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Executive summary

This document reports on an investigation into laboratory testing of pothole repair materials, with the aim of establishing a test that can be used to discriminate between products of differing quality. For this purpose two pieces of equipment were trialled, a so-called 'Dynamic Compression' test and an Immersion Wheel tracking apparatus. Also, three proprietary cold-lay pothole repair materials were selected together with a 160/220 pen hot-mix reference material. Specimens were made comprising a 40/60 pen asphalt concrete lower layer, overlaid with another similar layer half of which was then broken away to simulate a pothole and to generate a vertical joint. Simulated potholes were then filled with the different repair materials and subjected to testing.

The first phase of testing established that the Dynamic Compression test, while it caused distress to the repair materials, did not allow any quantifiable measure of deterioration; it was therefore discarded. The Immersion Wheel Tracking test was used with trafficking directions both along and across the joint between the original asphalt concrete and the repair. However it was clear that trafficking along the joint, while it encouraged material separation at the joint itself, failed to provide a reliable measure of distress; trafficking across the joint was therefore selected as the most suitable test mode.

A test programme was then devised that explored the effects of repair thickness, compaction level, joint preparation, spray coats and whether the pothole was clean and dry or dirty and wet. The principal conclusions were:

1. The test is suited to discriminating between pothole repair materials in terms of deformation (only).
2. This discrimination was clearest with a 40mm deep repair.
3. Compaction level had surprisingly little effect on performance for all materials tested.
4. All materials performed just as well under wet/dirty repair conditions as under dry/clean conditions.

These initial findings would require in-situ validation before any conclusions could be made about the suitability of the test method or the relative performance of the different repair products that were trialled.
1. Introduction

1.1. Background
This project stemmed from Highways England’s desire to be able to supply its service providers with up to date advice regarding pothole repair techniques and products. Current outcome-based highway maintenance contracts have increased the focus on this subject and there is a perception that not all of the products currently in use on the motorway and trunk road network are suited to heavily trafficked situations. Since the University had been involved with pothole-related research already, including joint research with Nottingham Trent University sponsored by the Institution of Civil Engineers (Rahman and Thom, 2012), they were able to propose two potentially applicable tests, a so-called ‘Dynamic Compression’ test and the ‘Immersion Wheel Tracking’ test. These tests utilised ready-to-use pieces of laboratory equipment, since equipment development was not included in this commission.

1.2. Task objectives
The objectives were set out in Section 2 of the Specification as follows:

> “...investigate a test method or methods that will measure the factors and/or combinations of factors that lead to differing rates of deterioration pothole repairs [sic]. The test method will need to simulate realistic insitu conditions and be able to discriminate between proprietary cold repair products”.

2. Test Programme Development

2.1. Repair products
Three cold-lay products and one hot-mix asphalt were investigated. The three cold-lay products were selected as representing the range of products currently in use on Highways England’s network. In this report they will be designated Material A, B and C. The following are brief descriptions of each:

- **Material A** is a 0/6mm asphaltic mixture using a blended binder including polymer and chemical additives which is designed to fill individual potholes. A designated proprietary bonding coat is specified to be used to prepare the sides and base of the pothole (after they have been cleaned of loose material).
- **Material B** is also a 0/6mm asphalt mixture containing chemical additives. It is claimed that it is suited to a wide range of repairs, not only potholes, and no bonding coat is specified, only that the area should be free from loose material.
- **Material C** is a 0/6mm mixture, also using bitumen with chemical additives, which is intended for use for potholes and other repairs. An optional proprietary bonding coat is supplied to be used where bond is otherwise likely to be suspect. In this study, the bonding coat was used in cases representing ‘good workmanship’ (see Section 2.2.5).

All three cold-lay materials are designed to be suitable for hand-lay and can be compacted by vibrating roller or mechanical rammer.

The hot-mix asphalt repair material was manufactured at the University of Nottingham laboratories and comprised a 10mm asphalt concrete (AC) to BS EN 13108-01 (2008), incorporating 160/220 penetration grade binder.

Proprietary repair products are generally available in 0/6mm and 0/10mm variants. The 0/6mm options were selected, after consultation with the respective manufacturers¹, as they were deemed to be the most suitable for pothole repairs under Highways England network conditions. The hot-mix asphalt repair instead utilised a 10mm nominal aggregate size. This is consistent with industry best practice and the guidance provided in IAN 157 (2011).

