Bituminous emulsions

European laboratory test methods for slurry surfacing revised in view of field practice

Joëlle De Visscher, Alexandra Destrée, Tine Tanghe, Stefan Vansteenkiste, Nathalie Piérard, Bart Beaumesnil, Ben Duerinckx
Belgian Road Research Centre (BRRC)

Abstract

Slurry surfacing is a maintenance technique frequently used in Belgium on low volume roads. The road surface is thereby restored, while protecting the underlying structure against water infiltration and deterioration. However, there is still a huge potential for this technique, even on higher volume roads, provided that slurry mixtures are properly formulated in view of traffic and climate, but also in view of the expected weather conditions during laying. Since it is a cold bituminous emulsion mixture, workability, curing and performance after opening to traffic depend strongly on weather conditions and on last minute changes made to the mix formula on site, and this should be anticipated in the process of mix formulation in the laboratory. The series of European test methods EN 12274 ('Slurry surfacing – Test methods') contains a number of performance related tests, devised to optimize the formulation of slurry mixtures in the laboratory. However, there are still many questions regarding these test methods. Procedures and test conditions are not adequately described and often not representative for the conditions on site, and precision of test results is generally unknown. Therefore, the Belgian Road Research Centre (BRRC), with support of the Belgian National Bureau for Standardization (NBN), is engaged in a project involving laboratory testing and fieldwork, with the aim of improving the EN 12274 series. This has led to many recommendations for mixture and specimen preparation and the choice of test conditions in view of the expected conditions on site. As a result, precision is improved and the test results are more relevant for the performance on site, allowing for better mix formulations. The main findings of this research are presented, together with recommendations on the use of the tests in the process of mix formulation.

This paper was first published in 2020 in version 1.0 of the proceedings of the 7th E&E Congress. This second edition (version 1.1.) of the proceedings is published in June 2021. The content of this paper has not changed, but the author(s) may have provided additional information in the form of an annex.

1. INTRODUCTION

A slurry is a mixture of mineral aggregate, bitumen emulsion, water and, where appropriate, additives. The mix is prepared on site, using mobile machinery, and evenly spread in one or two layers, with a thickness slightly greater than the maximum aggregate size. Slurry surfacing allows to restore surface characteristics such as skid resistance and imperviousness with little resources and minimum disruption of traffic. Moreover, the underlying road structure is protected from deterioration by water infiltration and, consequently, more drastic structural repairs are delayed for many years.

The cost of slurry surfacing is low, compared to repair or replacement of one or more asphalt courses. Long-term economic benefits of slurry surfacing can be calculated using LCCA (Life Cycle Cost Analysis) [1]. Besides economic arguments, there are various environmental and social arguments to justify regular application of slurry surfacing as a sustainable solution [2]:

- less material and energy consumption during construction;
- lower fuel consumption in the operation stage, thanks to lower rolling resistance;
- road safety and comfort maintained constant at a high level;
- less traffic disruption by road works, ….

In Belgium, slurry surfacing is a frequently used maintenance technique on low volume roads. It enables local authorities to maintain the road network in good condition with a small budget and little nuisance to road users and inhabitants. Unfortunately, road owners are still reluctant to apply slurry surfacing on high volume roads, because the performance and durability of slurry surfacing can be variable and difficult to control. The reason is that, like for all cold bituminous emulsion technologies, the final performance depends not only on the mix formula and the constituent materials, but also on the job site conditions (condition of the existing road, weather conditions, organization, workmanship, adjustments made in situ to mix composition, ...).

It is necessary to understand the impact of all these parameters, in order to improve the durability and performance of slurry surfacings. This will ultimately increase the lifetime of the underlying structure and thereby significantly contribute to the sustainability of the road infrastructure.

2. RESEARCH AIMS AND SCOPE

The Belgian Road Research Centre (BRRC) is conducting a 4-years research project, which aims at increasing the knowledge on slurry surfacing in order to improve performance and durability. This project is supported by the Belgian National Bureau for Standardization (NBN) and meets with BRRC's mission to improve and promote sustainable technologies in road construction through research.

To study the performance of slurry mixtures in the laboratory, reliable performance-related tests are needed. In this project, use is made of the series of European test methods EN 12274 ('Slurry surfacing – Test methods'), which contains a number of test methods, devised to optimise the formulation of slurry surfacing mixtures in the laboratory. However, there are many questions regarding these test methods. Procedures and test conditions are not adequately described and often not representative for the conditions on site, and precision of test results has not been determined. Therefore, the first phase of the project aimed at the improvement of the EN 12274 series of test methods and the determination of precision and ability to discriminate between poorly and well performing mixtures.

The bituminous emulsion plays a key role in the performance of slurry mixtures. To assess the impact of the emulsion characteristics on the performance of the slurry, the project also involves testing on emulsions and residual binders. Here also, the tests methods were evaluated in terms of test conditions, precision and ability to discriminate between different types of emulsions.

