Long-term performance of reinstated trenches and their adjacent pavements. Part 1: Literature review

Prepared for Department for Transport and CSS

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Executive Summary

Scope of the study
TRL Limited has carried out a two-part research study into the long-term performance of reinstated trenches and their adjacent pavements, commissioned by the Department for Transport (DfT) and the CSS. Part 1 of the study covers the results of a literature review of national and international research. Part 2 of the study covers the findings from a revisit programme to 168 reinstatements and two major reinstatement sites in the UK. The findings from the 168 sites and two major reinstatement sites revisit programme are reported in Part 2 of the study (Steele et al., 2003).

The 168 sites were studied over the period from 1995 to 1997 and the two major reinstatement sites were studied over the period from 1988 to 1993. Work on the 168 sites concentrated on identifying problems with the standard of reinstatements achieved following the introduction of the NRSWA Specification, and thereby aspects in need of amendment and improvement whilst the current work concentrates on the longer-term deterioration. The standards of workmanship were also examined to identify any shortcomings in current practice under the requirements of the Specification (first edition). The two major trial sites were designed from excavation through reinstatement. They were monitored prior to excavation and for three years thereafter at six-monthly intervals to determine the long-term performance of the reinstatements and their effect on the adjacent pavements.

The literature review covering the UK, Europe and elsewhere collated information on the long-term performance of roads that were excavated and reinstated. This involved interrogation of TRL’s extensive library database containing journal articles, conference papers, books, standards etc with informative summaries from a wide range of sources. The library’s participation in the OECD’s International Transport Research Documentation (ITRD) scheme provided a gateway to information from many countries including North America, Canada, Europe, Australia and New Zealand.

The overall aims of the study were to assess:

a whether the rate of deterioration of the pavement adjacent to trenches is different from that of the rest of the pavement;
b the extent of undertakers’ compliance with the Reinstatement Specification (NRSWA Code of Practice, 1992) and the effects of workmanship on the service life of a road pavement;
c the long-term pavement life of the trial sites at Wickford in Essex and on the A52 at Brailsford in Derbyshire;
d the long-term performance of roads that have been excavated and reinstated;
e the possible surface deterioration and environmental disbenefits of reinstatements.

Implicit in the aims of the project are the economics of premature maintenance and the effect on the environment should the long-term performance of the highway be adversely affected by the presence of reinstatements. Information about economics of road openings has therefore been included in the review.

Summary
Part 1 of the study is a review of national and international research carried out on trench reinstatements in highways (carriageways, footways and cycle tracks) over the last decade with the purpose of determining the possible effects of reinstatements on the service life of the highway.

National research concentrates on reinstatements carried out after the introduction of the NRSWA Specification (1992). Very few of the earlier studies included in the review concentrate solely on quantifying the effects of reinstatements on the service life of the highway. In some cases, authors have made general qualitative deductions to evaluate the likelihood of long-term damage that may result from reinstatements in the highway. Nevertheless, there is experimental evidence to support opinion that poor workmanship during the excavation and reinstatement of openings in highways and non-compliance with national Specifications reduces service lives of pavements, footways and cycle tracks. It also appears that surface deterioration and environmental disbenefits can be caused even if the reinstatements are fully in accordance with the specification. This has led some North American cities, and other cities outside the UK, to impose a mandatory charge on all utilities/companies intending to excavate roads to cover a reduction in the service life. For example, a report from the Dublin Corporation in the Republic of Ireland explains that ‘the charge is equivalent to the cost of overlaying half the carriageway for the full length of the roadworks’.

From the literature review, it shows that there is a need to increase knowledge on long-term performance of reinstated trenches and their adjacent pavements.

However, further evidence of existing reinstatement and adjacent pavement performance would need to be gathered and analysed. With the implementation of the new Specification, practices should continue to improve but the presence of reinstatements may in itself result in the need for premature maintenance intervention.

Finally, whilst some evidence concerning surface deterioration is given in the reviewed reports and papers they provide little research evidence about the environmental disbenefits of trenched carriageways, footways and cycle tracks. Further investigation of this aspect is needed.
1 Introduction

Do utility works in the highway (carriageways, footways and cycle tracks) reduce its service life? This issue has been the subject of many debates in the past decades. Some engineers argue that a trench excavated and reinstated properly does no lasting damage to the existing highway, whilst others think it has a detrimental effect.

What are the facts? The matter requires understanding of the mechanisms at work in trenches and the effect of the presence of a trench on the adjacent carriageway. Other considerations are ways of reducing settlement and associated problems such as joint openings to maintain structural integrity of both the highway and trench. Four possible kinds of failure are foreseen:

1. The possibility of the excavation process weakening the adjacent pavement, which then further deteriorates after a reinstatement is completed.
2. Any damage caused to a pavement from, for example, reinstated trenches, which create a weak boundary between the reinstatement and the adjacent pavement.
3. A deteriorating pavement that may cause an adjacent trench to fail earlier than expected.
4. Surface deterioration and environmental damage from the works.

The requirements of the Specification under the New Roads and Street Works Act 1991 (NRSWA) attempt to prevent these consequences by safeguarding the structural integrity of the adjacent pavement, and by attempting to minimise the disturbance caused by trenching. However, the disturbance caused by trenching and defective reinstatements is still thought to be common, as are the surface deterioration and environmental disbenefits caused by these activities. More in-depth investigations are trying to identify the fundamental causes of these problems.