¹ Only two out of the three manufacturers responded.
2.2. Test variables
In order to progress from a starting point where the most appropriate test method was unclear to a point
where real recommendations could be made, the following variables were explored.

2.2.1. Test methods
The Immersion Wheel Tracker is an existing piece of equipment, primarily used to investigate surface rutting
under wet conditions. Trafficking is applied through a solid rubber tyred wheel to a prepared 305mm by
305mm test slab confined in an aluminium mould, which is immersed in 25°C water to a depth of
approximately 20mm. It was considered that this equipment would both prove the rut-resistance of a material
and also allow the effect of water at an interface between a repair and an existing surface to be explored. It
was therefore selected for use on this project.

It was agreed that an alternative test, designated here as the ‘Dynamic Compression’ test, would also be
triailled. This is a test that applies a repeated vertical load onto the central 150mm by 150mm area of a
305mm by 305mm test slab confined in an aluminium mould through a ribbed rubber pad which is intended
to simulate a vehicle tyre. The test is also carried out in a submerged condition. This test, it was hoped,
would prove the resistance of a material to break-up under relatively high frequency repeated load at
relatively low temperature (10°C); it was based on previous testing carried out at the University of
Nottingham (Rahman and Thom, 2012).

Both tests are detailed in Appendix A.

2.2.2. Pothole depth
Since potholes typically extend through the depth of the surface course layer, and since surface courses on
Highways England roads are typically 25-40mm in thickness, two depths of repair have been investigated,
namely 25mm and 40mm.

2.2.3. Pothole area
Potholes are variously defined by different organisations. However, the emphasis of this investigation was on
repairs of small extent, i.e. less than 1m² on the road, usually much less. Thus the tests applied have
included repairs of 0.3m by 0.15m in area.

2.2.4. Prepared in wet/dry
The proprietary materials investigated in this project are intended for use in both wet and dry conditions, the
only stipulation being that there is no actual standing water. Nevertheless, it is important to obtain data on
any difference in effectiveness according to whether the substrate is wet or dry. Hence both conditions have
been investigated in this project. Wet conditions have been simulated by spreading a consistently measured
quantity of water across the area to be repaired, accompanied by a measured quantity of rock dust (i.e.
filler). The presence of rock dust is intended to replicate the dirt associated with uncleaned, wet potholes.

2.2.5. Good/bad workmanship
Each of the products is associated with installation guidelines, which include effective compaction and, in
some cases, use of a bonding coat and advice that the sides of the pothole should be squared off by saw-
cutting. To investigate the sensitivity of repair performance to workmanship, two cases have been simulated,
namely:

• un-sawn faces, no bonding coat and poor compaction;
• sawn faces, bonding coat (where specified) and good compaction.

Compaction was always carried out by the same operative in order to maximise repeatability between
specimens.

2.2.6. Surface joint
Experience with actual repairs suggests that it is often the edge of the repair – or sometimes the edge of the
adjacent original surface material – that fails first. Thus it was considered essential to simulate a joint
between original construction and repair material in the specimens produced for this project, and to test
across it. This was carried out in both test methods. In all cases, the joint was located in the centre of the
slab and ran across its full width.
2.3. Slab production

Test slabs were produced in the asphalt laboratory at the University of Nottingham, compacted into 305mm by 305mm moulds using a roller compactor. 22 slabs were produced in total. A full description of the slab preparation procedures used is given in Appendix B. Figure 2-1 is a section through a generic slab.

![Cross-section through slab](image)

2.4. Initial testing

The initial phase of work consisted of testing three specimens in each of three ways. The three specimens comprised 25mm deep pothole repairs using Materials A, B and C, each carried out under wet conditions, omitting bonding coats, with rough un-sawn edges and with poor compaction. The three test arrangements were: Dynamic Compression; Immersion Wheel Tracking with the wheel moving along the joint; and Immersion Wheel Tracking with the wheel across the joint. The intention was to prove the different test arrangements under the most unfavourable repair conditions. The rationale was that if the test methods were unable to generate realistic deterioration effects under the worst-case conditions there was no merit in exploring them further.

