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DEVELOPMENT OF PERFORMANCE CRITERIA FOR COLD-LAY SURFACING MATERIALS: LABORATORY STUDY

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Abstract

A number of cold-lay products that claim to satisfy the functional and other requirements set by road authorities have been developed by the private sector. Road authorities are, however, faced with the problem that insufficient (impartial) information is available on the products to judge whether these products would be suitable for the intended purpose. Stakeholders proposed that proprietary products be assessed in terms of their "fitness-for-purpose" and, if found to be compliant, a product certificate would be issued to the product owner. The objective of this paper is to present the results of a laboratory study aimed at setting performance criteria for cold-lay surfacing products, and to describe the rationale for selecting the test parameters. The scope of the project is limited to products intended for repair of potholes and patching. The performance criteria at this stage do not cover cold-lay surfacing applications. The paper discusses the laboratory testing protocol that was applied, as well as the results to develop certification requirements and limits. One of the materials selected was tested more widely to evaluate the implications of alternative test conditions, and this is presented first. Thereafter the results on all seven different materials are presented. Finally the results are compared to field tests previously performed in Kwazulu Natal (KZN), and acceptance limits are proposed. The critical acceptance limits are set for the:

- Moisture stability of briquettes compacted in the Marshall test at 30 ^{O}C.
- Voids content of samples compacted at 135 ^{O}C to reflect the long-term voids and to ensure that the mix does not close up and deform or remains too permeable. The hot mix guidelines related to traffic category serve as guideline for the lower limit.
- Rutting resistance of Gyratory compacted samples at 30 ^{O}C as measured in the Hamburg tester at 30 ^{O}C should be at least 5000 repetitions before a rut depth of 20 mm is achieved.
- A provisional optional requirement for permeability of 500 litres/sq m/hour on Marshall briquettes compacted at 30 ^{O}C is included.

1. BACKGROUND, MOTIVATION AND PROBLEM STATEMENT

Cold-lay surfacing materials can be an attractive alternative to conventional hot-mix asphalt (HMA) in situations where the required quantity is small or the site is in a remote location. Cold-lay materials are also used for patching and filling potholes. A number of cold-lay products that claim to satisfy the functional and other requirements set by road authorities have been developed by the private sector. Road authorities are, however, faced with the problem that insufficient (impartial) information is available on the products to judge whether these products would be suitable for the intended purpose.

Stakeholders proposed that proprietary products be assessed in terms of their "fitness-for-purpose" and, if found to be compliant, a product certificate would be issued to the product owner. Certificated products are defined as products developed by industry for which no standard has yet been established (i.e. proprietary products), but which have gone through a formal evaluation phase (certification process) in which the developer's specifications for the product have been validated, additional tests as requested by the certifying body conducted, their properties compared with those of standard products and/or specifications, and a certification statement issued by the certifying body in which the properties and application limits of the product are stated.

Agrément South Africa (SA) was identified by the roads sector as an ideal vehicle for the assessment and certification of cold-lay surfacing materials. An Industry Task Team was established and a workshop for stakeholders was held to define the parameters against which products should be assessed for certification. The scope of the work was limited to cold-lay materials intended for pothole repairs and patching. The development of a guideline for the certification of cold-lay products as an alternative surfacing application may be considered in the future.

The output of the industry workshop was used as the point of departure for the drafting of the certification guidelines. The British Board of Agrément (BBA) guidelines (Guideline for the approval and certification of permanent cold-lay surfacing materials [PCSMs], 2001) also provided guidance to the project. Subsequent to the earlier workshop and discussions by the Steering Committee, additional research became available, namely the Master's reports by Hyman (2002) and Munyagi (2006), as well as the report prepared by the KwaZulu Natal Roads Department (KZN, 2004?) on the experimental potholes that were filled, and the subsequent test results on cores performed by SRT Laboratory. An ASTM D6714-08 procedure for measuring workability was also considered.

The objective of this paper is to present the results of a laboratory study aimed at setting performance criteria for cold-lay surfacing products for patching and pothole repair, and to describe the rationale for selecting the test parameters. One of the materials selected was tested more widely to evaluate the implications of alternative test conditions, and this is presented first. Thereafter the results on all seven different materials are presented. Finally the results are compared with the KZN field test panels, and acceptance limits proposed.

2. LABORATORY STUDY

In the evaluation a distinction must be made between early performance and long-term performance. Early performance is the ability to place the material and its ability to provide stability and rut resistance at compacted density, which essentially depends on the stone skeleton. Long-term performance is related to the stability and rut resistance of the patch after traffic compaction, reduction of voids, and sometimes bleeding which provides lubrication signifying an over-saturated mix. Additionally binder aging will play a part. In terms of long-term performance it is invariably found that if the patch lasts a year it will last five years. In the KZN study after 9 months several mixes had deteriorated significantly, and the primary criteria evaluated were patch integrity and settlement.

