Coursework 2

Research Submission

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Submitted in part fulfilment for the requirements of the module ‘Work Based Project’ (ACBA 5009) for the completion of a HND In Civil Engineering at UWTSD.

“Evaluating the use and outlining the development of Stone Mastic Asphalts (SMA) in road construction and how problems with early-life skid resistance can be achieved”

ABSTRACT

There has been a wide development of surfacing materials and products being installed on the highway's networks in England and Wales. WG have highlighted concerns over HRA's and thin-surface course systems in the UK in recent years and the need for more durable products to be developed. SMA products have been improving since their inception in the 1960s in Germany with modern techniques such as post-grit applications improving early-life skid resistance issues in Wales has led to its massive uptake of installation here and surrounding countries i.e. Scotland. Moreover, improved construction regulations, technical specifications, quality control etc. have meant that these products are becoming more favourable for installation. These products continue to drive the current favour of many highway authorities and with continued research into it should enhance the overall cost/life benefit.

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Chapter One: Introduction

1.0 Introduction

1.1 Aim

The aim of this research project is to determine through primary and secondary research to investigate and prove whether skid resistance in SMA's can be improved through modern techniques in Wales and to prove if these SMA's are improving in development.

1.2 Objectives

To achieve these aims the researcher has identified the following objectives:

- To research from literature, have SMA's have developed since their inception, their associated advantages, disadvantages, and modern improvements in preventing early life skid resistance.
- Demonstrate how modern techniques have reduced or eliminated early life skid resistance problems are being reduced in Wales.

1.3 Hypotheses

The hypotheses for this research project are "Early life skid resistance can be achieved through modern developments and techniques" and "SMA's are improving"

1.4 Research Methodologies & Justifications

To achieve the objectives that are outlined above, this research project will explore industry standards, practices and theories regarding SMA's their development for use in Wales by critically analysing and interpreting data from a wide variety of sources. The researcher will critically analyse and interpret data from a wide variety of information via journals, books, government documentation as secondary data, this will allow us to directly target our research questions.

Also, by using primary research from leaders in the industry in the form of contractors that are directly involved in the manufacture and development of SMA's and other materials, Welsh Government designers who are specifying, leading, and pushing for 'new' SMA products to be installed throughout the trunk road network in Wales. Using the researchers

personal experience within the industry over the last 5 years as part of a client/delivery team will help provide a real representation to which stage SMA mixes are being driven, installed and the direction in which they are headed.

All research will be represented accurately through graphs and tables both quantitatively and qualitatively to effectively develop an understanding of the topic. All data will help form an analysis for discussion in an un-biased manor for gaps in research, where clarity or more information might be required and where SMA's currently stand as a leading pavement material in Wales.

Chapter Two: Literature Review

2.1 – The inception and development of SMA's

Stone Mastic Asphalts (SMA) originated and took popularity from Germany in the mid 1960's as an alternative answer to a "Chipped Gussasphalt" product which offered a reduction of wear that was caused by studded tyres (Transport Research Labratory, 1994). SMA's are regarded as having excellent performance as a more durable pavement providing superb rut resistance, is less susceptible to cracking, temperature deformations and weathering with heavier loads. Continued developments of the product then led to spread throughout Europe (1980's) following the recognition of its performance at a national standard in 1984 commonly referred to as the 'German Standard Specification' (The German Federal Department of Transportation, 1997) and subsequently spread through rest of the world (1990's) respectively.

In the UK the product has really took off in the 1990's when a study into German SMA's led to the Transport Research Laboratory (TRL) investigating the product and published a report in 1994 (Transport Research Labratory, 1994.). It included a specification for the use of SMA as a surface course material prepared by the Highways Agency for the trial of this product onto Trunk Roads (i.e., Motorways/A-Roads/B-Roads) in draft form in the UK. It was initially viewed as a heavy-duty product but following its inception, was heavily promoted due to its performance. One major incentive was that it offered a more practical and alternative solution to areas where Chipped-HRA (Hot Rolled Asphalt) (British Standards Institute, 2016) was not as easily installed. It then massively took popularity in 1995.

A variety of developments and design mixes of SMA's being installed and tested on several European countries including Wales and the development of their new 'WG SMA' (Welsh Government, 2020), SMA products are increasing in popularity amongst road authorities and within the asphalt industry itself moving away from TSCS (Thin Surface Course Systems) as a more cost-value material.