2.4.1. Dynamic Compression tests

It was anticipated, based on previous University of Nottingham student projects, that it might be possible to use this test to quantify the degree of material break-up caused by water pressure effects under dynamic load. Unfortunately however this did not prove feasible. Material A developed cracking at the edge of the loaded area together with some separation at the joint; Material B separated slightly at the joint; while Material C deformed significantly and then fragmented once removed from the mould. Thus, although the test was able to provide qualitative information on susceptibility to material break-up, it was not found possible to formulate a meaningful quantitative evaluation. Photographs of the tested slabs are shown in Appendix C.1.

2.4.2. Immersion Wheel Tracking tests

Trafficking along the joint was trialled in order to check whether the Immersion Wheel Tracking test was able to cause measurable localised deterioration at the joint. However it was found that the dominant form of deterioration was always deformation of the repair, which then transferred the wheel load onto the edge of the existing material. Thus, although one of the joints did show some signs of opening (see Appendix C.2) this was not due to material break-up but was a consequence of deformation. Furthermore the magnitude of deformation was very sensitive to the exact location of the joint relative to the wheel, which was not precisely controlled where the edge was not sawn. A greater contribution from the original asphalt led to a reduced rut depth.

Since deformation was clearly dominant in this test, it was decided that a test across the joint would probably be more useful since that would give a clear measure of the deformability of a repair relative to the original asphalt and it might also show up any additional defects appearing at the joint. Figure 2-2 compares the profile of the central 100mm (the length over which measurements are recorded) along the wheel track at the end of tests trafficked both along and across the joint.
Figure 2-2  Wheel track profile, initial Immersion Wheel Tracking tests

Of those tests across the joint, Materials A and C clearly show much greater deformation at negative offset, i.e. on the repair material. The third, Material B, proved a more deformation resistant material and showed relatively slight variation in deformation for both testing orientations. However, the tests along the joint for Materials A and C both gave variable deformations, which were clearly linked to the exact relative positions of the joint and the centre of the wheel track. This effect is visible in some of the photographs in Appendix C.3.

2.5. Agreed programme

Following discussion of the initial findings with Highways England, it was agreed to confine the remainder of the test programme to Immersion Wheel Tracking tests trafficked across the joint in order to explore the effects of repair thickness, wet/dry substrate, un-sawn/sawn joints, use of bonding coat, and level of compaction.

Table 2-1 shows the permutations that were trialled for the 16 specimens, which remained for the main test programme, using the notation system described below.

Example: C25 un-sawn/wet/poor


‘25’, ‘40’ refer to the depth of the repair in mm;

‘un-sawn’, ‘sawn’ refers to the preparation at the edge of the repair;

‘wet’, ‘dry’ refers to whether water and rock dust have been spread over the substrate or not;

‘poor’, ‘good’ refers to the standard of workmanship. No bond coating and poor compaction or addition of bond coating (where specified) and good compaction.
### Table 2-1 Agreed Test Programme

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Repair Material</th>
<th>Depth (mm)</th>
<th>Preparation Joint</th>
<th>Conditions</th>
<th>Workmanship</th>
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<tbody>
<tr>
<td>A25 un-sawn/wet/poor</td>
<td>A 25 Un-sawn</td>
<td>Wet</td>
<td>Poor</td>
<td>No spray coat + poor compaction</td>
<td></td>
</tr>
<tr>
<td>A25 sawn/dry/good</td>
<td>B 25 Sawn</td>
<td>Dry</td>
<td>Good</td>
<td>Spray coat + good compaction</td>
<td></td>
</tr>
<tr>
<td>A25 sawn/wet/good</td>
<td></td>
<td>Wet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A40 sawn/wet/good</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B25 un-sawn/wet/poor</td>
<td>B 25 Un-sawn</td>
<td>Wet</td>
<td>Poor</td>
<td>Poor compaction. No spray coat required.</td>
<td></td>
</tr>
<tr>
<td>B25 sawn/dry/good</td>
<td></td>
<td>Dry</td>
<td>Good</td>
<td>Good compaction. No spray coat required.</td>
<td></td>
</tr>
<tr>
<td>B25 sawn/wet/good</td>
<td></td>
<td>Wet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B40 sawn/wet/good</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C25 un-sawn/wet/poor</td>
<td>C 25 Un-sawn</td>
<td>Wet</td>
<td>Poor</td>
<td>No spray coat + poor compaction</td>
<td></td>
</tr>
<tr>
<td>C25 sawn/dry/good</td>
<td></td>
<td>Dry</td>
<td>Good</td>
<td>Spray coat + good compaction</td>
<td></td>
</tr>
<tr>
<td>C25 sawn/wet/good</td>
<td></td>
<td>Wet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C40 sawn/wet/good</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H25 un-sawn/wet/poor</td>
<td>Hot-mix 25 Un-sawn</td>
<td>Wet</td>
<td>Poor</td>
<td>No tack coat + poor compaction</td>
<td></td>
</tr>
<tr>
<td>H25 sawn/dry/good</td>
<td></td>
<td>Dry</td>
<td>Good</td>
<td>Tack coat + good compaction</td>
<td></td>
</tr>
<tr>
<td>H25 sawn/wet/good</td>
<td></td>
<td>Wet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H40 sawn/wet/good</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
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### 3. Results