To evaluate the early compaction characteristics, the specimens were compacted at ambient temperature as done by Munyagi (2006); this, since patching of pothole using cold-mix asphalt usually is done at ambient temperature in the field. Compaction temperatures in the laboratory typically range from 19^{O}C to 23^{O}C. This procedure was difficult to apply, as the temperature could not be controlled and the mix was rather stiff to handle. Consequently, the material was placed in the oven at 30^{O}C for 2 hours before the samples were compacted. The specimens were then left in the moulds to cure for 3 days in the oven at 30^{O}C. Workability was not tested specifically, but the ability of the mix to achieve the early performance criteria reflect workability.

To reflect the long term densification in the laboratory the procedure was as used by Hyman (2002). The sample was conditioned in an oven at 135^{O}C for 24 hours, and compacted at the temperature of 135^{O}C.

The executed test regime was as follows:
<u>Early age</u>
1. Compaction, and volumetric properties using the modified Marshall test, and the HMA guideline windows. The maximum theoretical relative density of the materials was determined using the Rice's method, so as to be able to calculate the voids content.
2. Rut resistance using the Hamburg Wheel Tracking Test (HWTT) or MMLS, at early age density.
3. Permeability tests.
4. Moisture sensitivity, by considering the retained indirect tensile strength.
5. Potential shelf life, by performing above tests on bag aged material at the shelf life recommended by the manufacturer, or six months, whichever is the earlier.

<u>Ultimate condition at late age</u>
1. Compaction, and volumetric properties using the modified Marshall test, and the HMA guideline windows. The same bulk density determined for early age was used.
2. Rut resistance using the Hamburg Wheel Tracking Test or MMLS, at terminal density.
3. Permeability tests

The laboratory study was aimed at setting performance requirements for the parameters shown in Table 1.

The materials that were selected included good performing as well as poorer performing mixes. The experience from the KZN experiment was valuable in this regard. Furthermore, Munyagi (2006) showed that the type of binder also has an influence on performance, consequently materials were selected with both cutback and bitumen emulsion as binders. The materials used are listed in Table 2, together with reference to previous studies. Four 25 or 30 kg bags of material were used, two for the early and two for the shelf life tests.

Table 1: Performance parameters and test methods for patching materials

Parameter	Proposed test method
Compaction and volumetric properties (early strength, late strength and shelf life)	Modified Marshall test, and the gyratory compaction procedure
Rut resistance (early strength, late strength and shelf life)	Hamburg wheel tracking test (HWTT)
Permeability test (early strength, late strength and shelf life)	Constant head permeameter
Moisture resistance (early strength)	Tensile strength ratio

Table 2: Listing of materials evaluated.

Sample number	Binder type	Previously used codes
11145	Cutback	KZN C
11146	Cutback	
11147	Cutback	KZN D,
11148	Cutback	Hyman
11149	Bitumen emulsion	Munyagi D
11150	Bitumen emulsion	Munyagi E
11151	Cutback	KZN J, Munyagi B

3. EVALUATION OF TESTING PROTOCOL ON MATERIAL 11148

Details of the laboratory study are available in Visser et al (2010). Material 11148 was selected for the evaluation of the protocol as this material was supplied first, and there was enough material for additional tests. The key activity is the compaction with the Marshall equipment, as this reflects the anticipated density obtained in the field. The modified Marshall test gives the change in height of the briquette, and this has to be converted to voids content by using the Rice's maximum theoretical density (MTD). For material 11148 the MTD was 2 744 (range of 3 replicates 2 743 to 2 746) kg/m^3.

After compaction the bulk specific gravity of the Marshall compacted briquettes was determined with the Corelok apparatus, as well as with the traditional TMH1 Method C3. Since the briquettes were relatively open the TMH1 method underestimates the voids.

Briquettes compacted at 30°C had an average bulk density of 2 413 (range 2 389 to 2 447) kg/m^3 when measured with the Corelok, whereas with the TMH1 method the average was 2 463 kg/m^3. In terms of voids content this was an average of 12.1% for the Corelok measurements and 10.2% for the TMH1 method. The Marshall compaction was also performed at 135°C to obtain an indication of the expected long-term density. The briquettes had an average bulk density of 2 558 (range 2 439 to 2 475) kg/m^3 when measured with the Corelok, whereas with the TMH1 method the average was 2 593. In terms of voids content this was an average of 6.8% for the Corelok measurements and 5.5% for the TMH1 method. The Corelok results were accepted as being the actual voids content, because the TMH1 procedure allows water to penetrate interconnected voids, which will lead to erroneous density results.