In the second (ongoing) phase of the project, the test methods are further used to study the impact of various parameters (material characteristics, composition, temperature, mixing time, …). The final aim is to apply the acquired knowledge for the development of a practical mix design procedure, which will help contractors to optimize mix formulations as function of the road condition and the expected conditions on site.

In parallel to the laboratory work, several job sites are being followed, starting from the assessment of the road condition before the application and continuing with monitoring the application and visual inspection of the condition every six months. This allows to acquire more knowledge on the impact of the condition of the existing road and job site conditions on the quality and long-term performance. This practical knowledge is also necessary to assess the relevance of laboratory tests. Another important aim of this field work is to develop a new method for the visual inspection of slurry surfacing, since experience with the European norm EN 12274-8 shows that reproducibility is not acceptable.

The present paper discusses the first phase of the project, in particular the laboratory testing on slurry mixtures and bituminous emulsions used for slurry surfacing. This work has led to recommendations for improvement of the test methods and for the choice of test conditions, in view of the expected conditions on site. As a result, precision of the tests is improved and the test results are more relevant for the performance on site. The main findings are presented, together with some preliminary recommendations on the usefulness of the tests in the process of mix design.

3. LABORATORY TESTING OF SLURRY SURFACING MIXTURES

The aim of the laboratory tests is to evaluate the performance of a slurry in the mix design phase. This consists in measuring resistance to the most common types of distress (ravelling, bleeding, delamination), as well as characteristics crucial for construction quality (workability, breaking and curing behaviour).

3.1. Preparation of slurry surfacing mixtures in laboratory conditions

The quantities needed for the preparation of laboratory samples are small and segregation of the aggregate may thus result in large variations in the grading between test samples. This will lead to poor repeatability and, therefore, it is crucial to control the aggregate grading as accurately as possible. This is done by separating the all-in aggregate in fractions on the sieves of 63 µm, 2 mm and, if appropriate, also on 4 and 6.3 mm. The aggregate mix is then recomposed according to the target grading, to obtain the quantity required for the test sample.

The laboratory mixing procedure with water and emulsion should be repeatable and mimic the mixing process on site as closely as possible. When comparing standards EN 12274-3, -4, and 5, it appears that the description of the mixing procedure is not entirely the same and not very precise. To improve repeatability, BRRC follows a more detailed protocol, which describes exactly the mixing sequence, mixing times and speed, temperature of constituents and environmental conditions.

3.2. Consistency

A freshly mixed slurry needs to be sufficiently fluid, to ensure a homogenous, fully coated and workable mixture, free of lumps. On the other hand, the slurry must be sufficiently consistent, to prevent segregation and excessive outflow.

A simple test to evaluate consistency is described in EN 12274-3 [5]. Immediately upon mixing, the slurry is poured into a cone placed at the centre of a plate engraved with a concentric scale. The cone is then removed vertically, allowing the slurry to spread (Figure 1). The outflow is read on the scale in four points (radially spaced by 90 °) and the average of the four readings is the test result.

Based on practical experience, recommendations were made to facilitate testing and improve the repeatability. Following these recommendations, the repeatability limit at BRRC was estimated to 0.6 cm (for the average of three repeated tests, determined in the range of 2 to 3 cm).

In addition to the quantitative determination of the outflow, visual inspection is essential. Asymmetric outflow, lumps, emulsion drainage (Figure 1(right)) or uncoated aggregates are indications that the mix is not well designed.

Figure 1: Removal of the cone (left), correct outflow (middle) and emulsion drainage (right)

Despite the limited repeatability, the test can logically discriminate mixtures with different compositions. As a general rule, it is observed that consistency decreases (and outflow increases) when increasing the amount of water, the amount of emulsion or by adding a dope to retard the breaking of the emulsion. The impact of cement (type and dosage) on the consistency of the mixture is less predictable: it can either increase or decrease the mix consistency.

Consistency will increase (and outflow decrease) with increasing temperature (see Figure 2), since the breaking of the emulsion is faster. Therefore, the test should be performed within the range of temperatures at which the mixture will be placed and the test temperature shall be accurately controlled and reported. Performing the consistency test at three different temperatures covering the expected range of use in the field is recommended, since this allows to evaluate the sensitivity to temperature fluctuations on site.

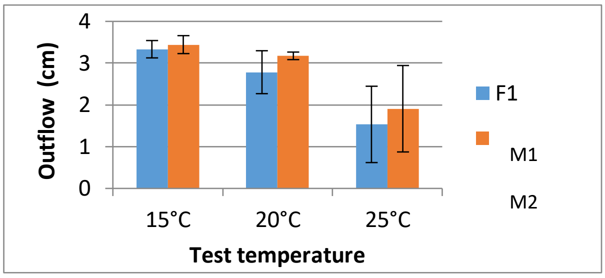

Figure 2: Outflow versus test temperature (M2 has a higher water content than M1) (bars denote +/- standard deviation of 3 repeated tests)

Particularly with slow setting emulsions, the mixing time of the emulsion with the aggregate may also have an impact on consistency, but just like on site, this parameter was fixed in the standard protocol for mix preparation (30 or 60 seconds, depending on the quantity). This is very short, like on site, but sufficient to homogenise the mixture.