This section of the report will include all Immersion Wheel Tracking tests trafficked across the joint including those from the initial testing phase. The results are shown as: deformation profiles over the central 100mm (Figures 3-1 to 3-4); average deformation over the first 50mm of repair material (Figures 3-5 to 3-8); maximum deformation over the first 50mm of repair material (Figures 3-9 to 3-12).
Figure 3-1  Wheel track profile, tests on Material A

Figure 3-2  Wheel track profile, tests on Material B
Figure 3-3  Wheel track profile, tests on Material C

Figure 3-4  Wheel track profile, tests on Hot-mix asphalt repair
Figure 3-5  Average deformation, tests on Material A

Figure 3-6  Average deformation, tests on Material B
Figure 3-7  Average deformation, tests on Material C

Figure 3-8  Average deformation, tests on Hot-mix asphalt repair
Figure 3-9  Maximum deformation, tests on Material A

Figure 3-10  Maximum deformation, tests on Material B
Photographs of all specimens after testing and removal from the mould are given in Appendix C.
4. Discussion

The first and most obvious point to make from the results obtained is that two materials performed very well (Material B and the Hot-mix asphalt) and two materials performed relatively poorly (Materials A and C). In terms of deformation resistance this test is therefore able to discriminate clearly between materials. In fact Material B can be considered as being at least equivalent to Hot-mix asphalt in this regard, both materials deforming only slightly more than the original 14mm 40/60 pen AC surface course. Furthermore, two clear differences can be detected between Materials A and C:

- Material C deformed very rapidly over the first 2000 cycles but then stabilised while the deformation of Material A was more gradual but continued to increase throughout the tests.
- The photographs in Appendix C show the specimens after they had been extracted from the mould at the end of the test. Material A maintained its overall integrity whereas Material C tended to disintegrate.

Turning to the effect of the other variables, both Materials A and C show much greater deformation with a greater depth of material whereas this is not the case for Material B or the Hot-mix asphalt. This implies that both Materials A and C sheared to significant depth under the applied load, and suggests that the test with a 40mm deep layer is a more discriminating measure of performance.

The most unexpected result is that poor compaction appears to have had no detrimental effect on deformation performance at all. Yet ‘poor’ compaction certainly resulted in lower densities. Although no actual measurement of density was made, the mass of material used for each repair was recorded. Naturally there was variation in the volume of the repairs due to small differences in location of the joint and also thickness of the upper asphalt layer; nevertheless, a greater mass of material was always used where ‘good’ compaction was applied (and where repair thickness was the same – i.e. 25mm), on average 26% more. This represents a very considerable difference in achieved density and would normally be expected to correlate to a large difference in deformation. Three possible reasons are seen for this apparent anomaly:

1. Deformation may be almost entirely in the form of shear rather than densification, something which is apparent from some of the photographs in Appendix C, and that the shear strength of these cold-lay materials may be almost independent of density.
2. In the agreed test programme (Table 2-1) poor compaction was always combined with an un-sawn joint between the repair and the original material, and this may have helped to ensure a bond between the two materials.
3. In the agreed test programme (Table 2-1) poor compaction was always combined with an absence of a bonding coat, and it is possible that this bonding coat on the vertical joint face in the well compacted samples acted as a slip layer and adversely affected the deformation resistance.