The same material was also compacted using the SUPERPAVE gyratory compactor at 30°C. The average bulk density of two samples was 2 470 (range 2 467 to 2 473) kg/m^3 when measured with Corelok, and 2 510 kg/m^3 according to TMH1. The respective voids content were 10% and 8.5%. Note that the gyratory compaction curves are approximate as it is an internal volumetric determination. At a temperature of 135°C the densities were 2 493 (range 2 477 to 2 510) kg/m^3 when measured with Corelok, and 2 533 kg/m^3 when measured according to TMH1. The respective voids content were 9.1% and 7.7%. A concern was that the gyratory compacted samples were not achieving the densities found with the Marshall compaction.

Consequently further compaction tests were conducted by varying the length of time the loose material was left in the oven for conditioning at 135°C. In stead of the 24 hours period, the material was left for 3 hours and 6 hours. The Corelok determined average bulk density of two tests was 2 447 kg/m^3 after 3 hours conditioning, and 2 498 kg/m^3 after 6 hours conditioning. It was evident that after 3 hours the material was not homogeneously hot, as the density was significantly lower than even at 30°C. However, the one sample achieved a density of 2 486 kg/m^3, whereas the other lowered the average. After 6 hours the density was similar to that achieved after 24 hours. It was concluded that the difference in density between the Marshall test and the gyratory compactor was due to inherent differences between the devices.

The densification curves shown in Figures 1, 2 and 3 illustrate that the compaction curves asymptote, which suggests that there is a refusal density with sufficient voids and that the mixes will not bleed. The voids content after 150 blows corresponds to the laboratory determined voids content, and this illustrates that measurement of the height is consistent with the other laboratory tests.

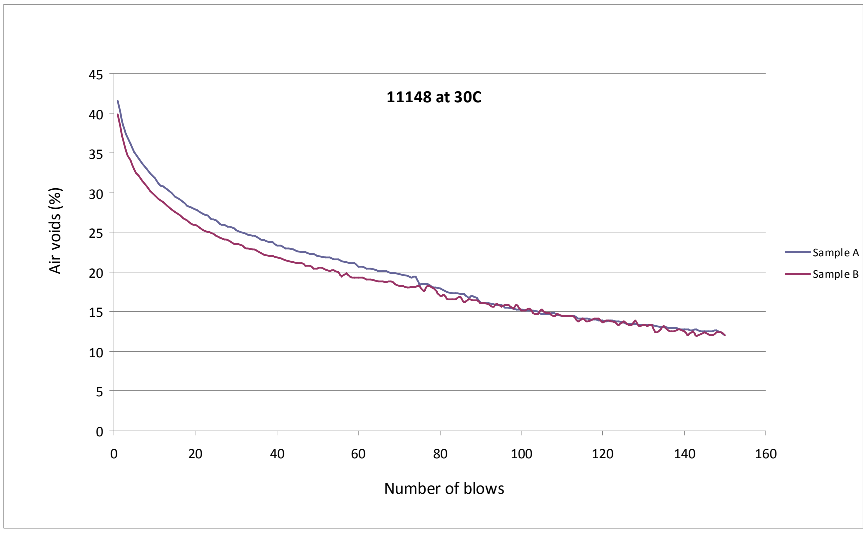

Figure 1: Marshall compaction for material 11148 at 30^{O}C.

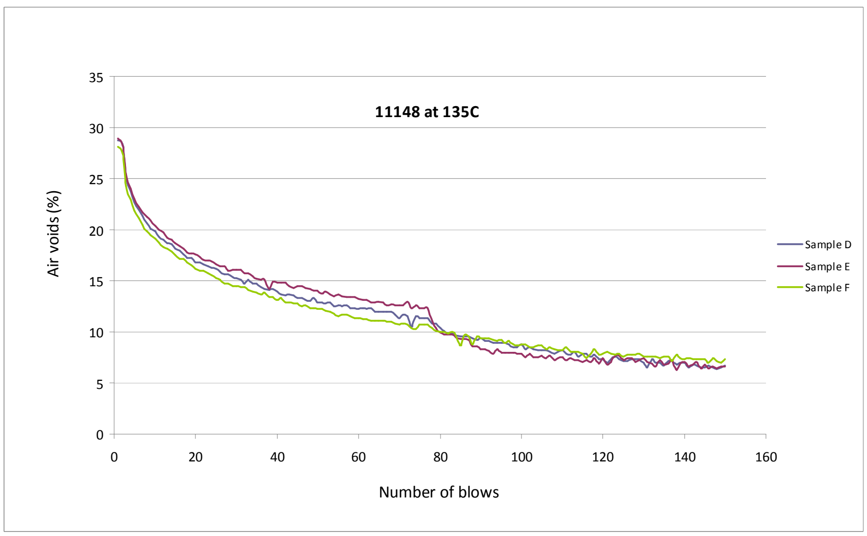

Figure 2: Marshall compaction for material 11148 at 135^{O}C.

