Reducing congestion on the road network: Part 2, Use of temporary backfill

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Executive summary

Nationally, the cost of delays caused by utility and highway works, both in lost time and the additional vehicle operating costs involved is estimated to be £4.3Bn per year. In London it is estimated that congestion caused by such works costs the economy about £750M per year. The economic benefits to be gained from employing innovative methods that will reduce the impact of road works on traffic congestion could therefore be substantial.

In June 2011, TfL and the Department for Transport (DfT) jointly commissioned TRL to investigate the feasibility of increasing the use of three technologies that could be used to reduce road traffic congestion on the road network. These are:

1. The use of plating and bridging systems over trenches and large openings in the carriageway (access chambers) to allow the carriageway to be opened to trafficking during the works period;
2. The use of ‘fast to install and remove’ temporary backfill materials for trenches and access chambers to allow trafficking at certain times during the works; and
3. The use of ‘faster cure and set’ materials for permanent reinstatement of the carriageway to shorten the duration of roadworks by opening of the carriageway to traffic earlier after the completion of the works.

In addition to these three main technologies, other techniques for reducing the duration of roadworks and resulting congestion were considered, including the use of the advanced utility mapping techniques, ‘no dig’ technologies, the ‘core and vac’ method of maintaining utility plant, and the use of alternative materials for reinstatement.

This report is the second in a series of four reports describing the results of the research. It describes the findings of research into the use of temporary backfill, including the development of pilot-scale laboratory trials to demonstrate the performance of different materials. The trials involved the evaluation of the use of commonly available materials that are in regular use by utility company contractors to temporarily backfill a trench or access chamber. Three materials; namely Type 1, pea shingle and sharp sand, were trialled in various combinations, together with a thin asphalt surface course, with the aim of providing a temporary surface that will perform sufficiently well to keep the road open to traffic for at least 5 days.

The work was overseen and directed by a Steering Group and a Working Group whose membership included representatives of TfL, DfT, other local authorities, utility companies, the Health and Safety Executive, contractors and suppliers.

The main conclusions from the trials are that temporary backfill materials can successfully be used as temporary or ‘immediate’ reinstatements, and will provide a practicable option for re-opening a road to traffic. This would be most beneficial in peak hours, and where there can be a saving in lane rental charges. The key findings are as follows:
• Temporary backfill can be used to form immediate reinstatements to enable the road to be opened at certain times during the works.;
• Temporary backfill is likely to be most beneficial when it can left in place for several days at busy periods.
• The types of materials that are regularly used in reinstatements are the most appropriate. Suitable materials are granular Type 1, sharp sand and 10 mm pea shingle, each of which is readily available and can be sourced at short notice;
• Hot mixed asphalt surface courses will provide a stable surface following adequate compaction. They perform much better than cold lay material, which is prone to secondary compaction (deformation) under trafficking;
• Temporary backfill provides a versatile technique that can readily accommodate variations in the width of excavations (unlike road plates);
• It is suitable for all road classes, as there is no need for speed restrictions as long as there is a minimum settlement;
• In most cases, small volumes of material would be required, and the time to place and remove the temporary backfill would be relatively quick; and
• The sub-surface apparatus is protected by the backfill, and the threat of vandalism or theft of sub-surface equipment or road plates is minimised.
• Using temporary backfill on the TLRN would encourage greater use both in London and elsewhere in the UK.

Typical delay cost savings that could be gained from using temporary backfill are estimated to be approximately £80,000 per day for a S2AP road with a flow of 20,000 vehicles AADT, and £30,000 per day for a D2AP road with a flow of 45,000 vehicles AADT. The savings to be gained will vary with traffic flow and working shift patterns, and individual assessments should therefore be undertaken for each works case.

A series of Advisory Notes known as ‘QWIRC Notes’ (Quick Win Innovation to Reduce Congestion) have been produced for the study, and the use of Temporary Backfill is included within these.
## Glossary

<table>
<thead>
<tr>
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<th>Description</th>
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<tr>
<td>AADT</td>
<td>Average annual daily traffic</td>
</tr>
<tr>
<td>AC</td>
<td>Asphalt concrete</td>
</tr>
<tr>
<td>CBR</td>
<td>California Bearing Ratio</td>
</tr>
<tr>
<td>D2AP</td>
<td>Dual 2 lane All Purpose road</td>
</tr>
<tr>
<td>DCP</td>
<td>Dynamic Cone Penetrometer</td>
</tr>
<tr>
<td>HAUC</td>
<td>Highway Authorities and Utilities Committee</td>
</tr>
<tr>
<td>LWD</td>
<td>Light Weight Drop tester</td>
</tr>
<tr>
<td>msa</td>
<td>Million Standard Axles</td>
</tr>
<tr>
<td>QWIRC</td>
<td>Quick Win Innovation to Reduce Congestion</td>
</tr>
<tr>
<td>PTF</td>
<td>Pavement Test Facility</td>
</tr>
<tr>
<td>S2AP</td>
<td>Single 2 lane All Purpose road</td>
</tr>
<tr>
<td>SMF</td>
<td>Stabilised Material for Fill</td>
</tr>
<tr>
<td>SROH</td>
<td>Specification for Reinstatement of Openings in the Highway</td>
</tr>
<tr>
<td>TLRN</td>
<td>Transport for London Road Network</td>
</tr>
<tr>
<td>WebTAG</td>
<td>(DfT) Website for Transport Analysis Guidance</td>
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1 Introduction

1.1 Project background

Nationally, the cost of delays caused by utility and highway works, both in lost time and the additional vehicle operating costs involved is estimated to be £4.3Bn per year (DfT, 2004). In London it is estimated that congestion caused by such works costs the economy about £750M per year. The benefits to be gained from employing innovative methods that reduce the impact of road works on traffic congestion could therefore be substantial.

In June 2012, the Mayor of London and Transport for London (TfL) introduced a lane rental scheme where roadwork contractors could be charged up to £2,500 per day to occupy the carriageway at key points on the road network in London. It is believed that this could eventually deliver a 40% reduction in disruption from roadworks on the Transport for London Road Network (TLRN) (TfL, 2011).

In advance of the scheme TfL and the Department for Transport (DfT) jointly commissioned TRL to investigate the feasibility of increasing the use of three technologies that could be used to reduce traffic congestion at roadworks on the road network, and to provide evidence to utility companies and highway maintenance contractors that such technologies will work. These three technologies are:

1. The use of plating and bridging systems over trenches and large openings in the carriageway (access chambers) to allow the carriageway to be opened to trafficking during the works period;
2. The use of ‘fast to install and remove’ temporary backfill materials for trenches and access chambers to allow trafficking at certain times during the works; and
3. The use of ‘faster cure and set’ materials for permanent reinstatement of the carriageway to shorten the duration of roadworks by opening of the carriageway to traffic earlier after the completion of the works.

In addition, other technologies and techniques for reducing the duration of roadworks and resulting congestion were considered, including the use of the advanced utility mapping techniques, ‘no dig’ technologies, the ‘core and vac’ method of maintaining utility plant, and the use of alternative materials for reinstatement.

The overall study comprised the following main activities:

- a literature review of available products and their capabilities;
- consultation with manufacturers, suppliers and users of technologies to determine operational requirements and the impact on works;
- site monitoring to assess the performance of existing products in the field;
- laboratory testing to assess and document the performance of new products that offer potential benefits for use at access chambers and trenches; and
- site trials to validate the performance of innovative methods in the field.
This report is the second in a series of four detailed reports describing the research that has been carried out and its findings. The four reports are:

- Part 1, Use of Road Plates;
- Part 2, Use of Temporary Backfill;
- Part 3, Early Strength Gain (Rapid-Cure) Concrete for Reinstatements; and
- Part 4, Other Technologies.

The work was overseen and directed by a Steering Group and a Working Group whose membership included representatives of TfL, DfT, other local authorities, utility companies, contractors, and suppliers. The list of the many stakeholders that contributed to the project is given in the Acknowledgements section.
2 The use of temporary backfill materials

Temporary backfill is known to have been used to provide a temporary running surface so as to open up a carriageway to traffic and to reduce congestion, particularly when there is a gap in the works programme and/or it is not possible to use road plates. The temporary backfill is removed to enable works to be resumed at a later date, and a permanent reinstatement completed.