It is considered probable however that the first reason is more likely since the effect of good bond at the joint would only be expected to be local and Material B had no bonding coat in either case. In one sense this is a positive finding since under-compaction may not mean unduly poor performance, and also because control of compaction in the preparation of test specimens may not be as critical as might have been expected.

The final variable tested was the condition of the pothole prior to filling, either wet with added rock dust or clean and dry. Surprisingly, the deformation of specimens with a clean and dry condition was always slightly more than that of specimens with a wet and dirty condition. However, the difference was never large. The conclusion is that the material manufacturers’ advice, that the hole should be free from standing water but that wetness is not a problem, is found to be justified. Since cold-lay asphalts already include water within the binder, this finding is not a surprise.

It should be noted that the data presented is restricted to the central 100mm of the wheel track and it may be seen in the photographs that the absolute maximum rut often occurred outside this zone and was considerably larger than the readings measured by the apparatus. Table 4-1 lists approximate absolute maximum deformations measured after removal of the specimen from the test mould. However these should only be seen as approximate whereas the LVDT reading may be taken as accurate.
Table 4-1  Absolute Maximum Deformations

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Maximum deformation measured during test (mm)</th>
<th>Absolute maximum deformation measured after test (mm)</th>
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<tbody>
<tr>
<td>A25 un-sawn/wet/poor</td>
<td>11.9</td>
<td>15</td>
</tr>
<tr>
<td>A25 sawn/dry/good</td>
<td>12.9</td>
<td>16</td>
</tr>
<tr>
<td>A25 sawn/wet/good</td>
<td>10.3</td>
<td>16</td>
</tr>
<tr>
<td>A40 sawn/wet/good</td>
<td>18.9</td>
<td>20</td>
</tr>
<tr>
<td>B25 un-sawn/wet/poor</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>B25 sawn/dry/good</td>
<td>2.6</td>
<td>2</td>
</tr>
<tr>
<td>B25 sawn/wet/good</td>
<td>1.6</td>
<td>3</td>
</tr>
<tr>
<td>B40 sawn/wet/good</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>C25 un-sawn/wet/poor</td>
<td>8.9</td>
<td>Specimen collapsed</td>
</tr>
<tr>
<td>C25 sawn/dry/good</td>
<td>10.9</td>
<td>14.5</td>
</tr>
<tr>
<td>C25 sawn/wet/good</td>
<td>9.9</td>
<td>13</td>
</tr>
<tr>
<td>C40 sawn/wet/good</td>
<td>19.0 (LVDT limit reached)</td>
<td>21</td>
</tr>
<tr>
<td>H25 un-sawn/wet/poor</td>
<td>1.2</td>
<td>2.5</td>
</tr>
<tr>
<td>H25 sawn/dry/good</td>
<td>1.7</td>
<td>1</td>
</tr>
<tr>
<td>H25 sawn/wet/good</td>
<td>1.0</td>
<td>2</td>
</tr>
<tr>
<td>H40 sawn/wet/good</td>
<td>1.8</td>
<td>2</td>
</tr>
</tbody>
</table>

Some changes in ranking of the specimens can be detected compared to the measurements over the central 100mm, but no major anomalies. Thus, while it is always desirable to have a fuller data set, the current restricted measurement zone is not seen as a bar to use of this equipment.

The test is clearly able to determine deformation susceptibility reasonably well and the confined conditions simulated are not unlike those of a pothole. However, it cannot be considered as a complete test of a repair material. It was originally hoped that information on ravelling and deterioration at joints might be obtained and this was not the case. Therefore, while the test may prove useful in discriminating between materials in terms of permanent deformation resistance, it should only be seen as one indicator of a material product’s suitability.

It is acknowledged that this was a scoping study and the test programme was limited to a small number of test specimens. The repeatability of the pothole production and repair preparation, whilst considered, could not be proven within the confines of this Task. Neither could the reproducibility of the test results.

5. Conclusions and Recommendations

Following the initial phase of the scoping study, the ‘dynamic compression’ test was rejected as unsuitable for discrimination between repair materials in its current state of development. It was able to produce a degree of material degradation, but this was not readily measurable.