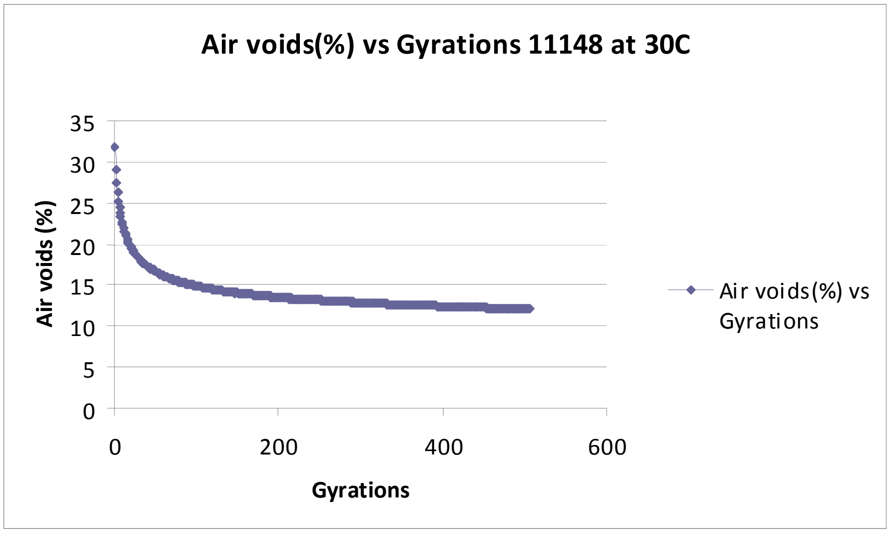

Figure 3: Air voids vs gyrations for material 11148 at 30^{O}C.

The next step in the evaluation process was to evaluate the rutting potential with the Hamburg Wheel Tracking Test (HWTT). Typically the rutting test is conducted at 50^{O}C, but this was considered to be too harsh. Initially the rutting test was conducted at 30^{O}C, and the results are shown in Figure 4. Rutting after 10 000 repetitions was about 11 mm.

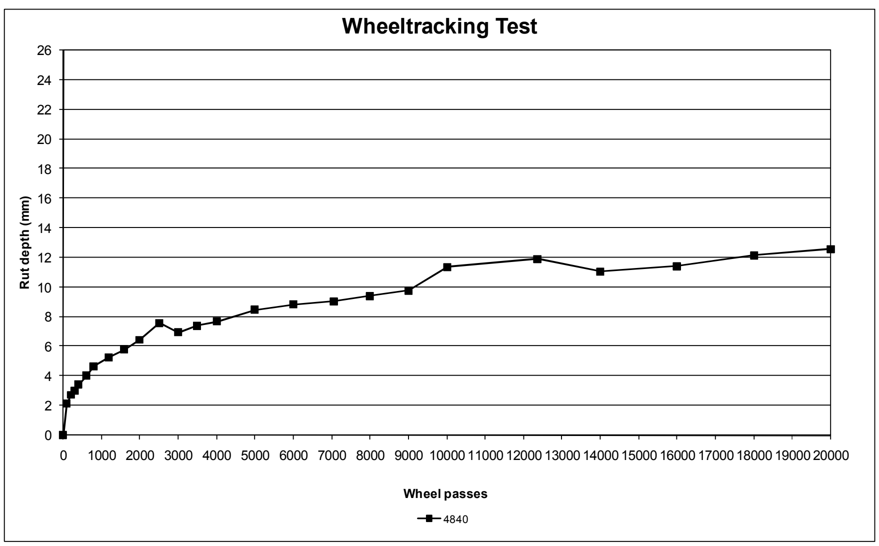

Figure 4: Rutting for material 11148 at compacted and tested at 30^{O}C.

The material compacted at 135^{O}C was tested at 50^{O}C, and is shown in Figure 5. The rut depth after 10 000 passes was about 2 mm. This demonstrated that the material compacted at 135^{O}C could be tested at 50^{O}C without disintegrating.