2.1 Existing use of temporary backfill

No examples of the use of temporary backfill were found in the literature review or internet searches. However, a questionnaire used in consultation with manufacturers, suppliers and users confirmed that some highway authorities and contractors, but few utilities, make use of temporary backfill. This section appraises possible forms of temporary backfill and how they are, and could be, used. Types of temporary backfill could include:

- Loose, bulk material
- Bagged material
- Block elements
- Pneumatic elements.

In most cases, it is thought that temporary backfill would need to be overlaid with either asphalt or a plate to provide a suitable running surface that does not deform excessively under wheel loading.

In general, temporary backfill will only be used if it is cost effective. There are two aspects to this; user delay costs which can be considerable during peak periods, and the extra works cost to the contractor, taking into account any potential lane rental charges. One advantage with temporary backfill is that it does not necessarily require special materials (such as with road plates or rapid curing materials), and it can be used with the plant that is normally available on site. However, due to the time required to place and remove the material, temporary backfill is likely to be practical only for small excavations or for excavations that would be left filled for several days.

The respondents to the industry questionnaire only use temporary backfill in relatively small volumes and not for long sections of trench. Excavations during kerbing works or those for the installation of gulley pots, manholes etc. may also be candidates for temporary backfill. It tends to be in place for around 3 to 5 days and not for very short time periods. Most contractors have used it over a weekend when no work was to be done, and in most cases small volumes of material have been required, when the time to place and remove the temporary backfill would be relatively short. If suitably compacted, the temporary backfill would be able to withstand the wheel loading of a works vehicle without the need for an asphalt layer.

The working ‘window’ available for using temporary backfill needs, therefore, to be carefully considered. For example, if the daytime off-peak period was only 5 hours long, and it takes an hour each time the temporary backfill is placed and removed, the remaining daytime working time window would be only 3 hours. As it is unlikely that
more than one or two cubic metres of temporary backfill could be removed within one hour, temporary backfill would be most feasible for relatively small trenches or when it can be left in place for a relatively long time. Examples of longer term usage include:

- when there are delays in progressing emergency or planned works;
- after the permanent backfill has been placed and there is a delay in completing the reinstatement;
- on weekdays when only weekend working is allowable;
- on weekends when there will be no works; and
- for special events.

**Case Studies**

In autumn 2012, a water utility company Water considered the possibility of using temporary backfill for works to install two 600mm diameter flow meters in Lane 2 northbound of the A41 Hendon Way. A work zone comprising a 50 m length of Lanes 1 and 2 has been requested for the works (using conventional methods), but this would leave only Lane 3 open to traffic for the planned works duration of 20 days. TfL had requested that at least two lanes be kept open at peak hours and had asked Thames Water to consider the potential of using road plates or temporary backfill to achieve this aim.

The original intention by the utility company was to make one excavation of approximate 2m width and 3m length to enable the installation of both flow meters. The depth of the excavation was to be approximately 3m. To maintain two traffic lanes in the peak periods, it was proposed that the flow meters be spaced further apart so that two smaller excavations could be made. Road plates were considered, but no suitable sized plates were available and their installation and removal was considered by them to be difficult at the site. It was suggested that temporary backfill would be a preferable solution, with the works being carried out at weekends and the excavations backfilled to enable trafficking of all three lanes during the week. As a result, there would be considerable reductions in delays to traffic during peak and off-peak periods during the week.

Another example, demonstrated that temporary backfill could also be used for non-trafficked areas of works, where an adjacent carriageway lane would need to be closed for working or safety purposes. During part of the works at Henlys Corner on the A406 North Circular, drainage was to be placed in the central reserve, and TfL required the adjacent lane to be open at peak times. This would, however, leave an open trench in the central reserve, close to the live traffic lane. To overcome this, the trench was backfilled with temporary backfill comprising fully compacted Type 1 material. It was considered unnecessary to cover the trench with a plate or to provide an asphalt surfacing because it would need to carry few, if any, wheel loads. The use of the temporary backfill enabled more traffic lanes to be open during the peak and substantially reduced delays to traffic. These works are still to take place.
2.2 Main factors for constructing temporary backfill

From the initial consultation and site visits, it was concluded that temporary backfill is best suited for use in immediate1 reinstatements, where works need to be ceased for a short period and the materials used are to be replaced within 10 working days.

The main factors to be considered when constructing temporary backfill are as follows:

- trench volume, depth and shoring
- availability of materials
- placement, compaction and bearing capacity
- effect on apparatus
- removal
- asphalt specification and layer thickness.

2.2.1 Trench volume, depth and shoring

Temporary backfill should only be considered where the volume of excavations will enable installation, compaction and removal in a time period that will make the re-trafficking of the carriageway beneficial to traffic flow without severely hampering overall works duration or incurring substantial additional costs. The need to remove or modify trench shoring and bracing will also need to be considered. It is thought therefore that it would need to be possible to place and compact the backfill within 2 hours, and remove it in the same time.

2.2.2 Availability of materials

Because immediate reinstatements tend to be made at short notice, the temporary backfill materials to be used must be readily available, which is often the case with the three materials identified by the respondents to the questionnaire (Type 1 material, sand and single sized aggregate). Similar types of material such as recycled SMF Type S material (WRAP, 2007), commonly used pipe bedding and surround materials, or some as-dug materials may also be suitable. It may be possible to use a mixture of different materials. However, mixing would limit the potential to use the same materials for other applications when removed. Furthermore, the emphasis should be on the quick use of individual materials that perform satisfactorily rather than needing to consider different mixtures.

2.2.3 Placement, compaction and bearing capacity

Temporary backfill materials must be both load bearing to prevent rutting and breakup of the asphalt overlay and also capable of limiting the load applied to the apparatus within the trench and the edges of the trench. Temporary backfill can be placed and compacted in the same way as permanent backfill. Ideally, temporary backfill should require little compaction. However, sufficient compaction would be required to achieve sufficient bearing capacity. Section 1.7.1 of the SROH requires materials to be properly compacted in 100mm layers. Type 1 material (which must be compacted) may be 1According to the Specification for the Reinstatement of Openings in Highways (SROH) (HAUC, 2010 ), an immediate reinstatement may be completed using excavated or other materials, properly compacted in 100mm layers, with a minimum surfacing thickness of 40mm of bituminous material and shall normally be replaced within 10 working days.
required for deep excavations. Damp sand or gravel that is lightly compacted may be suitable for shallow excavations or if placed above permanent backfill in place of the bound layers (e.g. before the placement of the bound layers).

Settlement requiring remedial action can occur if temporary backfill is in place for a long period. However, this is unlikely to form a hazard to traffic in the same way as, for example, a displaced road plate. It is likely that any complaints from road users concerning temporary backfill will relate to ride quality.

2.2.4 Effect on apparatus
With some types of temporary backfill, including bagged materials, it is possible that the apparatus would be subject to higher loading than with an interim\(^1\) (planned break in the works of up to 6 months) or permanent reinstatement. For example, this would be the case if traffic load dispersal is reduced by the temporary backfill material used. However, sub-surface apparatus is normally protected with a bedding and/or surround of loose materials, although some utility companies and highway authorities use bridging or block elements above and around apparatus. It is thought that damage to apparatus when using temporary backfill materials is very unlikely.

2.2.5 Removal
Temporary backfill can be removed by excavator in the same way as when a trench is excavated. Vacuum extraction could be employed although the additional costs of the hire of plant available needs to be considered. Respondents to the industry questionnaire said that temporary backfill is nearly always removed by excavator and none had used vacuum extraction. Such material is normally then stored off site but is sometimes stored on site or adjacent to the site for further use.

2.2.6 Asphalt specification and layer thickness
Section 1.7.1 of the SROH (HAUC, 2010) requires a minimum surfacing thickness of 40mm of bituminous material for an immediate reinstatement. The definitions section of the SROH suggests that cold-lay material is normally used.