The International Slurry Surfacing Association (ISSA) [3] recommends an outflow between 2 and 3 cm for slurries with a 0/4 or 0/6.3 mm grading. According to our experience, 2 to 3 cm outflow corresponds to an adequate consistency for most slurry mixtures, with some exceptions:

- In case of very slow setting emulsions, the test shows excessive emulsion drainage (even at higher temperatures) unless the mixing time is increased. This behaviour is not necessarily problematic, since practice shows that these emulsions are commonly used in warmer periods without obvious problems of consistency.
- Outflows of less than 2 cm are also not necessarily problematic in the field, as long as the mixture is homogeneous.

The fact that the behaviour of the mixture in the laboratory test is not always representative of the behaviour on site is not surprising, since there are many other parameters that will affect the outflow on site (nature and texture of the substrate, method of spreading, possibly also compaction on site, effect of wind, …).

The conclusion is that the consistency test according to EN 12274-3 is a simple and useful test to adapt the mix design with a view to adequate consistency and to evaluate the sensitivity of the mixture to temperature variations. An outflow of 2 to 3 cm may be considered as a target, but not as a necessary requirement.

3.3. Cohesion

Once the slurry is mixed and applied, the emulsion starts to break and the cohesion of the mixture increases steadily. For quick reopening of the road, cohesive strength shall achieve a level high enough to resist traffic within a short period.

A test to measure the development of cohesion with time is provided by EN 12274-4. After pressing a rubber stamp vertically on the test sample with a constant pressure of (200 ± 4) kPa, a torque is applied to the axis, subjecting the slurry surface to shear stresses (Figure 3). The maximum torque, which is a measure of cohesive strength, is measured at four times after spreading the slurry in the moulds. The test times are not specified by the standard, but BRRC generally performed the test after 15, 30, 60 and 90 minutes. In later tests, 24 hours were used (instead of 15 minutes), to obtain an indication of the final cohesion of the mix.

Figure 4 shows two samples after testing. After 15 minutes, cohesion is low and the sample is disintegrated, while after 90 minutes, the maximum torque is higher and the sample shows only minor damage.

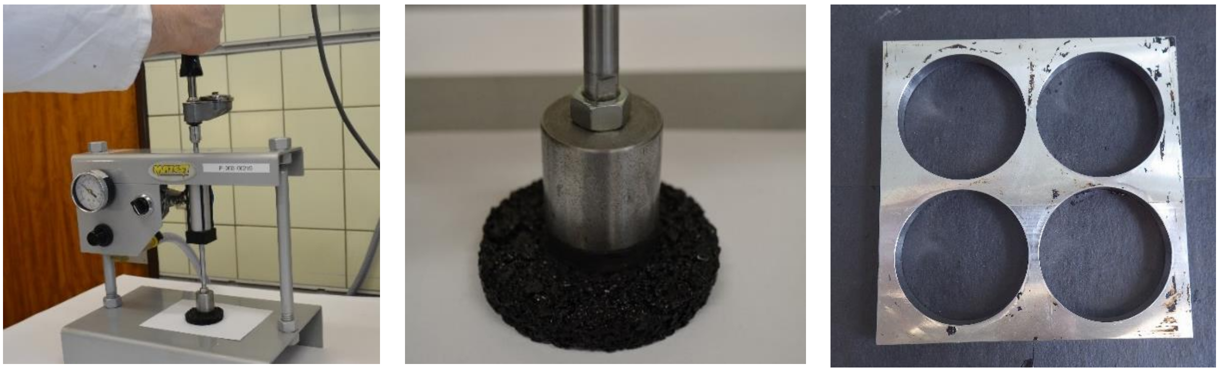

Figure 3: Test set-up (left), sample under loading (middle) and mould for 4 test samples (right)