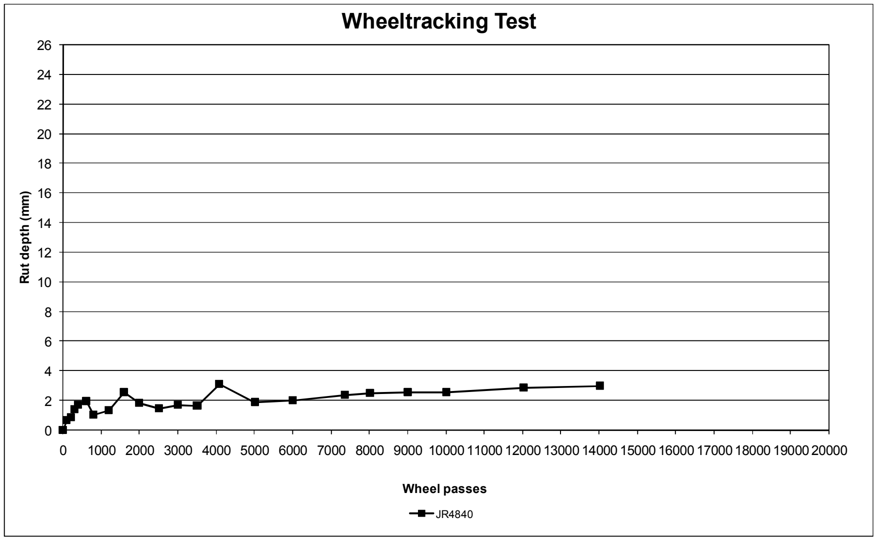

Figure 5: Rutting for material 11148 at compacted at 135^{O}C and tested 50^{O}C.

Material compacted at 30^{O}C was also tested at 50^{O}C, but the material did not have sufficient rutting resistance at this temperature, and disintegrated after 1 000 passes. It was thus concluded that the protocol is realistic in evaluating early rutting potential. It was decided to set the standard HWTT test temperature to 30^{O}C for specimens compacted at 30^{O}C.

A further test that was performed was the permeability, determined with a constant head permeameter. The head of water was kept constant at 1.02m. The results are shown in Table 3 for compaction at 30^{O}C and at 135^{O}C. It is interesting to note that the voids content does not correlate with permeability, as the latter depends to the extent of interconnected voids. As would be expected, the permeability is relatively high for compaction at 30^{O}C, as for hotmix asphalt a limiting permeability of 500 l/sqm/hour is used. However, when compacted at 135^{O}C the permeability is relatively low, as discussed later.

Table 3: Permeability results on samples of material 11148.

Sample designation	Voids content (%) at 30^{O}C	Permeability (l/sqm/hour)
a	10.8	363
b	12.3	768
c	12.9	473
d	12.8	503
e	11.0	Not tested
f	12.4	242
Sample designation	Voids content (%) at 135^{O}C	Permeability (l/sqm/hour)
A	7.0	20
B	5.5	<10
C	7.2	19

The modified Lottman test was planned to determine the moisture sensitivity of the mix. The retained tensile strength ratio is an indication of moisture susceptibility. Unfortunately the briquettes for material 11148 were destroyed before the test could be conducted. Since the samples were prepared on fresh mix, this part of the protocol could not be repeated. This test was, however, conducted on the other samples as discussed below.

4. COMPARISON OF RESULTS FOR ALL THE MATERIALS EVALUATED

4.1 Fresh mixes

A view of all the Marshall briquettes compacted at 135 ^{O}C is shown in Figure 6. The variation in voids is clearly visible.

Figure 6: Marshall briquettes compacted at 135 ^{O}C for all the materials.

The target air void content for the gyratory compaction (for HWTT samples) was obtained from the results of the Marshall compaction to the standard compaction effort of 75 blows each side at 30 ^{O}C. The required air voids content was achieved by setting the required height of the specimen to reach the desired volumetric density. In some cases the gyratory compaction was performed to an abnormally high number of gyrations to get to the desired density. Under normal circumstances 100 to 200 gyrations suffices to achieve Marshall type compaction density.

The cold mix samples compacted with the Marshall test at 135 ^{O}C, shown in Table 4, was hypothesized to represent the long-term densification. These results were compared with the hot-mix guidelines (Taute et al 2001), which is granted to be a different material, but nevertheless gives an indication. Samples 11145 and 11146 show that for light traffic they would fulfill requirements, but for medium and higher traffic the voids content is too low, and the material would bleed and also be unstable. From the voids content it is not possible to determine other performance characteristics such as rutting resistance or ravelling, which will be considered in the other tests of the protocol.

Table 4: Marshall voids on the different materials compacted at 135 ^{O}C for various traffic applications.