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\(^1\)In the SROH (HAUC, 2010) an interim reinstatement is defined as “the orderly placement and proper compaction of reinstatement layers to finished surface level, including any temporary materials”, and should be replaced within 6 months.
3 Temporary backfill trials- Phase 1

In order to investigate the performance of temporary backfill materials for immediate/temporary reinstatements, trials were conducted in TRL’s Pavement Test Facility (PTF) in two phases. The first phase trials were aimed at testing the performance of a thick layer of granular Type 1 material conforming to current specifications with sharp sand used as a bedding/surround material and with both coldlay and hot mix asphalt surfacings. The second phase trials were carried out with a reduced thickness of granular Type 1 material, and with sharp sand and pea shingle used as a bedding/surround material to identify the suitability of materials that could be installed and compacted more quickly.

Both phases included the construction and testing of two trenches excavated to 2m x 2m in width and 1.5m deep. The trials were designed to determine the performance and suitability of temporary backfill materials under accelerated and controlled traffic loading at slow speed (approximately 15km/h).

In order to ensure that the backfill material was subject to a level of trafficking that would be typical for most primary road works sites, it was assumed that temporary backfill would be in place for a period of 5 days. This would be the case if works were carried out at weekends and temporary backfill was used to enable trafficking on weekdays.

This section describes the construction of the trials, the layer properties of the reinstatements and the findings from the trials. Guidance on the use of temporary backfill follows the description of the second phase of trials. A series of Advisory Notes known as ‘QWIRC Notes’ (Quick Win Innovation to Reduce Congestion) have been produced for the study, and the use of Temporary Backfill is included within these.

3.1 Pavement materials and layer thicknesses

The pavement materials and layer thicknesses used for the reinstatements in the trials were selected on the basis of existing industry guidance and general practices reported by utility works contractors.

The trenches in the Phase 1 trial were identified as Trenches P1T1 and P1T2. Two types of asphalt surface course were used; cold lay asphalt in one trench (P1T1) and hot mixed asphalt in the other (P1T2). Both surface materials were Asphaltic Concrete (AC) 6mm dense surfacing 100/150 conforming to BS EN 13108-1 (CEN, 2006). The target surface course thickness was 50mm, which is slightly higher than the minimum thickness of 40mm specified for an immediate reinstatement in the SROH.

A granular Type 1 material conforming to the Specification for Highway Works (SHW) (HA et al., 2010) series 800 Clause 803 (classified in the SROH as Class A–Graded granular mixtures) was used as the backfill/subbase/base layer material. Sharp sand was used as a bedding/surround material in Trench P1T1. To produce a variable construction, no bedding/surround material was used in Trench P1T2. The target pavement layer thicknesses and the materials selected for the Phase 1 trials are given in Table 3.1.
Table 3.1 – Target pavement layer thicknesses in Phase 1

<table>
<thead>
<tr>
<th>Layer</th>
<th>Trench P1T1 Thickness (mm)</th>
<th>Material used for construction</th>
<th>Trench P1T2 Thickness (mm)</th>
<th>Material used for construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface course</td>
<td>50</td>
<td>Cold lay asphalt – AC 6mm dense surfacing 100/150</td>
<td>50</td>
<td>Hot mixed asphalt – AC 6mm dense surfacing 100/150</td>
</tr>
<tr>
<td>Base/Subbase</td>
<td>1300</td>
<td>Granular Type 1</td>
<td>1450</td>
<td>Granular Type 1</td>
</tr>
<tr>
<td>Bedding</td>
<td>150</td>
<td>Sharp sand</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Subgrade</td>
<td>-</td>
<td>Clay (3-4% CBR)</td>
<td>-</td>
<td>Clay (3-4% CBR)</td>
</tr>
</tbody>
</table>

Using the thicknesses in Table 3.1, a multi-layered elastic analysis of the pavement was undertaken using the BISAR\(^3\) computer program to estimate the strain in the asphalt layer ($\varepsilon_t$) and the pavement deflection ($\delta$ in micron). The estimated strain was then used to predict the life of the pavement in standard axles (sa). A Poisson’s ratio of 0.35 was used for the asphalt surface course and 0.45 was used for the granular Type 1 material, sand and subgrade. The predicted lives of the pavements in standard axles (sa) are presented in Table 3.2.

Table 3.2 – BISAR analysis output for Phase 1

<table>
<thead>
<tr>
<th>Trench</th>
<th>Asphalt surface course</th>
<th>Fatigue criteria</th>
<th>Deflection $\delta$ ((\mu)m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Thickness (mm)</td>
<td>Stiffness MPa</td>
</tr>
<tr>
<td>P1T1</td>
<td>Cold lay</td>
<td>50</td>
<td>2500</td>
</tr>
<tr>
<td>P1T2</td>
<td>Hot mixed</td>
<td>50</td>
<td>2500</td>
</tr>
</tbody>
</table>

3.2 Traffic to be carried by immediate reinstatements

Roads are categorised in the SROH in accordance with the expected traffic to be carried over 20 years. The limiting capacity of each road type is shown in Table 3.3 where the average numbers of standard axles expected over a period of 5 days are also shown.

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\(^3\) BISAR (Bituminous Structures Analysis in Roads) was developed by the Shell Oil Company to estimate stresses, strains and displacements in asphalt pavement structures. It assumes that the pavement structure is infinite in the horizontal plane.
Table 3.3 – Road categories from the SROH

<table>
<thead>
<tr>
<th>Road Category</th>
<th>Traffic capacity (msa)</th>
<th>Average traffic in 5 days (sa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 0</td>
<td>&gt;30 to 125</td>
<td>&gt;20,548 to 85,616</td>
</tr>
<tr>
<td>Type 1</td>
<td>&gt;10 to 30</td>
<td>&gt;6,849 to 20,548</td>
</tr>
<tr>
<td>Type 2</td>
<td>&gt;2.5 to 10</td>
<td>&gt;1,712 to 6,849</td>
</tr>
<tr>
<td>Type 3</td>
<td>&gt;0.5 to 2.5</td>
<td>&gt;342 to 1,712</td>
</tr>
<tr>
<td>Type 4</td>
<td>up to 0.5</td>
<td>To 342</td>
</tr>
</tbody>
</table>

Heavily trafficked roads are likely to have more than two lanes in each direction and the number of HGVs in the most heavily trafficked lane is, therefore, likely to be less than the total in each direction. Furthermore, there are few excavations, especially by utility companies, on Type 0 roads (the most heavily trafficked). Therefore, most immediate reinstatements should experience fewer standard axles over a period of 5 days than the traffic indicated for a Type 0 road and hence fewer than the predicted lives of the trial designs given in Table 3.2.

3.3 Preparation of trenches

The existing pavement in the PTF consisted of 300mm of asphalt and 600mm of granular Type 1 base/subbase over a 4% CBR clay subgrade. The trial areas were marked and saw cut to the required dimension. The asphalt layers were removed along with any granular base/subbase layers and part of the existing subgrade up to a depth of 1.5m. Figure 3.1 shows various stages during the excavation of the trenches. Reasonable attempts were made to make the side walls of the trenches vertical and no undercutting was observed as seen from Figure 3.1. No trench shoring was required.

An existing trench in between Trenches P1T1 and P1T2 was also prepared for the surfacing to provide additional performance data. A 100mm thick cold lay asphalt surface course was laid in Trench P1T3 over an existing Type 1 granular layer.
3.4 Pavement construction

3.4.1 General
The pavement construction was carried out by an experienced team from Ferns Surfacing Limited. The various stages involved in the construction are described in the following sections.

3.4.2 Pipe bedding/initial backfill
The sharp sand used to replicate pipe bedding/surround material in Trench P1T1 was laid in a single layer to a compacted thickness of approximately 150mm. A BOMAG vibratory jumping jack compactor model BT60/4 was used for compaction. Figure 3.2 shows the sand being compacted in Trench P1T1. No bedding/surround material was used in Trench P1T2.

3.4.3 Backfill/Base
The intention was to lay granular Type 1 material in layers of compacted thickness approximately 100mm to achieve a total thickness of 1300mm and 1450mm in Trenches P1T1 and P1T2 respectively. Compaction was again achieved using a BOMAG vibratory jumping jack compactor model BT60/4. The thicknesses were measured after each layer was compacted to monitor the construction. The total number of compacted...
layers of granular Type 1 material was 10 and 13 in Trenches P1T1 and P1T2, respectively, to achieve an overall thickness of 1290mm and 1442mm. Figure 3.3 shows the construction of the Type 1 layer in progress.