Similarly use of the immersion wheel tracking test with the wheel trafficking along the joint between original asphalt and repair material was also rejected. This test produced some opening of the joint – although this was again hard to quantify – but the deformation was clearly very sensitive to the exact relationship between the wheel path centre line and the joint.

Thus the immersion wheel tracking test with trafficking direction perpendicular to the joint was taken forward and the following findings were made:

1. The test is suited to discriminating between pothole repair materials in terms of deformation (only).
2. This discrimination was clearest with a 40mm deep repair.
3. Compaction level had surprisingly little effect on performance for all materials tested.
4. All materials performed just as well under wet/dirty repair conditions as under dry/clean conditions.

Based on these findings it is suggested that this test may potentially be suitable as part of a specification or set of guidelines regarding pothole repair materials. However, permanent deformation is only one characteristic of pothole repair deterioration and it is considered that further research would be required to develop a test method that is capable of generating a range of in-situ distress mechanisms.
The findings from this Task would need to be validated with field data in order to confirm the trends that were observed in the laboratory. Issues such as repeatability and reproducibility would also have to be addressed in order to improve the confidence levels that could be assigned to the test method and any product guidelines or recommendations that emerged from its use.

One possible change that might be considered is to simply test a slab of repair material without any ‘original’ material element. This has the advantage that measurement over the central 100mm would include near-maximum values; it also has simplicity (and therefore cost) on its side. On the other hand it fails to test the difficulties in compaction that occur at repair edges.

6. References


CEN, Bituminous mixtures: Material specifications; Asphalt Concrete, BS EN 13108-01, 2006.

CEN, Bituminous mixtures: Test methods for hot mix asphalt; Specimen prepared by roller compactor, BS EN 12697-33, 2003.


Highways Agency, Thin surface course systems - installation and maintenance, IAN 157, 2011

7. Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AC</td>
<td>Asphalt Concrete</td>
</tr>
<tr>
<td>BBA</td>
<td>British Board of Agrément</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
<tr>
<td>CEN</td>
<td>Comité Européen de Normalisation</td>
</tr>
<tr>
<td>EN</td>
<td>European Norm</td>
</tr>
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<td>IAN</td>
<td>Interim Advice Note</td>
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</table>
Appendices
Appendix A. Laboratory apparatus

A.1. Dynamic Compression Test

This test made use of a Mand universal testing machine able to apply repeated vertical load. This machine is regularly calibrated. The 305mm x 305mm specimen (see Appendix B) was placed centrally beneath the loading ram and load was applied through a steel platen and a ribbed rubber layer intended to simulate a vehicle tyre. The specimen was flooded to a depth of approximately 5mm. Loading was carried out at 6Hz, the intention being to force water into the specimen in a similar manner to the way that a vehicle tyre might pressurize standing water on a road. Figure A-1 illustrates the test set-up.

![Dynamic Compression Test set-up](image)

Figure A-1 Dynamic Compression Test set-up

The test was carried out at 10°C, it being considered that pavement surface distress tends to occur most commonly at low temperature rather than high. The load level chosen was 20kN, giving an average contact stress of around 1200kPa. Although significantly higher than the average stress from a super-single heavy goods vehicle tyre – around 700kPa – it was intended to represent the peak stress beneath the most heavily loaded parts of the tyre.

A.2. Immersion Wheel Track Test

This equipment is described in BS EN 12697-22. The machine at the University of Nottingham was manufactured by Cooper Technology and is regularly calibrated. Either one or two specimens can be tested at a time. The load on the 50mm wide solid tyred wheel is 700N, causing a maximum contact stress of over 500kPa, depending on the compliance of the surface being tested. Testing is conducted at 60 passes per minute, which equates to a wheel speed of around 0.5m/sec (approx. 1 mph). For this study 10,000 wheel passes were applied (Procedure B in BS EN 12697-22). While this is not a large number of passes compared to normal trafficking levels, the narrowness of the load creates a very damaging stress state within the material and therefore, as proved by some of the results, a greatly accelerated deformation rate. The test may therefore represent reasonably long-term trafficking. Figure A-2 shows the test set-up.

