm asphalt
C4	1885	Yes	Type N/A, excavation was asphalt with foundation and subsoil to a depth of 50 cm.
C5	+ 10000	Yes	Sand foundation, clinkers overlaid with asphalt
C5	+10000	New sewers	30cm crushed stone case, 10cm asphalt
C5	500	No	20 cm concrete and N/A cm crushed stone
C5	+10000	Yes	30cm crushed stone base, 10cm asphalt
C6	3240	Yes	old concrete slabs (20 cm), foundation on sand
C7	240000	Yes	Asphalt foundation 20 cm and asphalt 8 cm
C7	8000	Yes	Asphalt foundation 20 cm and asphalt 8 cm
C7	1000	Yes	Asphalt foundation 20 cm and asphalt 8 cm
C8	80000	No	20cm unbound crushed stone + 20cm asphalt
C9	500	Yes	Beton
C10	1500	Yes	20 cm foundation and 12 cm asphalt
C11	30	No	Concrete rubble type I - 20cm
C12	6100	Yes	Foundation: 25 cm cement-bound crushed stone Asphalt: 15 cm
C12	6250	Yes	Cemented foundation: 25 cm Asphalt: 17 cm
C12	2500	Yes	Foundation: 15 cm, Maas gravel Asphalt: 7 cm

Q3. What percentage of your roads have sewer covers in the carriageway (this may be an estimate? There is an opportunity for comments.

	%	Comment
C1	40	
C2	50	we use the special lids that you can lower and turn up so that they fit perfectly into the road surface
C3		
C4	10 to 15	Most sewers are located in the side verge under the pavements, but new roadworks involve the construction of a segregated system, in which the sewers are almost always moved into the roadway.
C5	75	
C6	N/A	
C7	70	
C8	5 - 80	motorways 5% regional roads 80%
C9	N/A	
C10	20	The municipal roads where there is sewerage. So not in regional roads or agricultural roads and certainly not in unpaved roads.
C11	80	
C12	N/A	