3.4.4 Asphalt surface course

Trenches P1T1 and P1T2 were surfaced with cold lay and hot mixed AC 6mm dense asphalt surface course, respectively. The surface course was laid in a single layer and compacted using a Terex 1-71 single drum vibrating roller to achieve adequate compaction (Figure 3.4). The asphalt surface course thicknesses were approximately 60mm, which was slightly thicker than the target of 50mm but this thicker surface level was considered acceptable for the trial. In actual practice, there is no upper tolerance for the structural layer thickness in the SROH.

The existing granular Type 1 material in Trench P1T3 was compacted and surfaced with 100mm of cold lay AC 6mm dense asphalt surface course.
The thicknesses of the final pavement layers, based on the measurements taken during the course of construction, are presented in Table 3.4.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Trench P1T1</th>
<th>Trench P1T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average thickness (mm)</td>
<td>Material type</td>
</tr>
<tr>
<td>Surface course</td>
<td>60</td>
<td>Cold lay asphalt - AC 6mm dense surfacing 100/150</td>
</tr>
<tr>
<td>Base/Subbase</td>
<td>1290</td>
<td>Granular Type 1</td>
</tr>
<tr>
<td>Bedding</td>
<td>150</td>
<td>Sharp sand</td>
</tr>
</tbody>
</table>

### 3.4.5 Duration of construction

During the literature review, it was identified that because of the time required to place and remove the material, temporary backfill is likely to be feasible only for small excavations or for excavations that could be left filled for several days. Therefore, an attempt was made to assess the time required for the construction allowing, in this case, for the time for installation of performance measurement equipment and the special circumstances of the trail. The works started at 10:15 hrs when sand was placed into Trench P1T1. The entire construction of both trenches was completed by 16:00 hrs. This included time for all the measurements and testing performed. Although Trenches P1T1 and P1T2 were constructed in parallel, there were delays not only for the measurements but also because only one grab and one compactor were used. Taking these delays into account, it is estimated that each construction would have been completed within approximately 2.5 hours if there had been separate plant for each trench and no testing. This estimation does not account for delays due to the limited working space, and the movement of equipment and materials in the PTF.
3.5 Testing and measurements during construction

Dynamic Cone Penetrometer (DCP) and Light Weight Deflectometer (LWD) tests were carried out on Trenches P1T1 and P1T2 to gather information on the properties of the materials laid. The measurement locations are shown in Figure 3.5. No testing was conducted on Trench P1T3.

![DCP test locations and LWD test locations](image)

**Figure 3.5 – Phase 1: Test locations and nominal dimensions of the trial trenches**

3.5.1 Dynamic Cone Penetrometer (DCP)

In-situ measurements using the TRL Dynamic Cone Penetrometer (DCP) were carried out to determine the strength of the subgrade and the layers of granular Type 1 material. Figure 3.6 shows DCP testing in progress.

Six DCP tests were conducted (Figure 3.5). The results are summarised in Figure 3.7 and the plots of the DCP results are presented in Appendix A. The DCP test results indicate that a fairly uniform strength of granular Type 1 base (DCP3 to DCP6) was achieved during the construction over the existing clay subgrade with an in situ strength of 3 to 4% CBR (DCP1 and DCP2).
3.5.2 Light Weight Deflectometer (LWD)

A Light Weight Deflectometer (LWD) was used to determine the deflection and the surface modulus of the compacted layers. Figure 3.8 shows LWD testing in progress. Nine tests were conducted (Figure 3.5) over each of the following layers:

- Compacted granular Type 1 layer 5
- Finished granular Type 1
- Finished asphalt surface course

The average deflection and modulus measured are presented in Table 3.5. The individual results are given in Appendix B.

<table>
<thead>
<tr>
<th>Test location</th>
<th>Trench P1T1</th>
<th>Trench P1T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deflection (μm)</td>
<td>Modulus (MPa)</td>
</tr>
<tr>
<td>Top of compacted Type 1 layer 5</td>
<td>568</td>
<td>148</td>
</tr>
<tr>
<td>Top of compacted Type 1</td>
<td>826</td>
<td>144</td>
</tr>
<tr>
<td>Top of asphalt surface course</td>
<td>340</td>
<td>251</td>
</tr>
</tbody>
</table>

Figure 3.7 - DCP test results

Figure 3.8 – LWD test in progress
3.6 Trafficking

3.6.1 The Pavement Test Facility

The Pavement Test Facility (PTF) allows accelerated testing of road pavements under closely controlled conditions of loading and pavement temperature. The test facility comprises a wheel assembly mounted on a gantry frame which spans across the 10m wide test pit and can be positioned over experimental pavement sections. Wheel loads can be applied to within 2% of the set load and trafficked up to a speed of 20km/h. The line of loading can be distributed transversely to simulate typical site traffic conditions, and the loading can be applied in one or both directions.

A dual wheel assembly was used and trafficking applied to the trenches in both directions at a speed of approximately 15km/h. The line of loading was spread across the trial area to replicate typical variations in traffic on site and to avoid any channelisation. The trafficking pattern is shown in Appendix C. Figure 3.9 shows trafficking in progress.

The wheel load was 40kN (representing the wheel load for half a standard axle) for the first 28,320 passes. The load was then increased to 55kN for a further 13,216 passes to assess the impact of more severe traffic loading. The total number of wheel passes was 41,536 (both directions), which was equivalent to the level of trafficking that would be exceed over a 5 day period on a 60msa (million standard axles)\textsuperscript{4} design pavement.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{traffic.png}
\caption{Figure 3.9 - Trafficking over trial sections in Phase 1}
\end{figure}

\textsuperscript{4} The increase in the wheel load from 40kN to 55kN was not included in the estimate of the equivalent number of standard axles (esa in million). It was assumed that the increase produced a more severe trafficking regime than reported.
3.7 Pavement settlement

Pavement surface levels were recorded before the start of trafficking and intermittently during the trafficking at the positions shown in Figure 3.10. Table 3.6 shows the cumulative settlement and the corresponding number of passes at which levels were measured.

<table>
<thead>
<tr>
<th>Cumulative number of passes</th>
<th>Wheel load (kN)</th>
<th>Cumulative settlement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trench P1T1</td>
<td>Trench P1T2</td>
</tr>
<tr>
<td>Before trafficking</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>944</td>
<td>40</td>
<td>-6 0.2</td>
</tr>
<tr>
<td>5664</td>
<td>40</td>
<td>-8 0.1</td>
</tr>
<tr>
<td>9440</td>
<td>40</td>
<td>-8 0.2</td>
</tr>
<tr>
<td>28320</td>
<td>40</td>
<td>-8 -0.3</td>
</tr>
<tr>
<td>41536</td>
<td>55</td>
<td>-9 -0.6</td>
</tr>
</tbody>
</table>

The plot of the settlements in Trenches P1T1 and P1T2 are given in Figure 3.11 and Figure 3.12, respectively. Trench P1T1 and Trench P1T3, which were surfaced with cold lay, settled significantly (approximately 6mm) after only 944 passes, while no settlement was recorded at Trench P1T2. The final settlement after 41,536 passes was nearly 10mm in trench P1T1 and less than 1mm in trench P1T2. Figure 3.13 gives the plot of the average settlement within ±300mm from the centre line.
Figure 3.11 – Measured pavement settlement in Trench P1T1

Figure 3.12 – Measured pavement settlement in Trench P1T2
Figure 3.13 – Average pavement settlement in centreline of Trenches P1T1, P1T2 and P1T3
4 Temporary backfill trials - Phase 2

4.1 Pavement materials and layer thicknesses

Following the Phase 1 trial, a second phase trial was carried out with a reduced thickness of granular Type 1 material and with sharp sand and pea shingle used as a bedding/surround material in Trenches P2T1 and P2T2, respectively. It was thought that these materials would be quicker to place and compact, although the pavement construction would be weaker. The target pavement layer thicknesses and the materials selected for the Phase 2 trial are given in Table 4.1. Hot mixed asphalt was used for the surface course, which proved to be a more robust surfacing material than cold lay asphalt in Phase 1.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Trench P2T1</th>
<th>Trench P2T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thickness (mm)</td>
<td>Material type</td>
</tr>
<tr>
<td>Surface course</td>
<td>50</td>
<td>Hot mixed asphalt – AC 6mm dense surfacing 100/150</td>
</tr>
<tr>
<td>Base/Subbase</td>
<td>300</td>
<td>Granular Type 1</td>
</tr>
<tr>
<td>Bedding</td>
<td>1150</td>
<td>Sharp sand</td>
</tr>
<tr>
<td>Subgrade</td>
<td>-</td>
<td>Clay (3-4% CBR)</td>
</tr>
</tbody>
</table>

As for the Phase 1 trials, a multi-layered elastic analysis of the pavement was undertaken using the BISAR computer program. A Poisson’s ratio of 0.45 was used for both the sand and pea shingle. The results of the analysis are presented in Table 4.2.