2.2 – Differences between SMA's and conventional surfacing mixes

There are a wide variety of surfacing mixes and products constantly being developed all over the world including Open Grade Asphalts (OGA's) Textured Thin Asphalts (TSCS) & Hot Rolled Asphalts (HRA's).

SMA's are described as dense, gap-graded bituminous mixtures that have high contents of stone, bitumen and filler that are modified with a suitable binder carrier such as fibres (Civilenggseminar.blogspot.com. 2022). The European definition of an SMA (Hainin et al., 2010) describes them as "a gap-graded asphalt concrete composed of a skeleton of crushed aggregates bound with a mastic mortar".

SMA's typically have a minimum binder content of 6.5%, high stone content greater than 70% that ensures good stone on stone contact after compaction and a high stiffness that can be achieved through the addition of fibres and crushed aggregate/sand (AAPA, 1993), this means that there are significantly less voids than its counterparts of OGA and TSCS. It should be noted that although the product is denser in SMA's resulting in lower air void content and surface texture, the product is only slightly quieter than its counterparts compared to that of loud HRA's due to high positive surface textures.

Typically, SMA's have polymer modified binders that help to increase resistance to permeant deformation, increases life span of the pavement, reduce drainage inhibitors this can help to increase stability in SMA's as seen in figure 1 particularly between 5-7% binder content.

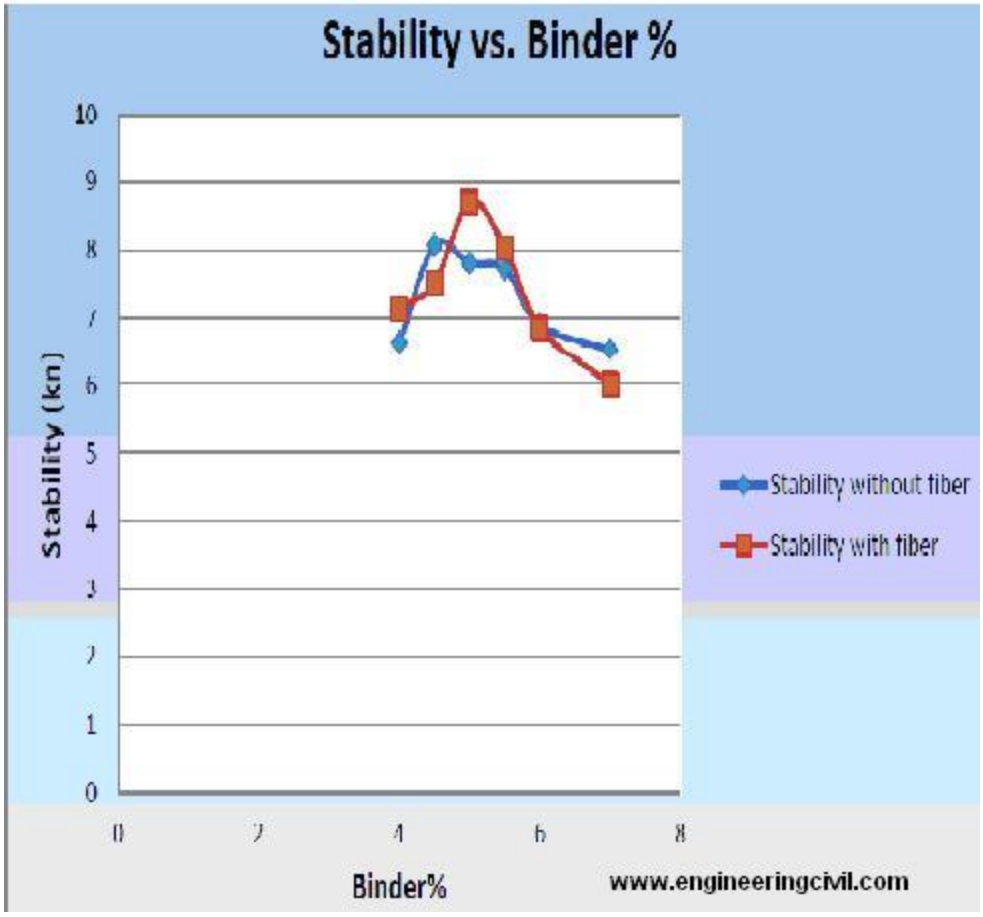

Figure 1 – Shows the stability with and without Polymer modified binders in SMA's (https://www.engineeringcivil.com/wp-content/uploads/2013/04/Stability-vs-Binder-curve-analysis.jpg)

2.3 – Road Surfacing Characteristics

To get good surface course characteristics it is often derived that materials should aim to be picked considering a variety of factors, whilst safety is taken primarily into account, durability and value for money should also be reviewed as significant factors.