Material number	Light 75+15 blows	Medium 75+45 blows	Heavy 75+75 blows	V Heavy 75+75 blows
11145	3.5	3.1	2.7	2.7
11146	3.1	1.9	1.4	1.4
11147	10.6	8.8	7.6	7.6
11148	9.4	7.8	7.1	7.1
11149	18.9	17.9	17.3	17.3
11150	11.7	10.1	9.3	9.3
11151	Information inadvertently overwritten in test equipment			

The Hamburg rutting results are shown in Figure 7 and it shows that a number of materials are prone to rutting when compacted at 30 ^{O}C, despite the relaxed testing regime applied to cold mix materials. The number of repetitions to a 20 mm rut will be compared with the field performance for those materials that are available in the discussion section. Samples compacted at 135 ^{O}C and tested at 30 ^{O}C showed minimal rutting, with a maximum rut of 4 mm after 20 000 repetitions. The test thus does not have the ability to discriminate.

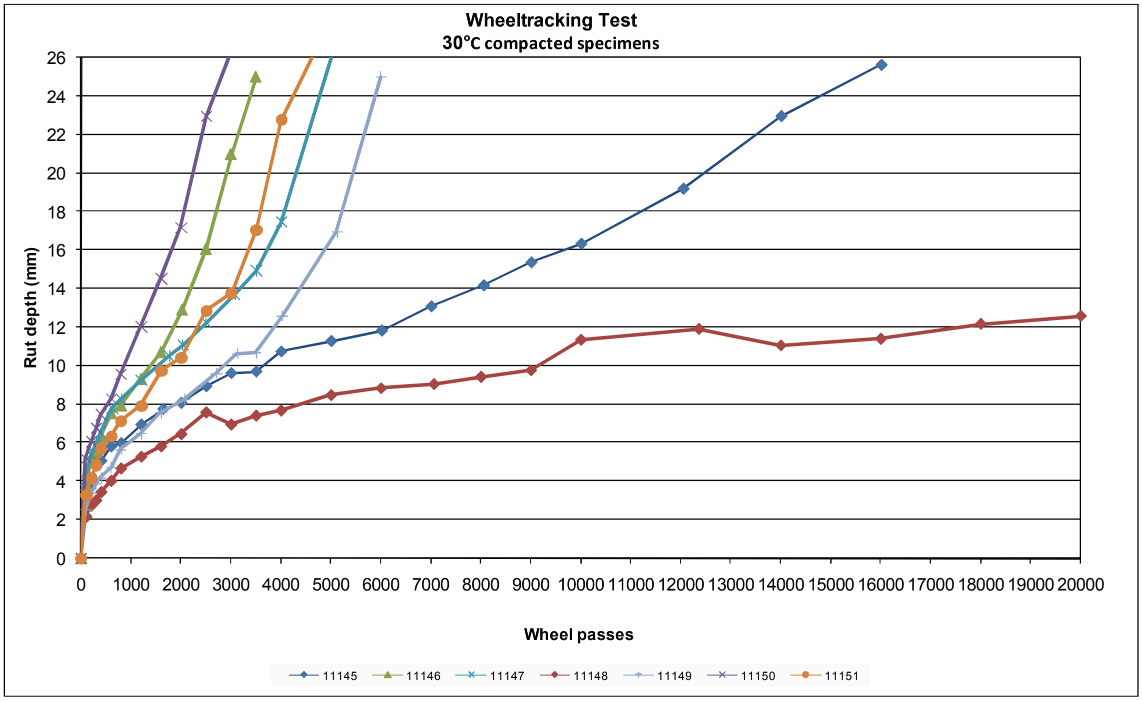

Figure 7: Rutting for all materials compacted and tested at 30^{O}C.

The permeability results for samples compacted at 30 ^{O}C and 135 ^{O}C are shown in Table 5, whereas the Modified Lottman results, conducted on samples compacted at 30 ^{O}C are shown in Table 6. These results are discussed in the discussion section.

Table 5: Permeability results on the different materials.

Material number	Voids content (%) at 30^{O}C	Permeability (l/sqm/hour)
11145	9.4 to 15.2	354 to 899
11146	4.7 to 9.2	296 to 494
11147	13.8 to 16.8	764 to 1119
11148	10.8 to 12.9	242 to 768
11149	22.0 to 26.0	797 to 1604
11150	17.0 to 21.8	1492 to 2141
11151	15.2 to 17.3	1100 to 1461
Material number	Voids content (%) at 135^{O}C	Permeability (l/sqm/hour)
11145	1.6 to 3.9	<10
11146	1.1 to 1.7	<10 to 327
11147	7.0 to 8.1	<10 to 71
11148	5.5 to 7.2	<10 to 20
11149	16.7 to 18.4	1422 to 1543
11150	8.8 to 9.7	<10 to 1295
11151	9.9 to 11.0	151 to 592

Table 6: Indirect Tensile Strength results

Material number	Unconditioned ITS (kPa)	Conditioned ITS (kPa)	Modified Lottman ratio
11145	232; 108	43; 41	0.25
11146	197, 217	68; disintegrated	0.33
11147	112; 123	63; 62	0.53
11148	No test performed	No test performed	
11149	64; 64	47; disintegrated	0.73
11150	Samples disintegrated in water bath, or while standing in lab		
11151	259; 247	137; 165	0.60

4.2 Shelf life tests on 6 month old mixes

During Marshall compaction of the six month aged specimen an interesting phenomenon was found. When the samples with bitumen emulsion as binder were left in the mould to cure for 3 days in the oven the samples appeared to expand in the mould and delaminate, as shown in Figure 8.