<table>
<thead>
<tr>
<th>Trench</th>
<th>Asphalt surface course</th>
<th>Fatigue criteria</th>
<th>Deflection δ (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Thickness (mm)</td>
<td>Stiffness MPa</td>
</tr>
<tr>
<td>P2T1</td>
<td>Hot mixed</td>
<td>50</td>
<td>2500</td>
</tr>
<tr>
<td>P2T2</td>
<td>Hot mixed</td>
<td>50</td>
<td>2500</td>
</tr>
</tbody>
</table>

4.2 Trial pavement construction

The temporary backfill materials from the Phase 1 trenches P1T1 and P1T2 were dug out to 2m by 2m wide and 1.5m deep to make way for the new construction. The new pavements were constructed by an experienced contractor. The various stages involved in the construction are described in the following sections.
4.2.1 **Trench backfill material**

The sharp sand was laid in 8 layers with an average compacted thickness of approximately 140mm in Trench P2T1. The compaction was achieved using a lightweight vibrating plate compactor with a 500mm wide base plate (aka Wacker plate). The 10mm Pea shingle was placed in Trench P2T2 in one layer up to the required thickness. The pea shingle was assumed to be self levelling, but the top layer was compacted/levelled with a Wacker plate. Figure 4.1 shows the sand being compacted in Trench P2T1 and pea shingle being placed into Trench P2T2.

![Figure 4.1 - Trench backfilling in progress with sand and pea shingle](image)

4.2.2 **Preparation of base/subbase**

The granular Type 1 subbase material was laid in three layers of compacted thickness approximately 100mm to achieve a total thickness of 300mm in both Trenches P2T1 and P2T2. A Wacker plate was used to compact the material. Figure 4.2 shows the construction of the granular Type 1.

![Figure 4.2 – Granular Type 1 layer under construction](image)

4.2.3 **Asphalt surface course**

Trenches P2T1 and P2T2 were surfaced with hot mixed AC 6 surf 100/150 (CEN, 2006) asphalt. The surface course was laid in a single layer and compacted.
using a BOMAG (BW 55 E) Single-Drum Vibratory Roller to achieve adequate compaction (Figure 3.4). The finished asphalt surface course thickness was approximately 55mm, which was slightly thicker than the target of 50mm but this was considered acceptable for the trial.

Figure 4.3 – Surface course compaction in progress

The thicknesses of the final pavement layers, based on the measurements taken during construction, are presented in Table 4.3.

Table 4.3 – Summary of pavement layer thicknesses

<table>
<thead>
<tr>
<th>Layer</th>
<th>Average thickness (mm)</th>
<th>Material type</th>
<th>Average thickness (mm)</th>
<th>Material type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface course</td>
<td>54</td>
<td>Hot mix asphalt – AC 6mm dense</td>
<td>55</td>
<td>Hot mix asphalt – AC 6mm dense</td>
</tr>
<tr>
<td></td>
<td></td>
<td>surfacing 100/150</td>
<td></td>
<td>surfacing 100/150</td>
</tr>
<tr>
<td>Base/Subbase</td>
<td>296</td>
<td>Granular Type 1</td>
<td>290</td>
<td>Granular Type 1</td>
</tr>
<tr>
<td>Bedding</td>
<td>1150</td>
<td>Sharp sand</td>
<td>1155</td>
<td>Pea shingle</td>
</tr>
</tbody>
</table>

4.2.4 Duration of construction

The construction was initially planned for a day but due to the unavailability of material, the work was undertaken over two days. The construction started on the first day at about 9:20hrs with the placement of the first layer of sand. Trenches P2T1 and P2T2 were constructed in parallel as in Phase 1 and the entire construction up to the top of subbase was completed by 14:30 hrs. Asphalt surfacing was laid on the second day at about 11:30hrs and completed at 13:00 hrs. There were delays due to measurements being taken intermittently, with only two people undertaking the construction, limited working space and material being transported from a stockpile outside the PTF. It is estimated that the trenches with sharp sand and 10mm pea shingle construction would have been completed within approximately 2 and 1.5 hours, respectively, if there had been separate plant for each trench and no testing.
4.3 Testing and measurements during construction

4.3.1 Dynamic Cone Penetrometer (DCP)

Six DCP tests were conducted at the test locations shown in Figure 4.4. The results are summarised in Figure 4.5 and the plots of the DCP results are presented in Appendix B.

![DCP test locations and LWD test locations](image-url)

**Figure 4.4–Phase 2: Test locations on plan and cross section of the trial trenches**

![DCP results chart](image-url)

**Figure 4.5 - DCP test results**

1. The numbers represent the CBR values at different depths
2. Layers are based on the CBR values
4.3.2  **Light Weight Deflectometer (LWD)**

Light Weight Deflectometer (LWD) tests were conducted over the top of the Type 1 subbase, and the average deflection and modulus measured are given in Table 4.4.

**Table 4.4 – LWD test results**

<table>
<thead>
<tr>
<th>Test location</th>
<th>Deflection (μm)</th>
<th>Modulus (MPa)</th>
<th>Deflection (μm)</th>
<th>Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of compacted Type 1</td>
<td>617</td>
<td>128</td>
<td>639</td>
<td>124</td>
</tr>
</tbody>
</table>

4.3.3  **Trafficking in the PTF**

Trafficking in the PTF over the trial areas was undertaken using a dual wheel assembly with a wheel load of 40kN with trafficking in both directions at a speed of approximately 15km/h. The pattern of trafficking was similar to that in the Phase 1 trials (Appendix C). The total number of passes was 33,147, which was approximately equivalent to about 5 days trafficking on a 50msa (million standard axles) design road.

4.4  **Pavement settlement**

The finished level of the trial section was measured at the points shown in Figure 4.6. These levels were then used to reference subsequent measurements after trafficking. Table 4.5 shows the cumulative settlement and corresponding number of passes at which levels were measured.

**Table 4.5 – Measured cumulative settlement**

<table>
<thead>
<tr>
<th>Cumulative number of passes</th>
<th>Wheel load (kN)</th>
<th>Cumulative settlement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trench P2T1</td>
<td>Trench P2T2</td>
</tr>
<tr>
<td>Before trafficking</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>944</td>
<td>40</td>
<td>-4</td>
</tr>
<tr>
<td>2832</td>
<td>40</td>
<td>-6</td>
</tr>
<tr>
<td>4720</td>
<td>40</td>
<td>-8</td>
</tr>
<tr>
<td>12500</td>
<td>40</td>
<td>-12</td>
</tr>
<tr>
<td>18987</td>
<td>40</td>
<td>-15</td>
</tr>
<tr>
<td>23707</td>
<td>40</td>
<td>-15</td>
</tr>
<tr>
<td>33147</td>
<td>40</td>
<td>-15</td>
</tr>
</tbody>
</table>

The cumulative settlements in Trench P2T1 and P2T2 after the first 944 passes were 4mm and 7mm respectively. The settlement in both trenches increased steadily up to 18,987 passes with settlements measuring 15mm and 24mm in Trench P2T1 and P2T2 respectively. Further trafficking from 18,987 to 33,147
passes produced no more settlement in Trench P2T1 and only 2mm more in Trench P2T2.