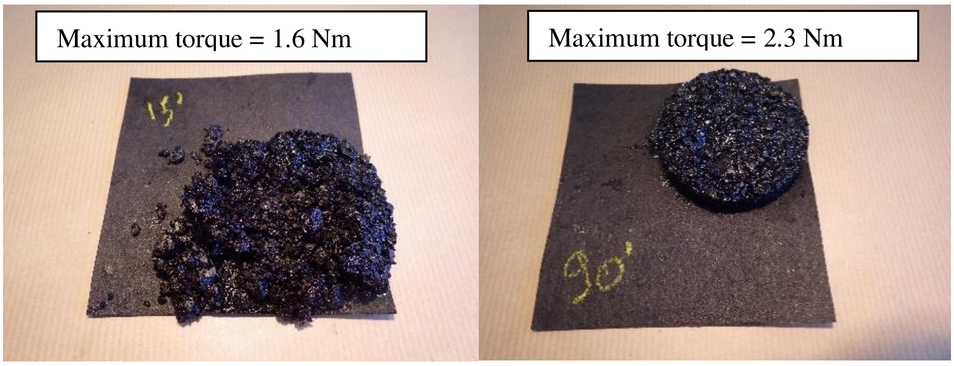

Figure 4: Examples of test samples, tested after 15 minutes (left) and 90 minutes (right)

Ambient temperature has a significant impact on the rate of increase of cohesion and, therefore, the test should be performed within the range of temperatures at which the mixture will be placed. The exact test temperature shall be accurately controlled and reported.

Preparing the samples requires good practice and skill from the operator; the surface texture should be repeatable, because this significantly influences the test results. The amount of mixture prescribed by the norm is too high and consequently, the excess of material needs to be removed to obtain a surface at the same level of the mould. This requires a lot of manipulation of the slurry and is very unpractical. Preparing the exact amount of mixture significantly facilitates the mould filling and results in a more homogeneous and repeatable texture. This is one of the recommendations made to improve the test method. Following all recommendations, the repeatability limit at BRRC was estimated to 0.4 Nm (for the average of three repeated tests).

In the interpretation of the test results, the guidelines of the International Slurry Surfacing Association (ISSA) [3] are followed: a minimum torque of 1.2 Nm after 30 minutes and 2.0 Nm after 60 minutes, for quick opening to traffic. However, the interpretation of the results is not easy. Some samples can withstand a high maximum torque, but disintegrate completely, while others only exhibit minor loss of aggregates or damage to the binder film. The visual inspection of the tested samples may sometimes be operator dependent, but it is nonetheless important to consider this qualitative appreciation of the failure mode together with the quantitative torque values.

The results obtained in this project show that the test gives a fairly good indication of the rate of cohesive strength growth and can detect differences between mixtures with variations in composition. For example, figure 5 shows results of two mixtures that differ only by the emulsion (note: binder content was maintained, thus less emulsion in case of emulsion 2). Mixture 2 is less cohesive in the beginning, but after 24 hours, the cohesive strength is higher than for mixture 1. The slower development of cohesion is in accordance with the difference in breaking behaviour of the emulsions (Table 1).

Figure 6 shows two other mixtures, which differ by the aggregate, while composition and emulsion are identical. The difference in cohesion is in this case explained by the different grading of the aggregate, which leads to a significant difference in surface texture. The sandstone slurry showed a very smooth surface, so that the applied load was more evenly distributed over the surface, causing less stress concentrations.

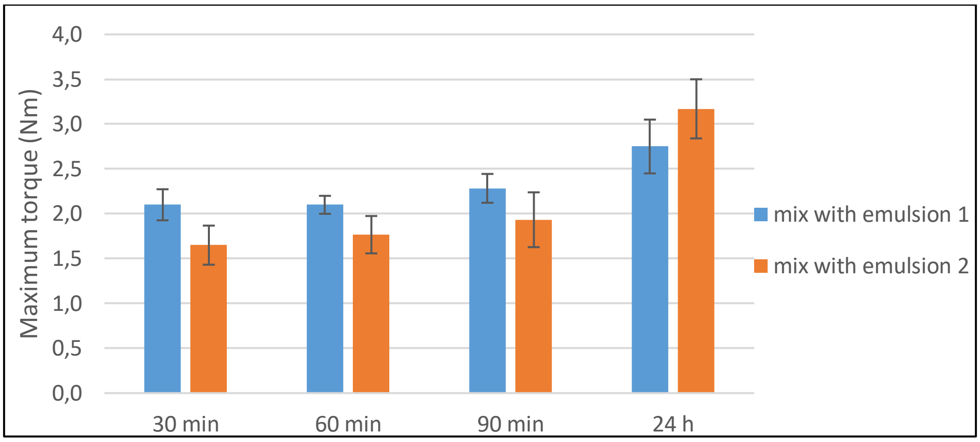

Figure 5: Cohesion versus time, for mixtures with two different emulsions (bars denote +/- standard deviation on 3 repeated tests)

Table 1. Characteristics of emulsions used in Figure 5

		emulsion 1 (PMM2-19-0397)	**emulsion 2 (PMM2-19-0398)**
Binder content (%)	EN 16849	59.3	61.9
Breaking value – Forshammer (s)	EN 13075-1	158	195
Viscosity (2 mm at 40 °C) (s)	EN 12846-1	36	47
Residue on 0.5 mm sieve (%m)	EN 1429	0.02	0.00
pH	EN 12850	5.92	2.91