Figure 8: Expansion of shelf life sample after Marshall compaction and conditioning at 30^{O}C.

A comparison of the voids content of the shelf life samples with the fresh mix samples showed that only sample 11150 had a shelf life voids content similar to that of the fresh mix.

The Hamburg wheel tracking results on the shelf life samples showed that the rut development was more rapid than on the fresh mix samples because of the less dense mixes (higher voids content). A comparison of the permeability of the fresh mix compacted Marshall briquettes and the shelf life briquettes is shown in Table 7. As expected, because of the higher voids, the shelf life briquettes have a higher permeability. The materials that were problematic during compaction disintegrated and no test could be conducted.

Table 7: Permeability of fresh and shelf life samples compacted at 30 ^{O}C.

Material number	Permeability fresh mix (l/sqm/hour)	Permeability shelf life mix (l/sqm/hour)
11145	354 to 899	869 to 1529
11146	296 to 494	657 to 1389
11147	764 to 1119	1227 to 1368
11148	242 to 768	1690 to 1757
11149	797 to 1604	Sample disintegrated
11150	1492 to 2141	Sample disintegrated
11151	1100 to 1461	Sample disintegrated

5. DISCUSSION OF RESULTS

The results will be discussed next in terms of potential acceptability criteria.

Volumetric properties: Materials compacted at 30 ^{O}C showed high voids content, and high permeability. It is appreciated that when newly placed the materials do not have the ability to prevent the ingress of moisture, but over time, as demonstrated by the reduced voids content and lower permeability the materials are able to seal the road. Normally a prime is applied prior to placing the cold mix, and this will assist in protecting the underlying material. Instability and the implications of high voids content will be identified in the rutting test.

The compaction at 135 ^{O}C, hypothesized to reflect the long-term performance, showed that the voids content is significantly reduced, and materials 11145 and 11146 had a voids content that would bleed under traffic greater than light, as defined in the HMA interim design guidelines. The compaction test at 135 ^{O}C and the resultant voids content is therefore a realistic evaluation. As would be expected the permeability is much lower than when compacted at 30 ^{O}C. Permeability in the long-term should be low, and comparable to that of hotmix asphalt. It is suggested that an optional requirement when compacted at 135^{O}C is that the permeability should be less than 500 litres/sq m/hour. This criterion was provisionally selected based on the spread of the cold mix samples evaluated, as well as results of hot mix materials.

This laboratory study has also highlighted an aspect that is explicitly used in hot-mix asphalt design, namely that traffic is considered in the design. It is recommended that cold mix materials be supplied and certified for a particular traffic category, namely light, medium and heavy, which incorporates areas of slow moving traffic. Different coloured bags could be used to distinguish the materials.

Rutting resistance: Stability after placing is evaluated by the rutting test. For materials compacted and tested at 30 ^{O}C, it is proposed that a material should be able to sustain at least 5000 repetitions before reaching a 20 mm rut in the Hamburg test. If it is assumed that the materials used in this laboratory evaluation are the same as evaluated in the KZN study (even after 5 years), and that field settlement should be less than 10 mm, then materials 11145 and 11147 should fail and material 11151 should pass. This outcome is opposite to what was found in the laboratory study, and means that the materials are likely not to be the same as was tested in KZN. The field voids content available for materials 11147 and 11151 were lower than found in the laboratory study, and for material 11145 it was higher. Materials compacted at 135 ^{O}C were far more rutting resistant, as they were also tested at 30^{O}C, and the test was not sufficiently discriminatory.

From the Hamburg rutting test it is not possible to predict how much rutting would take place in the field, as the rut depth measured was a combination of deformation and stripping. This is reflected on the graphs by the steep increase in rut development.

Moisture sensitivity: The Modified Lottman test compares the indirect tensile strength (ITS) before and after moisture conditioning. In the literature concern was expressed about the comparison, as the ITS values are invariably low. All results were less than 300 kPa, which is much less than the 1000 kPa considered in hot-mix design. The absolute ITS is therefore of little value. This test procedure had an unexpected spin-off, as a number of samples disintegrated when placed in water. The inability of a mix to resist moisture, particularly when freshly placed (note that the samples were conditioned in an oven and were at least one month old), should be a performance requirement.