The plot of the cumulative settlements in Trenches P2T1 and P2T2 are given in Figure 4.6 and Figure 4.7, respectively. Figure 4.8 gives the plot of the average settlement within ±300mm from the centre line. Ramping was placed on the edge of P2T2 after the material had dropped slightly. This was important from a PTF operational point of view to avoid having steps in the pavement as the wheel passes as this would cause spikes in the loading and potentially stop the test.

![Figure 4.6 – Measured pavement settlement in Trench P2T1 (sharp sand and Type 1)](image)
Figure 4.7 – Measured pavement settlement in Trench P2T2 (pea shingle and Type 1)

Figure 4.8 – Averaged pavement settlement in Trenches P2T1 and P2T2
5 Discussion

5.1 Main factors concerning the viability of temporary backfill

The trials showed that the four main factors that are likely to determine whether it is viable to use temporary backfill to form an immediate reinstatement are:

- The time required to place and remove the materials (which is related to trench volume and depth)
- The availability of the materials
- The equipment and staff required (for standard materials these should be no different from the normal works.
- The performance of the immediate reinstatement (which relates to compaction and bearing capacity and deformation/settlement during trafficking).

These factors have been considered in discussing the findings from the trials, and guidance on the use of temporary backfill, based on the results, is presented in Section 6 of this report.

5.2 Phase 1

The Phase 1 trials demonstrated a solution which would be suited to a situation where the only remaining work would be the placement of the permanent bound layers. The advantage of this approach would be to avoid occupation of the carriageway at peak times, reducing impact of the works on congestion.

5.2.1 Hot mix asphalt surfacing

Trench P1T2 with granular Type 1 material overlaid with a hot mixed asphalt surface course performed very well and showed no signs of failure. The settlement was less than 1mm. Granular Type 1 material is readily available, as is hot mixed asphalt at certain, if not all, times of the day. However, the time needed to install the backfill, and possibly the need for extra staff and equipment to install and compact a thick layer of granular Type 1 material and subsequently remove it when the works resume could be prohibitive. Nevertheless, the trial demonstrated that it is possible to form immediate reinstatements that will perform well under heavy traffic and require little or no intervention due to settlement to improve ride quality. Also, any noise generated by vehicles crossing this type of reinstatement would be expected to be no different from the noise generated from interaction with the surrounding carriageway.

5.2.2 Cold lay asphalt surfacing

The cold lay surface course in Trenches P1T1 and P1T3 was still mobile at the start of the trafficking, which was two days after laying. The results indicate that secondary compaction occurred under wheel loading which resulted in a settlement of 6mm after the first 944 passes. Subsequent increases from 944 passes to 41,536 passes resulted in only 3mm more settlement. Therefore, it appears that, once secondary compaction occurred, the cold lay asphalt performed satisfactorily. This finding was confirmed by the settlement results
recorded in the middle trench where a 100mm thick layer of cold lay AC 6 surf 100/150 asphalt (BS EN 13108-1, CEN 2006) was applied. There was no observed rate of increase in deformation in either trench resulting from the increase in load from 40kN to 55kN at 28,320 passes.

The structural integrity in terms of ‘Cumulative Settlement’ given in Figure S2.6 of the SROH (HAUC, 2010) requires reinstatements over 1000mm wide to settle less than 1.5% of the total unbound thickness (i.e. approximately 22mm in both Trenches P1T1 and P1T2) or 35mm, whichever is greater. Although the settlement in Trenches P1T1 and P1T3 was significantly more than that in Trench P1T2, it was still within the limits specified in the SROH. However, there are concerns that the initial yielding of a large area of cold lay asphalt could cause the material to break up under emergency braking, although no tests were conducted to investigate this aspect. Therefore, although the effect of the initial settlement could be resolved by having a certain surcharge thickness to allow for the secondary compaction of cold lay asphalt, or by adding further material or ramps to improve the ride quality and avoid excessive dynamic loading across the reinstatement, hot mix asphalt would be a preferred option due to its immediate stability after compaction.

Apparatus may be damaged if granular Type 1 material is used for the bedding and surround and, therefore, any bedding material around utility apparatus should be that which is normally used by the contractor.

5.3 Phase 2

With a reduced thickness of the asphalt layer there was much more settlement in both Trenches P2T1 and P2T2, using sharp sand and 10mm pea shingle, respectively. The settlement of both trenches increased steadily up to 18,987 passes reaching 15mm and 24mm in Trenches P2T1 and P2T2, respectively. Further trafficking from 18,987 to 33,147 passes produced no more settlement in Trench P2T1 and only 2mm more in Trench P2T2. The final settlements in both trenches were less than the maximum 35mm limit specified in the SROH. It will be important to ensure that normal compaction procedures are followed, even though the contractor will be aware that the materials are to be removed after a short period, so that excessive deformations are not generated.

It was necessary to form asphalt ramps at the edges (as shown in Figure 5.1) of trench P2T2 containing the pea shingle to provide a smooth transition from the permanent pavement to the reinstatements for PTF operational reasons. It is likely that some intervention would be required on such reinstatements on heavily trafficked roads to improve the ride quality and prevent excessive noise generated by vehicles. Some of the initial settlement could be countered by surcharging the surface course. Dependent on the vicinity of the site to residential properties and the speed limit, the effects of settlement could be reduced by forming ramps or applying additional material during off peak periods. An assessment would need to be made of the need to do this during routine inspections carried out by the works contractor.
Use of Temporary Backfill

Figure 5.1 Asphalt ramps at edges of pea shingle trench

The additional time and cost to reduce the effects of settlement would offset the savings when 10 mm pea shingle (especially) and sharp sand (to a lesser extent) are used instead of granular Type 1 material for the lower layers of an immediate reinstatement. Pea shingle would be the preferred material when there is little time to complete an immediate reinstatement before a road must be opened to traffic. Pea shingle will also be very easy to remove when it comes to completion of the works and installation of the permanent reinstatement. Furthermore, it may be possible to avoid the need for remedial measures, especially on roads without much heavy traffic by surcharging the surface course and/or with appropriate signing and a speed limit.

5.4 General

Large settlements above the 35mm SROH limit may be indicative of a lack of compaction and load dispersal down through the depth of an immediate reinstatement and, therefore, could give rise to potential damage to certain apparatus. All of the settlements recorded in the trials were below this level. Furthermore, CBR measurements through the upper unbound layer of Type 1 were all in excess of 30, and the surface modulus values measured on top of the unbound layers using the lightweight drop tester were all above 100MPa (the limit specified in HD30 (HA et al, 2008) for laying asphalt).

Where the road surface becomes uneven, wheel loading from vehicles may increase as a result. However, the increase in load in the first set of tests did not cause any further increase in the development rate of rutting which would indicate that if the unbound layers are installed correctly there should not be any issues.

Any utility apparatus should ideally be installed with the bedding and surround normally used for the permanent reinstatement to reduce the risk of damage. Clearly, sharp sand and 10mm pea shingle are used as bedding and surround for some types of apparatus so the use of the same material below a 300mm thick layer of granular Type1 material would be appropriate and advantageous.
5.5 Traffic delay savings from using temporary backfill

This section describes the use of the programme QUADRO (Queues and Delays at Roadworks) (DfT, 2006) to estimate the traffic delay and the value of these delays in monetary terms to be saved by using temporary backfill to keep the carriageway open at certain times during the works to traffic. QUADRO estimates the total time delay and converts this to a monetary value representing the cost of road user delays using the market price of the value of time. Currently, in line with the DfT WebTAG guidance, this is £13.91 per hour for an average vehicle (in 2010 prices and values). It is important to note that this cost does not include any lane rental costs that may be incurred.

For comparison purposes, the delays caused by a conventional closure were also estimated. The results presented are examples to be used as guidance only as it is recognised that potential user delay savings will differ for individual sites.

Two works scenarios were modelled with a number of different volumes of traffic, works length and closure duration in order to assess the sensitivity to these factors. These scenarios were a four-day works duration and an eight-day works duration.

For both scenarios two road types were modelled; a single two lane all purpose (S2AP) and a dual two lane all purpose (D2AP). Each was modelled using a range of traffic flow rates (AADT) appropriate for that type of road as shown in Table 5.1.