The service life of materials is described in Table 1, where SMA's provide a good median material in life cycle of around 10-20 years. Comparatively to standard cheap AC (Asphalt Concrete) materials of 6-8 years and more expensive HRA's that can extend to 20+ years.

MATERIAL	MATERIAL SERVICE LIFE IN DESIGNED ROADS	MATERIAL SERVICE LIFE IN EVOLVED ROADS
Asphalt Concrete e.g. AC dense, AC close	8	6
Hot Rolled Asphalt (HRA)	20	20
Thin Surface Course Systems (TSCS) e.g. CI 942	15	10
Stone Mastic Asphalt (SMA)		
a. Low texture	20	20
b. Other	15	10
NOTE: HRA and 'low texture' SMA are more able to accommodate the variability of evolved roads.		

Table 1 – Design life of materials in roads (Mpa-uat.spindogs.com. 2015)

Each material has different characteristics that contribute to Micro/Macro textures, noise, wheel tracking, skid resistance, cracking resistance, ride quality and spray control, that all influence how schemes are designed. Hampshire County Council (2016) have adopted and developed guidance on surfacing options within their authority Table 2 shows how these surfacing materials and characteristics can be 'ranked' in a simple readable format.

Table 2

MATERIAL		Relative attributes							
		Skid Resistance	Durability	Wheel tracking	Cracking Resistance	Ride Quality	Structural Contribution	Noise level	Spray Control
Design mix HRA	Performance Mixture Clause 943 L2	5	6	6	5	4	6	2	3
	Design mix	5	6	4	4	4	6	2	3
	High Stone Content	2	5	4	3	5	6	4	1
Asphalt Concrete		3	3	4	3	5	4	4	2
Surface Course Clause 942 / SMA		5	4	6	5*	6	4	6	4
Micro- asphalt Surface Course (12-18mm)		3	2	2	2	2	2	4	3
Surface Dressing, Single		5	2	NA	3	2	1	1	3
Surface Dressing, Racked in		4	2	NA	3	2	1	1	3
High Friction Surfacing Surface Treatment		6	1	NA	1	1	1	1	1

Note: ** Polymer modified & low void content 942 derivatives have proven best at crack inhibition (concrete overlays)*

1	2	3	4	5	6

Poor ⇦ ⇨ **Excellent**

Table 2 – Materials and their associated attributes ranked (Hampshire County Council, 2016)

It should be noted that Surface Course Clause 942 (thin surfacing systems) and SMA's are broadly categorised within the same section, it does however, give good indication of how the material will perform over a whole life cycle. It does not give indication of early-life and associated skid resistance issues and how design mixes can be accounted for within the table such as the WG SMA and how they are countering this issue and may be ranked differently and arguably should perform better.

2.4 – <u>Advantages of SMA's</u>

There are a variety of advantages of SMA's that are listed below and are generally widely accepted adapted from Richardson (1999):

1. 20-30% increase in whole pavement life over other conventional pavements such as Asphaltic concretes and Thin Surface Course Systems.
2. High resistance to rutting

3. Low Permeability & high aggregate interlock (higher binder percentages) – allows less water through the surface which leads to less surface break up.
4. Potentially higher skid resistance after early life due to high percentages of fractured aggregate
5. Strength and stiffness due to binder percentages and structure thus resulting in a longer service life, equal to or greater than that of DGA's and longer than OGA's and AC's.
6. Reduction in reflective cracking due to being a more flexible material
7. Usable on heavily trafficked roads.
8. 100% recyclable.

2.5 – <u>Disadvantages of SMA's</u>

SMA's also have a variety of associated disadvantages that need to be accounted for when choosing this product that need to be accounted for especially when installing the product that may result in a variety of modes of failures.