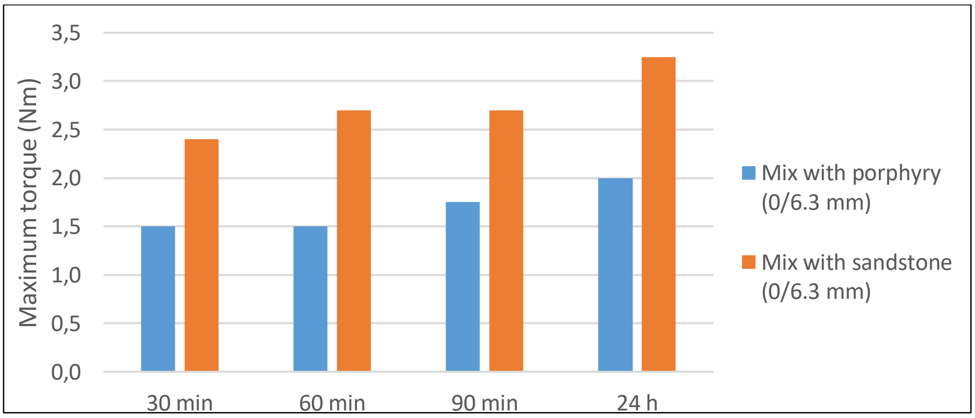

Figure 6: Cohesion versus time, for mixtures with two different aggregates (only one test per mix)

The conclusion is that the cohesion test according to EN 12274-4 is a useful test to evaluate the mix design for its ability to allow for quick reopening to traffic. However, it is not an easy test, requiring a skilled operator to prepare high quality samples and perform the test in a repeatable way. The test is also time consuming, since three repeats are needed to obtain an average result, with a reasonable repeatability of 0.4 Nm.

3.4. Wearing resistance

After curing, the slurry surfacing has to resist wearing by traffic and water. A laboratory test to determine this resistance is the test according to EN 12274-5 [7]. Test samples are cured and subsequently conditioned for 1 hour in a water bath. They are then subjected to wearing by the action of a rubber hose on the surface (during 5 minutes), while being submerged in water at a test temperature of 25 °C (Figure 7 (left)). The loss of material by wearing is determined by weighing. Note that the weight loss is mainly due to a loss of aggregate (ravelling), since wearing of the bitumen film produces very little weight loss.


Figure 7: Test set-up (left) and sample after testing (right)

The surface texture of the samples has a considerable impact on the test results, since the rubber hose has less grip on a smooth surface. Hence, it is crucial to produce test samples with equal texture, representative of the texture of the slurry on the road. This was verified by texture measurements made on the samples and on a job site with the same mixture (one day after laying, between the wheel paths). It was also shown that, when samples with outlying texture are discarded, repeatability generally improves.

The repeatability of this test has not yet been determined because of insufficient test data, but it is clear that repeatability is rather poor. It depends on the amount of material loss; the more material is lost, the smaller the coefficient of variation. It is recommended to do at least three tests per mixture to obtain a more accurate average result. Other recommendations to improve the facility and repeatability of the test were made.

In the interpretation of the test results, we again follow the guidelines of the International Slurry Surfacing Association (ISSA) [3]: a maximum loss of 807 g/m² for slurry surfacing and 538 g/m² for microsurfacing.

Despite of the poor repeatability, the test is capable of discriminating mixtures in a logical way:

- As expected, the composition has a considerable impact. The amount of emulsion needs to be sufficiently high (see Table 2);
- The type of emulsion has a large impact. Table 3 shows that a polymer modified emulsion (C60BP5) can significantly improve the results.
- Also in Table 3, the effect of the aggregate is huge. The difference is explained by the grading, which leads in the sandstone case to a very smooth surface. The affinity between the emulsion and the aggregate is not at cause; it is good for both porphyry and sandstone, as verified with other types of tests.

Table 2. Impact of mix composition on material loss

Mix composition (on 100 % dry aggregate)	10 % emulsion - 10 % water	12 % emulsion - 9 % water	14 % emulsion - 8 % water
Material loss (g/m²)	1082 ± 347	325 ± 124	331 ± 114

Table 3. Impact of aggregate (porphyry, sandstone) and emulsion type on material loss

Mix variant (aggregate - emulsion)	porphyry - C60B5	porphyry - C60BP5 (polymer modified)	sandstone - C60B5	sandstone - C60BP5 (polymer modified)
Material loss (g/m²)	2055 ± 208	939 ± 116	113 ± 87	-24 ± 33

Since ravelling is one of the most frequent types of damage on slurry surfacing, this test should be considered in the mix design and the ISSA guideline for a maximum loss of material seems adequate. When the material loss exceeds this threshold, the mix design should be adapted, e.g. by increasing the amount of emulsion, by using a polymer modified emulsion or by improving binder/aggregate adhesion.