<table>
<thead>
<tr>
<th>Traffic</th>
<th>S2AP</th>
<th>D2AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Low/Med</td>
<td>12,500</td>
<td>34,000</td>
</tr>
<tr>
<td>Medium</td>
<td>15,000</td>
<td>38,000</td>
</tr>
<tr>
<td>Med/High</td>
<td>20,000</td>
<td>45,000</td>
</tr>
<tr>
<td>High</td>
<td>25,000</td>
<td>58,000</td>
</tr>
<tr>
<td>Very High</td>
<td>30,000</td>
<td>70,000</td>
</tr>
</tbody>
</table>

Here we consider the use of temporary backfill to allow work to be completed on a large chamber opening. The options of weekend only working, with temporary backfill in place during the normal working week, is compared with a traditional full closure with combined weekend and weekday working. When the work is being performed at the weekend only a traditional traffic management arrangement would be in place.

The first scenario modelled is where the work is planned to take four days (day time working only). The conventional traffic management arrangement would be to put a 24 hour closure in place for the duration of the works and it has been assumed that the works will start on a Sunday (lowest traffic flow day) and run through to Wednesday. If temporary backfill is used during the working week
the works can be completed over two weekends, with a 24 hour closure in place on the weekend and the temporary backfill in place during the working week thus keeping the road open during peak periods.

Table 5.2 summarises the user delay cost savings from using temporary backfill as a percentage of costs compared to those incurred by a conventional closure for the different traffic levels.

For low traffic flows there are no user delay benefits to be gained by using temporary backfill. For traffic flows above approximately 30,000 vehicles AADT on D2AP and above 10,000 vehicles AADT on S2AP savings can be realised. At higher flows, although the benefits to be gained start to reduce because the limiting capacity of the road plays a part in traffic delays, significant benefits can still be obtained.
Table 5.2 User delay cost saving potential for 8h weekend working (scenario 1)

<table>
<thead>
<tr>
<th>Traffic (2 way AADT)</th>
<th>Cost Saving using Backfill day working only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S2AP</td>
</tr>
<tr>
<td>10,000</td>
<td>4%</td>
</tr>
<tr>
<td>12,500</td>
<td>59%</td>
</tr>
<tr>
<td>15,000</td>
<td>69%</td>
</tr>
<tr>
<td>20,000</td>
<td>61%</td>
</tr>
<tr>
<td>25,000</td>
<td>47%</td>
</tr>
<tr>
<td>30,000</td>
<td>35%</td>
</tr>
<tr>
<td>34,000</td>
<td>-</td>
</tr>
<tr>
<td>38,000</td>
<td>-</td>
</tr>
<tr>
<td>45,000</td>
<td>-</td>
</tr>
<tr>
<td>58,000</td>
<td>-</td>
</tr>
<tr>
<td>70,000</td>
<td>-</td>
</tr>
<tr>
<td>100,000</td>
<td>-</td>
</tr>
</tbody>
</table>

The second scenario modelled is where the work is planned to take eight normal working shifts with the options of day time working and 24 hour working to complete the works in a shorter period. As with the first scenario, the conventional traffic management arrangement would be to put a 24 hour closure in place for the duration of the works. If temporary backfill is used the work could take four weekends for day time working only; or could be completed in two weekends if 24 hour weekend working is permitted. Both options using temporary backfill show considerable savings for various traffic flows compared with the conventional approach of full closure for the duration of the works which would include weekday closures during peak periods. Substantial savings are to be made where traffic flows are above 10,000 vehicles (AADT) on a S2AP road and above 30,000 vehicles AADT on a D2AP road.

With both scenarios, when converted to monetary values, the typical delay cost savings that could be gained are estimated to be approximately £80,000 per day for a S2AP road with a flow of 20,000 vehicles (AADT), and £30,000 per day for a D2AP road with a flow of 45,000 vehicles (AADT). The lower level of savings to be gained from the dual carriageway road reflects the ability to make use of the additional lanes to retain traffic flow. It must be noted, however, that in all cases the savings to be gained will vary with traffic flow and working shift patterns, and individual assessment should therefore be undertaken for each works case.
6 Concluding guidance on the use of temporary backfill

6.1 Potential uses of temporary backfill

Temporary backfill is likely to be most useful when only a relatively small volume of material is required and/or it can be left in place for several days. An excavation can be filled before the apparatus is positioned (see Figure 6.1), although a large amount of material might be required to completely fill a large excavation. Temporary backfill could, however, be used to fill only part of an excavation. Figure 6.2 shows an immediate reinstatement with the apparatus, surround and permanent backfill in place. Temporary backfill could also be used to fill the ends of trenches and other excavations (e.g. for kerbs) at the end of a working day for peak periods.

![Figure 6.1 - Temporary backfill completely filling an excavation up to the surface course]

![Figure 6.2 - Temporary backfill filling part of an excavation up to the surface course]

6.2 Times when temporary backfill could be used

Because of the time required to place and remove temporary backfill, the times when temporary backfill could be used are most likely to be:
- during delays encountered during emergency and planned works, (e.g. waiting for specialist staff or equipment to arrive);
- on weekdays if work is limited to weekends;
- at weekends and public holidays if work is restricted to weekdays; and
- for special events (e.g. parades, market days) when plates, especially surface mounted plates, would not be appropriate.

It may be appropriate to use temporary backfill with cold lay surfacing at small openings for one or two peak periods.
6.3 Selecting temporary backfill for a particular site

6.3.1 General

The findings from the literature review and the trials in the PTF have indicated that the most suitable material for a particular application depends on site specific factors. For example, the material that performed the best under trafficking took the longest to install.

When selecting temporary backfill for a particular application, the following should be considered:

- Trench volume, depth and shoring
- Materials proposed for works and their availability
- Placement and compaction
- Settlement under trafficking
- Potential effect on apparatus
- Removal and storage
- Asphalt specification and layer thickness.

These factors are considered in turn below. For completeness, some details of the Phase 1 and 2 trials and their findings are repeated below.

6.3.2 Trench volume, depth and shoring

The volume of excavations suitable for temporary backfill is dependent on the time available for its placement, compaction and removal, and the production rate with the plant available. It is thought that it would need to be possible to place and compact the backfill and clear the site of plant and materials within 2 hours. The removal of the temporary backfill and the resumption of work should be within the same time. Therefore, temporary backfill should be used only when a reduction in the working window can be justified in terms of reduced congestion. There may be an overall increase in the duration of the works but the actual number of days (24h periods) on site could be reduced.

Any shoring could be removed when the temporary backfill is placed, as when making a permanent reinstatement. Alternatively, the shoring could be left in place if it was trimmed to below the level of the surface course. It is recommended that the designer of the shoring be consulted to determine what is possible and, for example, if it is necessary to remove any bracing that may be damaged under trafficking.

6.3.3 Materials and their availability

Generally, temporary backfill materials should be those that are regularly used in reinstatements, are readily available, and can be sourced at short notice. It should be possible to use any materials with suitable properties, including compacted as dug material.

The performance of the immediate reinstatement is dependent on the form of construction and the amount of trafficking. However, even if trafficking does cause settlement, remedial measures should be possible at off peak periods to restore the surface condition and ride quality. Less settlement will occur if
materials with a higher CBR are used, but normally these will take longer to place and/or compact.

Trials were carried out with granular Type 1 material, sharp sand and 10mm pea shingle. The immediate reinstatements that were constructed were 2 m x 2m and 1.5 m deep and they were subjected to trafficking that was equivalent to 5 days trafficking on a Type 0 road (30 to 80 msa). The main findings from the trials are given in Table 6.1.