1. Longer mixing and higher mixing temperatures which may result in delayed production and supply chain of the product to site.
2. Bleeding of bitumen through the aggregate may lead to areas of poor skid resistance on the surface which may lead to increased costs down the line where surfacing may need to be re-installed or re-textured.
3. Higher material costs associated with design mixes with higher bitumen and filler and within new materials such as WGSMA the post-applied grit to the surfacing to increase early life skid resistance.
4. Poor early life skid resistance in conventional mixes needs to be accounted for until thick binder film has 'worn off' by traffic (Civilenggseminar.blogspot.com. 2022)
5. Stripping of asphalt layers below the SMA surface course
6. Premature rutting

2.6- <u>Skid Resistance in SMA's</u>

Having good skid resistance in materials/products on roads is important in ensuring the safety of traffic on the road, especially when the road becomes wet. SMA's are negatively textured and therefore the composition of these products have a major part to play to ensure the materials integrity (Wasilewska, 2014). Due to the high binder content in SMA's it tends to

create a film on the surface which can take time to wear off (i.e., first year of installation) and therefore the application of post applied grit can minimise this issue in the early life. Figure 2 below shows the change in skid resistance (SCRIM – sideways coefficient routine investigation)in a section of 14mm SMA (Mean Grip number – Intervention Level) over the first 350 days of trafficking. Initially the skid resistance was very low 0.35-0.45 and after 9-12 months resulted in values of around 0.8 (Stankiewicz, Slabonski and Slabonska, 2018).

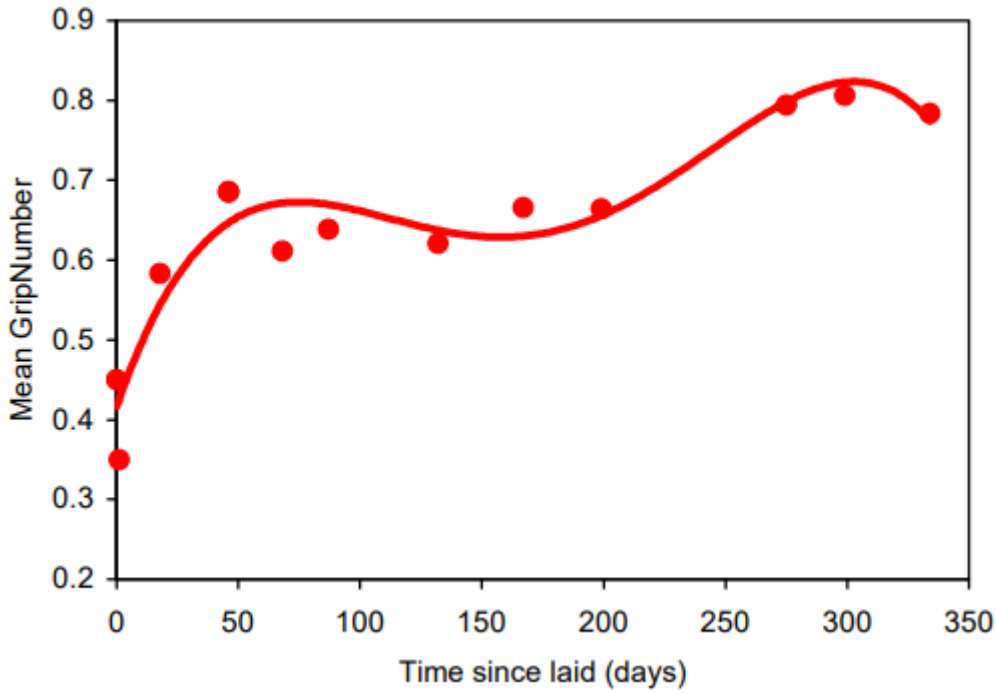

Figure 2 – The effective estimation of skid resistance of SMA pavements in relevant aspect of safety and durability of asphalt roads (Stankiewicz, Slabonski and Slabonska, 2018)

As a result it is derived in figure 3 that the application of post-applied grit can provide texture depths of 1.5mm initially falling to 1.2mm after 9 months and 1.1 mm after 12 months as seen in figure 3. However, with the wearing of binder film on trafficking after 12 months reaching a higher level will offset and create an equilibrium for the product to reach it's optimum surface texture of anywhere between 0.8-1.1mm.