![Immersion Wheel Track Test set-up](image)

Rut depth is measured by a built-in LVDT that measures the wheel carriage level relative to a fixed-level frame, recording over the central 100mm of the wheel track. Since the specimens in this study had a split surface with (in the main part of the study) a joint approximately along the centreline of the slab, this means that approximately 50mm of the measurement (12 individual readings) was on the original material and the other 50mm on the repair material.
In one case (C40 sawn/wet/good) the LVDT reached its limit at 19mm, although it is possible that this could have been extended had the initial setting of the LVDT been different. There is no physical limit on rut depth due to the mechanical set-up other than the base of the mould in which the specimen sits.

Figure A-2  Immersion Wheel Tracking Test set-up
Appendix B. Slab preparation

All test specimens were prepared in the Nottingham Transportation Engineering Centre laboratories at the University of Nottingham. Binder course and surface course layers were both prepared from 14mm asphalt concrete mixtures according to BS EN 13108-01 (2006). The aggregate used was granodiorite from Bardon Quarry in Leicestershire; the binder was 40/60 penetration grade at a content of 5.0%.

Mixing was carried out in laboratory-scale mixing units at 160°C and compaction was carried out at 150°C in 305mm by 305mm moulds in a roller compactor according to BS EN 12697-33 (2003). The target void content was 6%. An emulsion tack coat was applied between the binder course and surface course layers across just over half the slab area while a sheet of building paper was placed over the remainder.

After cooling the mould was removed. Where a sawn edge to the repair was required, a saw cut was made along the centre of the slab. The surface course above the building paper was then prised off and the specimen was re-placed into the mould. Care was taken to ensure that, even where no saw cut was made, the rough edge was within a few millimetres at most of the slab centre.

After some experimentation, it was determined that ‘wet’ conditions would be represented by 10g of water spread over the base and sides of the hole and that 5g of limestone rock fines should be added to provide a reasonably realistic simulation of ‘dirt’.

Where required, the next operation was to spray a proprietary bonding coat over the base and sides of the hole.

The volume of the void left by the removed surface course layer was then estimated. This allowed an appropriate weight of repair material to be placed into the void, again following initial experimentation. Compaction was applied, always by the same operative, via a vibrating hammer compactor. The same compaction time was used for each nominally ‘poorly compacted’ slab, and similarly for each nominally ‘well compacted’ slab. The weights of material used were as follows:

<table>
<thead>
<tr>
<th>Table B-1 Weights of Repair Materials</th>
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<tbody>
<tr>
<td>25mm deep</td>
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<tr>
<td>Poor compaction</td>
</tr>
<tr>
<td>Material A</td>
</tr>
<tr>
<td>Material B</td>
</tr>
<tr>
<td>Material C</td>
</tr>
<tr>
<td>Hot-mix repair</td>
</tr>
</tbody>
</table>
Appendix C. Photographs of tested slabs

C.1. Dynamic Compression tests

Plate C.1.1

A25 un-sawn/wet/poor
Dynamic Compression

Plate C.1.2

B25 un-sawn/wet/poor
Dynamic Compression
C.2. Immersion Wheel tracking – along the joint

Plate C.2.1

Plate C.2.2
Plate C.2.3

C25 un-sawn/wet/poor Immersion Wheel Track
C.3. Immersion Wheel Tracking tests – across the joint

Plate C.3.1

A25 un-sawn/wet/poor Immersion Wheel Track

Plate C.3.2

A25 sawn/dry/good Immersion Wheel Track
Plate C.3.5

B25 un-sawn/wet/poor Immersion Wheel Track

Plate C.3.6

B25 sawn/dry/good Immersion Wheel Track
Plate C.3.9

C25 un-sawn/wet/poor Immersion Wheel Track

Plate C.3.10

C25 sawn/dry/good Immersion Wheel Track
Plate C.3.11

C25 sawn/wet/good Immersion Wheel Track

Plate C.3.12

C40 sawn/wet/good Immersion Wheel Track
Plate C.3.13

H25 un-sawn/wet/poor Immersion Wheel Track

Plate C.3.14

H25 sawn/dry/good Immersion Wheel Track
Plate C.3.15

H25 sawn/wet/good Immersion Wheel Track

Plate C.3.16

H40 sawn/wet/good Immersion Wheel Track