3.5. Adhesion of the slurry mixture to the substrate

To test resistance to delamination between different layers of a road, BRRC uses an instrument called LAMI (Layer Adhesion Measuring Instrument), developed by the Ministry of Transport, Urban Mobility and Electrification of

Transportation of Quebec (MTQ) [4]. This instrument measures the adhesive bond strength between two layers in tensile mode. Good experience has been obtained with this instrument on interfaces between bituminous layers or between a bituminous and a cement concrete layer.

In this project, it was applied on slurry mixtures prepared in the laboratory (Figure 8). The slurry was applied on concrete blocks, since in practice, delamination due to poor adhesion of the slurry is mostly seen on concrete.

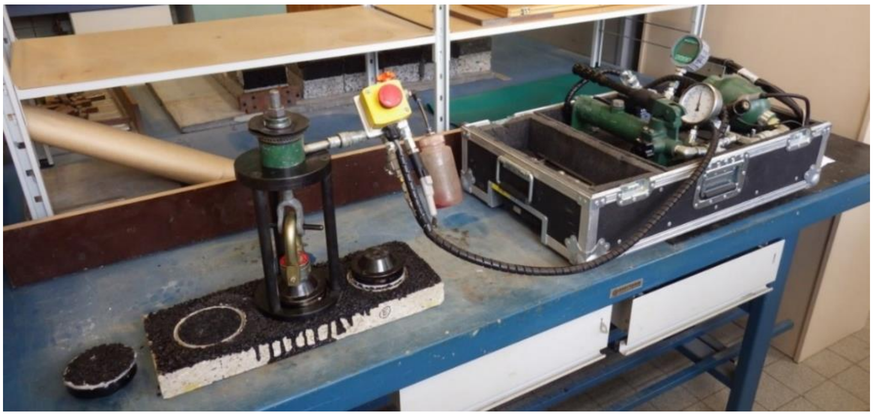

Figure 8: Measurement of the adhesion between a slurry and a concrete substrate using the LAMI

In the laboratory tests, failure always took place in the slurry mixture and never at the interface. Adhesion between the slurry and the concrete substrate was thus not the weak point. The tests were not representative for practice, because the concrete was fresh and clean, unlike the concrete on a road that needs maintenance, but they did show the feasibility of using the LAMI on slurry surfacing. The LAMI will not further be used in the laboratory test program, but only for diagnosis of delamination problems on slurry surfacings in the field.

3.6. Resistance to bleeding

At this moment, there is no test for resistance to bleeding in the EN 12274 series of European test methods. This is a shortfall, since bleeding is a critical and frequently encountered phenomenon – particularly on two-layer slurry surfacing subjected to heavy traffic. It was also mentioned in paragraph 3.4 that the resistance to ravelling could be improved by increasing the amount of emulsion, but this could equally increase the risk of bleeding. Therefore, in the framework of this project, BRRC is setting up a test method to evaluate the resistance to bleeding and deformation of slurry surfacing. The test uses the large size device of the European wheel tracking test with modified test conditions (25 °C, less cycles) and combined with texture measurements.

3.7. Interaction between aggregate and emulsion

Standard EN 12274-7 [8] provides a test to assess the suitability of the aggregate/emulsion combination. Mixtures are prepared using a 0/2 mm fraction of the aggregate and compacted in cylindrical moulds. The test samples (four per mix) are then placed in rotating tubes and subjected to shaking abrasion in the presence of water (Figure 9). The amount of material loss is measured.

Several inconsistencies were found in the standard and some descriptions of the procedure are open to different interpretations. These issues were investigated and the findings resulted in recommendations for corrections to the standard.

BRRC has performed this test on combinations of the two types of aggregate commonly used in Belgium (porphyry and sandstone) with various types of emulsion. The test results are systematically low (less than 2.5 % weight loss), suggesting good adhesion between aggregates and the tested emulsions. Repeatability is good and the test can discriminate between different types of emulsion, even though the weight loss is always very small.

Unlike the previous tests, this is not a test on the complete slurry mixture and, therefore, it will not assess the impact of aggregate grading or mix composition. The correlation between the test results and the previously discussed tests on the slurry mixture is further investigated, in order to draw a conclusion on the usefulness of this test for mix design.