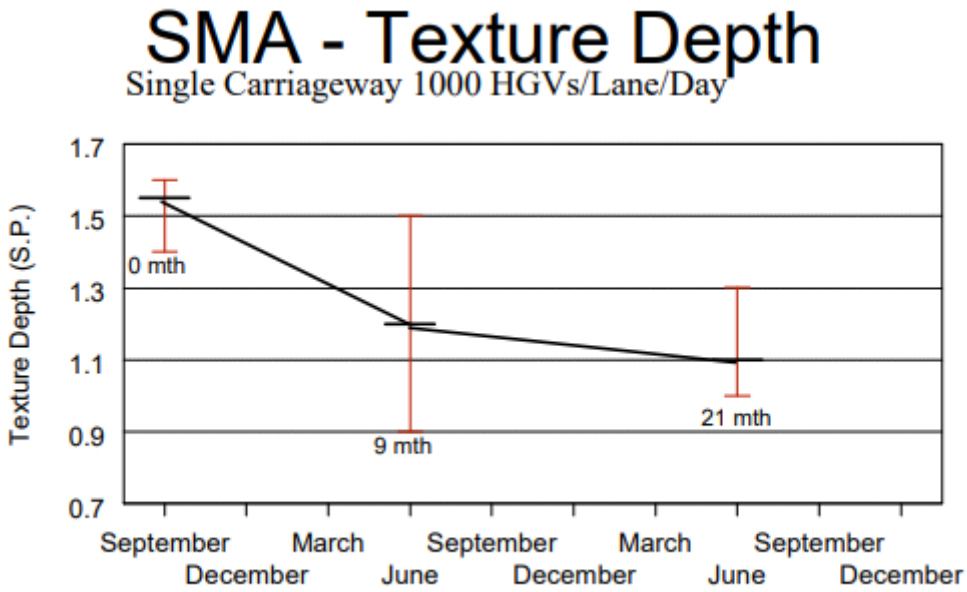

Figure 3 – expected change in texture depth over months of trafficking of post applied grit SMA. (Richardson, 1999).

2.7 – Welsh Government SMA

The new WGSMA is a new SMA mixture that has adopted similar practices and specifications to that of the "cousin" mixtures of the Germany and Scottish developed SMA's. This mixture also is comprised of a mixture of close gap-graded aggregate mix, modified bitumen and is stabilised with natural fibres. This WGSMA shall be treated with a post applied grit to improve early life skid resistance.

As a result, WG expect the new mix will provide the following results (Welsh Government, 2020);

- Overall Increased Durability
- Decreased maintenance investigations
- Increase in the use of sustainable local aggregates
- Reduced use of premium aggregate
- Good skidding resistance (through whole life cycle)
- Excellent overall ride quality
- Improvements in Quality management systems (QMS)
- Lower whole life costs

The PAG 112/20 (Welsh Government, 2020) document was produced by Welsh Government to provide a procedure and guidance on the new ‘Welsh Government Stone Mastic Asphalt’ specification a variety of contractors within South Wales have begun to develop and get new WGSMA’s approved to align with the new guidance for installation on the Welsh trunk network in both North and South Wales. These contractors have had to adhere to the TAIT process (outlined in Chapter 3) to get their mixes approved, a significant number of contractors have already had their 10mm product approved with some working on attaining 6mm accreditation and 20mm soon. The product is expected to conform to a variety of British standards namely, BS EN 13108-5 – stone mastic asphalt (British Standards Institute, 2016) and a variety of clauses (Welsh Government, 2020).

3.0 - Methodology

3.1 – Mixes, manufacture, laying & compaction (TAIT trials for approval in Wales)

To get approved to install the new WGSMA on the network each supplier/plant must undertake the TAIT process for each of the different variances or mixes. The TAIT process is a standard procedure that all new materials must follow to be installed on the public maintained highways network. This means that any changes to any constituent materials, mixing plant or surfacing contractor is considered a 'variant'. There are 3 stages to the TAIT process and are outlined below.

Stage 1 - Laboratory validation trial.
Stage 2 – Product mix trial that comprises of a minimum of a 20-tonne batch produced at the supplier/plants chosen location. This batch must be sufficient to lay a minimum of 60m.
Stage 3 – The new mix must be installed on the network and shall be a minimum length of 300m.

Each of these stages have a significant number of tests that they must undergo before being approved and allowed to proceed to the next stage. Ultimately, Welsh Government must approve these.