**Table 6.1 – Main findings from trials at TRL on immediate reinstatements**

<table>
<thead>
<tr>
<th>Thickness of hot mixed asphalt surface course (mm)</th>
<th>Top layer of temporary backfill</th>
<th>Lower layer of temporary backfill</th>
<th>Estimated time to construct reinstatement (hours)</th>
<th>Settlement (mm)</th>
<th>Road 'type' with equivalent trafficking in 5 days (msa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 Granular Type 1 300 Granular Type 1 1140 2.5 &lt;1 0 (60)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 Granular Type 1 300 Sharp sand 1145 2 15 0 (50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 Granular Type 1 300 10mm pea shingle 1145 1.5 26 0 (50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the findings from the trials, the recommended thicknesses and material properties for the construction of immediate reinstatements of similar depth to those tested are given in Figure 6.3. It is recommended that the minimum surfacing thickness is 50mm and that the top 300mm of temporary backfill is a material with a CBR>30% (e.g. granular Type 1 material). The lower layer of temporary backfill should be constructed with material with a CBR>15%, but there will be less settlement if a material with a compacted CBR>30% is used.

**Figure 6.3- Possible temporary backfill construction for trenches of depth >1m**
6.3.4 Placement and compaction
Temporary backfill can be placed and compacted in the same way as permanent backfill. 10mm pea shingle is effectively self-compacting. In the trials it was placed in one layer (1145mm thick) and the top of the layer was compacted and levelled with a Wacker plate.

Measures must be introduced to ensure adequate compaction of all types of temporary backfill so it:
- has sufficient load bearing capacity to prevent rutting and the breakup of the asphalt overlay;
- limits the load applied to the apparatus; and
- supports the edges of trench.

The benefit of materials with a high CBR, such as granular Type 1 material, will not be realised unless they are adequately compacted. In particular, care must be taken to ensure that the top layer of temporary backfill is fully compacted.

6.3.5 Effect on apparatus
It is possible that apparatus could be subject to higher loading in an immediate reinstatement than in an interim or permanent reinstatement. For example, this would be the case if load dispersal was less with temporary than with permanent backfill. However, there have been no reports of apparatus being damaged in this way when temporary backfill has been used. Apparatus should be protected with a bed/surround as would normally be the used for permanent reinstatements.

6.3.6 Settlement under trafficking and signing
As shown in Table 6.1, almost no settlement occurred during the trial when all of the temporary backfill was granular Type 1 material. The maximum settlement of 26mm was when 10mm pea shingle was used for the lower layer of temporary backfill.

Immediate reinstatements should be inspected on a regular basis for settlement. The settlement will be dependent on the level of trafficking, so the inspection frequency should be determined by taking into account the amount of traffic and the type of temporary backfill.

The effects of settlement can be (partly) offset by surcharging the surface course. However, remedial action may be required to restore ride quality and limit the noise generated when vehicles cross an uneven road surface. Ramp or uneven road signs or a reduced speed limit should be used as appropriate.

On high speed roads, if may be necessary to lay further material to bring the level of the reinstatement up to the level of the adjacent pavement. On other roads, it may be possible to form ramps from cold lay or hot mixed material to provide a smooth transition at the edges of the reinstatement.

6.3.7 Removal and storage
It will be necessary to remove all plant and materials from the site to a safe location after an immediate reinstatement has been completed. Similarly, plant
Use of Temporary Backfill

and materials need to be returned to site when works are to continue. The time to complete these activities needs to be considered in addition to the time required to complete and remove the immediate reinstatement.

Temporary backfill can be removed by excavator in the same way as when a trench is normally excavated. Vacuum extraction could also be employed, but the plant required may be costly to hire. The production rate of vacuum extraction plant (including extraction, tipping etc.) varies with the material; typical rates may range from about 1m³/h to over 6m³/h, depending on the plant used.

Where possible and suitable, the removed temporary backfill should be stored nearby for future use in the permanent reinstatement or as temporary backfill for other excavations.

6.3.8 Asphalt specification and layer thickness

In the trials in which Type 1 material was overlaid with a 50 to 60mm thick 6mm dense AC surface course, hot mix performed significantly better than cold lay material. The cold lay material remained relatively soft until it had been subjected to a number of wheel loads. Therefore, cold lay material would be more susceptible to damage due to braking and traction forces in the first few hours of trafficking.

It is recommended that hot mixed asphalt be used for the surface course of reinstatements whenever possible, and especially for large reinstatements which will be subject to heavy braking and acceleration. The thickness of asphalt that was laid in the trials was 55mm. On the basis of the results, it is recommended that the minimum thickness is not less than 50mm.

Although the minimum thickness of cold lay material of 40mm that is specified in the SROH for an immediate reinstatement was not tested, it is considered to be suitable only for small reinstatements in lightly trafficked areas with free flowing traffic.

6.4 The benefits of temporary backfill

The trials have shown that temporary backfill can successfully be used for immediate reinstatements to reduce congestion at certain times during certain types of road and street works. This use of temporary backfill allows trafficking:

- before the bound layers are fully excavated and when the old backfill, surround and apparatus are in place; or
- when there is a delay in placing the bound layers of the permanent reinstatement.
- To allow trafficking of an adjacent lane if temporary backfill is used as a safety measure in an excavation immediately next to the carriageway (e.g drainage works).

The first two require a relatively small volume of temporary backfill so placement and removal times should be relatively quick. The third option may not require the material to be compacted so could also be quick to install. Temporary backfill
can be considered as a viable alternative to road plates and is potentially a more versatile technique than plating for the following reasons:

- It does not require special materials (e.g. plates or rapid curing materials);
- It does not require special plant (if an excavator is used for its removal);
- It may not require shoring;
- It is suitable for excavations of any size – depending on the time available to place and compact the material, to clear the site of plant and equipment, to reposition the plant and equipment and to remove the material so that work can recommence;
- The excavation can vary in width along its length;
- It is suitable for all classes of road but is likely to be most beneficial on higher trafficked roads;
- There is no need for signs and speed restrictions as long as any settlement is minimal;
- The sub-surface apparatus is protected and the risk of damage from the use of temporary backfill is minimal;
- There is no threat from vandalism and theft (e.g. removal of plates);
- Ride quality may be impaired but this is likely to be minimal; and
- No operations are required to bed and fix equipment such as plates to the road surface.

Typical delay cost savings that could be gained from using temporary backfill are estimated to be approximately £80,000 per day for a S2AP road with a flow of 20,000 vehicles AADT, and up to £30,000 per day for a D2AP road with a flow of 45,000 vehicles AADT. It must be noted, however, that in all cases the savings to be gained will vary with traffic flow and working shift patterns, and individual assessments should therefore be undertaken for each works case.

The use of temporary backfill needs to be encouraged through the publication of the results of this study; and in particular, by providing utility companies, contractors and highway authorities with the evidence, as found in this study, showing that such techniques can confidently be used. In addition to the study reports, a series of Advisory Notes known as ‘QWIRC Notes’ (Quick Win Innovation to Reduce Congestion) have been produced for the study, and the use of Temporary Backfill is included within these. Using temporary backfill on the TLRN would encourage greater use both in London and elsewhere in the UK.
7 Acknowledgements

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- Cliff Nicholls (TRL)
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- Lawrence Eggleton (TfL)
- Wayne Duerden (DfT)
- David Capon JAG (UK)
- Veronica Wong (AGMA)
- Peter Loft (NJUG)
- Adrian Wathen (NJUG)
- Ian Hopper (NJUG)
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- Ralph Harris (Consultant).

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- John Hakewill (TfL)
- Peter Loft (NJUG)
- Ian Ackerman (Hampshire CC)
- John Underwood (HSE)
- Lee Henley (FACTA)
- James Kavanagh (Ringway Jacobs).
References


Appendix A  Phase 1 - DCP test results

Figure A.1 – DCP 1, Trench P1T1-Over the compacted sand

Figure A.2 – DCP2, Trench P1T1-Over the compacted sand

Figure A.3–DCP 3, Trench P1T1-Over the compacted granular Type 1 Layer 5
Appendix B  Phase 2 - DCP test results
Use of Temporary Backfill

**Figure B.1 – DCP 1, Trench P2T1-Over the compacted granular Type 1**

**Figure B.2 – DCP 2, Trench P2T1-Over the compacted granular Type 1**
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Figure B.3 – DCP 3, Trench P2T2-Over the compacted granular Type 1

Figure B.4 – DCP 4, Trench P2T2-Over the compacted granular Type 1
Appendix C  Pattern of trafficking

The numbers in the cells indicate the number of wheel passes before moving on to the next line of trafficking. This pattern was repeated but narrowing down as the number of wheel passes increases.