Shelf life: Invariably materials that are stored in bags are considered to be protected from the elements and the material would not deteriorate. The tests that were conducted showed that this is not correct, and significant changes take place in the material properties even when sealed in a bag. Although the intention was to carry out the test programme on freshly made mixes, the intervention of the Christmas break resulted in samples being tested about 2 months after manufacture. These tests are considered as the fresh mix. The results after 2 months gave the above results, and if a mix meets the criteria, then it can be accepted that a shelf life of 2 months is acceptable. The high voids content, rapid rut formation and high permeability after 6 months aging show that none of the mixes are suitable at this age. It is recommended that all cold mix materials should have a production date and a use-by date clearly indicated on the bag.

Acceptability of materials: Table 8 shows a summary and the extent to which the materials fulfil the proposed requirements. A tick mark (√) shows compliance, a cross (X) non-compliance, and partial compliance (√x). Although material 11148 was not evaluated by the Modified Lottman test, the samples did not disintegrate when placed in water. It may be accepted that this material as well as material 11149 fulfil requirements. The other materials failed on at least one aspect. The type of binder is not related to performance criteria, and therefore it cannot be used as a criterion. Invariably the cutback binders were more moisture resistant. Inability to resist rutting and low voids content are mix design properties, and the mixes could be adjusted to fulfil these requirements.

Table 8: Compliance with suggested acceptance criteria.

Material number	Binder type	Long-term voids	Rutting resistance	Resistance to moisture	Optional permeability
11145	Cutback	X	√	√	√
11146	Cutback	X	X	√x	√
11147	Cutback	√	X	√	√
11148	Cutback	√	√	No test	√
11149	Emulsion	√	√	√x	X
11150	Emulsion	√	X	X	√x
11151	Cutback	√	X	√	√

6. CONCLUSIONS AND RECOMMENDATIONS

The objective of this paper was to give the background and laboratory procedures that were used to develop acceptance limits for cold mix materials. The critical acceptance limits are:

- Moisture stability of briquettes compacted in the Marshall test at 30 ^{O}C.
- Voids content of samples compacted at 135 ^{O}C to reflect the long-term voids and to ensure that the mix does not close up and deform or remains too permeable. The hot mix guidelines related to traffic category serve as guideline for the lower limit.
- Rutting resistance of Gyratory compacted samples at 30 ^{O}C as measured in the Hamburg tester at 30 ^{O}C should be at least 5000 repetitions before a rut depth of 20 mm is achieved.
- A provisional optional requirement for permeability of 500 litres/sq m/hour on Marshall briquettes compacted at 30 ^{O}C is included.

A total of 7 mixes was evaluated, and two of the mixes complied with the requirements. The mixes that did not comply with the requirements failed on one or more of the criteria. For example, if the early age voids content is high this results in an unstable mix that readily ruts. When a mix has low early age voids content, and thus rut stability, the long-term voids are low.

The recommended testing protocol is based on the results of this laboratory investigation.

a. The material must be tested within one month of manufacture and bagging (this is critical as overstretched laboratories may not appreciate the time influence on the test results).
b. A manufacturer should provide about 50 kg of bagged material, indicating for which traffic level it is suitable.
c. The tests that need to be conducted are:
   - Marshall compaction at 30 ^{O}C to determine the moisture stability and the Indirect Tensile Strength ratio. Samples that disintegrate do not fulfil requirements.
   - Optionally the permeability of Marshall briquettes compacted at 30 ^{O}C can be determined. Provisionally a permeability of less than 500 litres/sq m/hour is used.
   - Compaction of mixes at 135 ^{O}C to determine the long-term voids content. Tests to be conducted either with the modified Marshall test that provides a continuous record of compaction, or else with a Gyratory compactor. Voids content requirements as given in Table 6 for different traffic categories.
   - Rutting resistance with the Hamburg rut tester should be at least 5000 repetitions to achieve a rut of 20 mm. Samples are compacted at 30 ^{O}C in the Gyratory compactor, and tested at 30 ^{O}C in the Hamburg test.
d. Shelf life: At the maximum shelf life of the product to be indicated by the applicant, the product shall still meet the requirements listed above.

These results only relate to the laboratory test protocol. Aggregates used must have an ACV of maximum 21 and a polished stone value of at least 50. Materials will also have to undergo a field validation trial over a period of at least 2 years.

The results were implemented in the form of an Agrément SA guideline for the assessment and certification of cold-lay materials (Visser and Denneman 2010). Several proprietary cold-mix products are currently undergoing technical evaluation to for the purpose of obtaining Agrément SA certification.

ACKNOWLEDGEMENTS

Permission by Agrément SA to disseminate the background research is gratefully acknowledged. Guidance by the Industry Steering Committee is also appreciated.

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