3.2 -Lab & Site measurements

Within each stage of the TAIT process there are both lab and site testing that needs to be met to proceed to the next stage. At stage 1 the following evidence must be given (PAG 112/20) and all testing must be done by a UKAS (United Kingdom Accreditation Service) Accredited Laboratory;

- Composition
- Grading and binder content (+/- 0.2% by mass) (Table 1)
- Air Void content (SMA 10 = Vmin3;Vmax4) & (SMA 6 Vmin 3.5; Vmax4.5), which means it is an extremely dense product
- Binder Drainage
- Water Sensitivity
- Binder Penetration
- Softening point
- Resistance to Permanent deformation

Lab Design Results:

- Coarse & Fine aggregate source and geological rock group
- Filler source and supplier
- Bitumen source and supplier
- Proposed production plant
- Complaint table of results supplied to WG

Table 1

D (mm)	10	6
Sieve	Proportion passing sieve (% by mass)	
20	-	-
14	100	-
10	93 – 100	100
6.3	35 – 52	93 – 100
4	-	32 – 45
2	20 – 32	25 – 35
0.5 [1)]	±4	±4
0.25 [1)]	±4	±4
0.63	8 -12	8 – 14
Minimum target binder content Bact (% by mass)	6.7(±0.2)	7.1(±0.2)

Table 1 – Grading and Binder content for WG SMA 10mm & 6mm.

At Stage 2 there are now on-site tests that are included as part of the process along with lab tests to supplement the data on the ground these include.

- Binder & Grading Analysis
- Air Void Content
- Laid and compacted matt (minimum thicknesses)
- Optional Grit in stage 2 (requirement stage 3)
- Composition of grit
- Surface texture of grit
- Transport laying and compaction methods outlined in PAG document
- Min & Max temps.
- Trial length (60m)

With the information supplied to WG including table of testing results, UKAS certificates, Quality Assurance certification for plant, Highways Sector Scheme 16 certification for pavement contractor, they will then be able to continue to stage 3.

At Stage 3 there are also more rigorous site testing inclusive of those outlined in stage 1 and 2 but with increased testing and more regular intervals across the site. There is significant consideration and testing on the application of the grit at this stage, special consideration is given to the uniform spread, timing of grit application (first pass of the roller of the newly installed surface), sweeping of the surface, texture testing. The new surface must also comply to early life skid resistance compliance requirements. All set of tests for each stage of TAIT are included in Appendix A, B & C that must be supplied to WG.

4.0 – Discussion

In this project there were two different hypotheses we are investigating these include researching if and how SMA's have developed since their inception, their associated advantages, disadvantages, and modern improvements in early life skid resistance. We also are investigating what modern techniques have been introduced to help reduce or eliminate early life skid resistance problems in Wales for SMA's.

It has been identified that there have been a variety of different material compositions that have been used on roads throughout Wales and England. HRA's were the prime choice until the mid-1990's. Developments in asphalt materials meant that thin-surface course systems were beginning to be introduced this was due to the perception that they could be as durable as its predecessor the HRA but without it's disadvantages, meanwhile developments in SMA's were being made throughout Europe. There was however increased concern from Highway Agents over the performance of these Thin-surface course systems and associated disadvantages in HRA's, this continued over several years until 2012 where the trunk roads particularly in Wales were deteriorating faster than ever and led to investigation by several highways authorities to establish the cause of these poor performances and where improvements could be made.

Since 1995 it has been noted that the development of these SMA's have improved dramatically and the Scottish SMA spec from its inception in 2010 declared that these products should be denser, binder rich and use small stone sizes and proved successful. The WGSMA spec has been developed on this basis and regarded as the cousin of the German

and Scottish SMA to improve the highways network and is regarded as a long-term solution to more durable roads with a cost/life balance.

Throughout this project we have raised and discussed that there are a variety of different advantages to SMA's and the benefits of these new products however, there is no getting away from the inherent skid risk factors that have been outlined by a variety of sources including the Welsh Government whom highlight the need for a post-grit application to the new WGSMA to improve overall early-life skid resistance, without this newly developed technique the skid resistance would not be suitable to be used on a trunk road network.

There are a few limitations one being how there is no true data on how these SMA's will perform over 5+ years and even 10 years and beyond due to the new product and installing on a wide network may cause problems further down the line if unforeseen weaknesses do not show until later on and the design life is not met, this may lead to unforeseen costs and design-cycle life programmes in the future. Although it may appear as a high standard material it may prove otherwise although by most engineers agree it is unlikely it is something that should be considered.