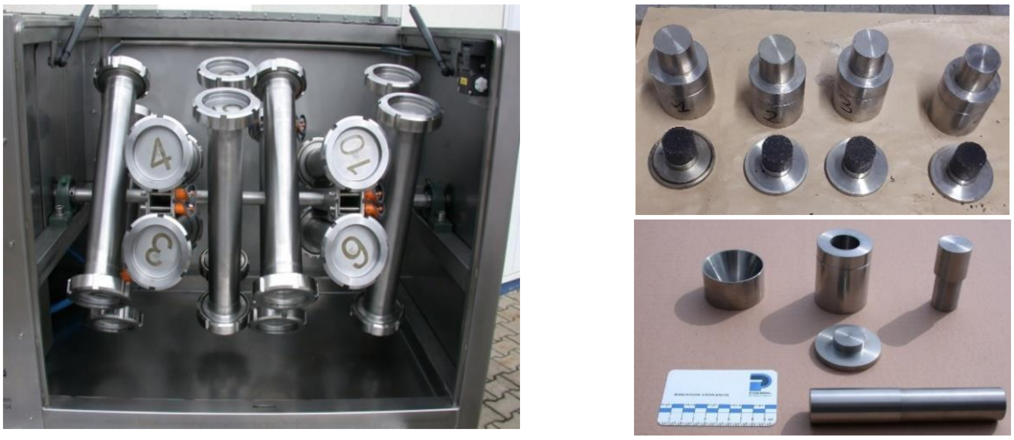

Figure 9: Test equipment (left) and moulds used for sample compaction (right)

4. TESTS ON EMULSIONS AND RESIDUAL BINDERS

It is important to understand the relation between the characteristics of the emulsion (and residual binder) and the performance of the slurry, in order to select the right emulsion for a given application. In this project, characteristics of the emulsions and residual binders are systematically measured, to collect data and to investigate correlations with the performance of the slurry mixtures prepared with these emulsions.

4.1. Emulsion tests

In addition to the classical characteristics (binder content, viscosity, breaking index, storage stability and acidity), BRRC measures the stability when mixed with cement, according to EN 12848 [10]. This test is presumed to be relevant for the breaking behaviour in slurry mixtures, because the emulsion needs to remain sufficiently stable upon contact with materials with high specific surface such as filler or cement, in order to prevent the emulsion from breaking prematurely in the mixer or spreader.

The test is able to discriminate between different types of emulsions and the stability logically decreases with increasing temperature, as illustrated by the test results in Table 4. It is recommended to do the test at different temperatures, covering the temperature range for which the emulsion is intended. For some emulsions, the stability is more sensitive to temperature than for others. An emulsion with low sensitivity to temperature is preferable, since the expected temperature on site is always very uncertain in the Belgian climate. The test is also useful for checking the stability of the emulsion as function of storage time.

Table 4. Stability with cement, for two emulsions, as function of test temperature

Emulsion	Type	Residue in g (cement type CEM I 42,5 R HES)			
		Maximum temperature of use, recommended by the producer	Test temperature		
			20±1 °C	25±1 °C	30±1 °C
1	C60Bx	27 °C	0.0±0.1 g	0.1±0.2 g	0.3±0.2 g
2	C60BPx	25 °C	0.2±0.0 g	0.4±0.0 g	1.5±0.3 g

4.2. Residual binder tests

The characteristics of the residual binder are important for the performance after curing. Therefore, residual binders are characterized by empirical tests such as needle penetration (EN 1426) and ring-and-ball softening point (EN 1427), as well as by DSR tests to measure the complex shear modulus as function of temperature and frequency (EN 14770).

For polymer modified emulsions, the cohesive strength of the residual binder is measured as a function of temperature, using the Vialit Cohesion pendulum (EN 13588 [14]). A high cohesive strength over a wide temperature range is required to optimize the cohesion of slurry surfacing subjected to heavy traffic.

5. EVALUATION OF FIELD PERFORMANCE

The project attaches great importance to the monitoring of road sites, with a view to:

- assessing the impact of job site conditions (before, during and after application) on durability and the development of defects;
- evaluating European standard EN 12274-8 for the visual evaluation of defects in slurries;
- assessing the relation between laboratory test results (using EN 12274-3, -4 ,-5 and -7 test methods) and field performance;
- gaining practical knowledge and expertise on good practice.

Test sites are inspected prior to the application of the slurry, to assess the condition of the existing surface layer. A mobile mapping system called Imajbox® is used for that purpose. The Imajbox® collects images of the road surface at driving speed. Post-processing with dedicated software allows to quantify the various types of defect and to calculate an overall index. This assessment is imperative for a correct interpretation of future observations, because defects such as large cracks, potholes and deep rutting (> 20 mm) will quickly reappear unless they are correctly repaired beforehand. During application, all conditions are recorded and reported. Samples of constituents and mixtures are taken for laboratory analysis.

The sites are also used to evaluate European standard EN 12274-8 and to determine reproducibility when different persons perform the inspection. Reproducibility is crucial, since the standard method is used to determine performance categories according to standard EN 12273 (‘Slurry surfacing – Requirements’). Unfortunately, reproducibility of this method was found to be unacceptable. Several actions were taken to improve reproducibility, but the problem is inherent to the approach specified by the standard. BRRC decided to develop an alternative method, following a different approach. This new method is currently under evaluation and the improvement of reproducibility still needs to be demonstrated.