5.0 – Conclusion

SMA's and the WGSMA are paving the way for better more durable surfacing products throughout the world with these new compositions and advancements helping push for better products and installation from contractors. SMA's have developed since their inception in the 1960's in Germany to the modern products we see today (Scottish SMA and WGSMA) with modern techniques having highlighted a variety of advantages and tried to eliminate a major disadvantage (in early life skid resistance) by utilising post-applied grit which has proven through evidence has been able to do so.

Tight construction product regulations, technical specifications, quality control and assurances and construction techniques have all aided in the development of these products and so far, the on-going success and continued implementation of the product across the network in Wales

There is, however, the need for continued research around this topic as more WGSMA products are developed in different stone sizes i.e. 'WGSMA 14mm and 6mm' and also how the material in general performs over its entire life cycle as it is still a relatively new product and performance still needs to be analysed to ensure the cost/life benefit remains and other

products like the previously favoured HRA's are not more beneficial long term. I think that an overall combined approach of a variety of different materials i.e. HRA, Thin-surface course systems and SMA's installed on the network should be utilised dependant on their location should be the best strategy to have for the continued maintenance of a trunk network.

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Appendices

Appendix A – TAIT Stage 1 Results

Property	Test method[1)]	Limits
Aggregate		
Particle density	BS EN 1097-6	Results declared
Resistance to polishing	BS EN 1097-8	Results declared
Resistance to abrasion	BS EN 1097-8, Annex A	AAV12
Resistance to fragmentation	BS EN 1097-2	LA30
Resistance to wear	BS EN 1097-1 Micro Deval Method	Results declared
Flakiness	BS EN 933-3	≤F20
Binder		
Penetration	BS EN 1426	75 – 130
Softening point	BS EN 1427	≥75
Composition		
Binder content	BS EN 12697-1	Relevant column of Table 1 & Figures 1 - 2
Grading	BS EN 12697-2	Relevant column of Table 1 & Figures 1 - 2
Maximum Density	BS EN 12697-5 Procedure A	
Bulk Density	BS EN 12697-6 Procedure B	
Air Voids		
SMA 10 surf	BS EN 12697-8	Vmin 3 : Vmax 4
SMA 6 surf	BS EN 12697-8	Vmin 3.5 : Vmax 4.5
Water Sensitivity	BS EN 12697-12	$ITSR_{80}$
Binder drainage	BS EN 12697-18 Beaker method	$D_{0.3}$
Resistance to permanent deformation	BS EN 12697-22	Rut rate and depth shall be reported
Stabilising additive (cellulose fibres)		0.3% by mass
Grit		
Binder content	BS EN 12697-1	Relevant column of Table 5
Grading	BS EN 12697-2	Relevant column of Table 5

[1)] all testing shall be undertaken by a UKAS accredited laboratory. CE markings for constituent materials or UKAS test certificates shall be supplied upon completion.

Appendix B – TAIT Stage 2 Testing

Property	Test method [1]	Limits
Binder content	BS EN 12697-1	Relevant column of Table 1 & Figures 1 - 2
Grading	BS EN 12697-2	Relevant column of Table 1 & Figures 1 - 2
Resistance to permanent deformation	BS EN 12697-22 Procedure B	
Air voids in mat	BS 594987, Annex G and Chapter 9	
SMA 10 surf		Vmin 2 : Vmax 5
SMA 6 surf		Vmin 2 : Vmin 6
Texture	BS EN 13036-1	To be recorded

[1] all testing shall be undertaken by a UKAS accredited laboratory. CE markings for constituent materials or UKAS test certificates shall be supplied upon completion.

Appendix C – TAIT Stage 3 Testing

Property	Test method [1]	Limits
Binder content	BS EN 12697-1	Relevant column of Table 1 & Figures 1 - 2
Grading	BS EN 12697-2	Relevant column of Table 1 & Figures 1 - 2
Air Voids in mat	BS584987, Annex I and Chapter 9	
SMA 10 surf		Vmin 2: Vmax 5
SMA 6 surf		Vmin 2 : Vmax 6
Texture	BS EN 13036-1	To be recorded
Mean Grip Number at 4 weeks and 6 months	BS 7941-2	Mean Grip Number from relevant column of Table 7

[1] all testing shall be undertaken by a UKAS accredited laboratory. CE markings for constituent materials or UKAS test certificates shall be supplied upon completion.