Assessing relations between laboratory test results and field performance proves to be very challenging. The reason is that, besides mix design, there are numerous other parameters playing a role on a real job site and even the mix composition may be changed on site, depending on the actual weather conditions.

6. CONCLUSIONS AND PERSPECTIVES

The European test methods for slurry surfacing (series EN 12274) were implemented and the existing standards were evaluated. This resulted in several recommendations for improvement of the standards, which will be proposed to CEN TC 227/WG2 for future revisions.

Since the existing standards contain no information on precision, BRRC evaluated the repeatability within the laboratory of BRRC. Repeatability will not be the same for every laboratory, since the tests involve a lot of manual operations and the skill of the operator is an important factor. Interlaboratory tests are needed to estimate overall repeatability and reproducibility.

Three performance-related tests proved to have sufficient ability to discriminate between slurry mixtures with variations in mix design: the tests for consistency, cohesion and resistance to wearing. These tests are feasible in terms of equipment and time and, therefore, useful in the process of mix design. A test for resistance to bleeding is still missing in the series of performance-related tests, which is why BRRC is setting up a new test method for that purpose.

The test conditions should be selected in view of the average temperature for the season. However, weather conditions on site are difficult to predict and may change abruptly. Therefore, it is recommended to do the tests over a range of temperatures to evaluate the temperature susceptibility of the slurry mixture.

It is important to better understand the relation between the characteristics of the emulsion (and its residual binder) and the performance of the slurry mix. BRRC is collecting these characteristics in order to identify the relations with mix performance in laboratory tests and in the field.

Several sites with slurry surfacing are being monitored, to investigate the impact of all parameters and conditions on long-term performance and durability. It was found that visual assessment of defects according to the European standard (EN 12274-8) leads to unreproducible results. BRRC is working on an alternative method.

The project is still in progress, and the main perspectives are as follows:

- Further development of the laboratory test method to measure the resistance to bleeding of slurry mixtures;
- Completion of the study of the impact of mix parameters – in particular the characteristics of the emulsions –, and site conditions on performance of slurry surfacing.
- The development of a mix design procedure, based on laboratory performance testing;
- Study of the long-term performance on site, including the development of a reproducible method for visual inspection, and the validation of the laboratory tests using site data and observations.

ACKNOWLEDGEMENTS

The financial support of the Belgian National Bureau for Standardization (NBN) (through convention CCN/NBN/PN/16A04-B04) is gratefully acknowledged. The authors are also very grateful to the technical staff for the dedication to their work both in the laboratory and in the field.

REFERENCES

[1] Al-Mansour Abdullah, Sinha Kumares, Economic Analysis of Effectiveness of Pavement Preventive Maintenance, In TRANSPORTATION RESEARCH RECORD (1442), 1944, pp. 31–37

[2] Chan Susanne, Lane Becca, Kazmierowski Tom, Lee Warren, Pavement Preservation. A solution for sustainability, In Transportation Research Record: Journal of the Transportation Research Board 2235 (1), 2018, pp. 36–42, DOI: 10.3141/2235-05.

[3] International Slurry Surfacing Association (ISSA), Recommended performance guideline for Emulsified Asphalt Slurry Seal. ISSA (A105), 2010

[4] LC25-010, Mesure de la force de liaison avec un appareil de mesure d'adhésion des couches, Secteur – liants hydrocarbonés, Section 3, Transports Québec, December 15, 2017 (in French).

[5] EN 12274-3 : Slurry surfacing - Test methods - Part 3: Consistency, 2018

[6] EN 12274-4 : Slurry surfacing - Test methods - Part 4: Determination of cohesion of the mix, 2018

[7] EN 12274-5 : Slurry surfacing - Test method - Part 5: Determination of the minimum binder content and wearing resistance, 2018

[8] EN 12274-7: Slurry surfacing - Part 7: Shaking abrasion test, 2005

[9] EN 12274-8: Slurry surfacing - Test methods - Part 8: Visual assessment of defects, 2008

[10] EN 12848: Bitumen and bituminous binders – Determination of mixing stability with cement of bituminous emulsions, 2009

[11] EN 13075-1: Bitumen and bituminous binders - Determination of breaking behaviour - Part 1: Determination of breaking value of cationic bituminous emulsions, mineral filler method, 2016

[12] EN 1426: Bitumen and bituminous binders - Determination of needle penetration, 2015

[13] EN 1427 : Bitumen and bituminous binders - Determination of the softening point - Ring and Ball method, 2015

[14] EN13588: Bitumen and bituminous binders - Determination of cohesion of bituminous binders with pendulum test, 2017

[15] EN 14770: Bitumen and bituminous binders - Determination of complex shear modulus and phase angle – Dynamic Shear Rheometer (DSR), 2012

[16] EN 12273: Slurry surfacing – Requirements, 2008