A two-part research study, commissioned by the Department for Transport (DfT) and the CSS, has been carried out by TRL Limited. Part 1 of the study covers the results of a literature review of national and international research. Part 2 of the study covers the findings from a revisit programme to 168 reinstatements and two major reinstatement sites in the UK. The findings from the 168 sites and two major reinstatement sites revisit programme are reported in Part 2 of the study (Steele et al., 2003).

The 168 sites were studied over the period from 1995 to 1997 and the two major reinstatement sites were studied over the period from 1988 to 1993. Work on the 168 sites concentrated on identifying problems with the standard of reinstatements achieved following the introduction of the NRSWA Specification, and thereby aspects in need of amendment and improvement whilst the current work concentrates on the longer-term deterioration. The standards of workmanship were also examined to identify any shortcomings in current practice under the requirements of the Specification (first edition). The two major trial sites were designed from excavation through reinstatement. They were monitored prior to excavation and for three years thereafter at six-monthly intervals to determine the long-term performance of the reinstatements and their effect on the adjacent pavements.

Together with the reinstatement study briefly described above, a literature review has been carried out to collate information from the UK, Europe and elsewhere about the long-term performance of pavements that are trenched and the impact on their service lives and that of the adjacent pavements. This involved interrogation of TRL’s extensive library database containing journal articles, conference papers, books, standards etc with informative summaries from a wide range of sources. The library’s participation in the OECD’s International Transport Research Documentation (ITRD) scheme provided a gateway to information from many countries including North America, Canada, Europe, Australia and New Zealand.

2 Objectives of the study

The study aims to examine the performance of existing reinstatements through a literature review in order to assess:

a. whether the rate of deterioration of the pavement adjacent to trenches is different from that of the rest of the pavement;
b. the extent of undertakers’ compliance with the Reinstatement Specification (NRSWA Code of Practice, 1992) and the effects of workmanship on the service life of a road pavement;
c. the long-term pavement life of the trial sites at Wickford in Essex and on the A52 at Brailsford in Derbyshire;
d. the long-term performance of roads which have been excavated and reinstated;
e. the possible surface deterioration and environmental disbenefits of reinstatements.

Implicit in the aims of the project are the economics of premature maintenance and the effect on the environment should the long-term performance of the highway be adversely affected by the presence of reinstatements. Information about economics of road openings has therefore been included in the review.

3 Background

Since the introduction of the Public Utilities Street Works Act 1950 (PUSWA) (HMSO, 1950) and its inadequacy to deal with modern aspects of reinstatements, many attempts have been made to identify any underlying problems with long-term damage to pavements caused by excavation and reinstatement. In 1984, a committee set up by the Government reviewed PUSWA and a great number of recommendations for improvements to street works were made (Horne et al., 1985).

The Horne recommendations resulted in the development of a national Code of Practice Specification for the Reinstatement of Openings in Highways (Department of Transport et al., 1992), hereinafter referred to as the Specification, which gives practical guidance.
about the reinstatement standards required for the national network. A review of the impact of street works was completed by the Street Works Advisory Committee (SWAC) (Department of Transport et al., 1996). Early evidence showed that about 10 per cent of reinstatements were not meeting the performance requirements in the national Specification.

An amendment to the Specification was issued in October 1996 (HAUC, 1996). It introduced a number of changes including a new road category, alternative specification for materials, layer thickness and compaction methods to take advantage of new or local materials and/or new compaction equipment, subject to prior agreement of the Authority. After a further three years of review, a second edition of the Specification was published on 1 July 2002.

4 New roads and street works legislation

The New Roads And Street Works Act 1991 (NRSWA) requires all Utilities making openings in the highway (carriageways, footways and cycle tracks) to reinstate them to the Specification standards and to guarantee such reinstatements for a minimum period of two to three years depending on the depth of excavation and method of reinstatement.

The Foreword of the Specification states under section 71 (in Scotland, section 130) of the NRSWA:

‘An undertaker executing road works shall in reinstating the road comply with such requirements as may be prescribed as to the specification of materials to be used and the standards of workmanship to be observed. He shall also ensure that the reinstatement conforms to such performance standards as may be prescribed (in the case of interim reinstatement, until permanent reinstatement is effected, and in the case of permanent reinstatement, for the prescribed period after the completion of the reinstatement. This obligation is extended in certain cases and restricted in others by the provisions of section 73 (in Scotland, section 132) as to cases where a reinstatement is affected by subsequent works’.

The Specification gives guidance about how reinstatements should be carried out in the highway and about the required performance standards. It states:

‘It should be noted that if an undertaker fails to comply with his duties under section 71 or 130 he commits an offence. Compliance with the Code will satisfy the undertaker’s statutory obligations; failure in any respect to comply with it, whilst not of itself an offence, will be evidence of a breach of such obligation.’

A number of measures have already been introduced to encourage improvements in the planning and execution of street works and to help to minimise disruption, notably a Best Practice Guide for Street Works and Highway Works (TSO, 2001).

To safeguard road openings against poor reinstatements, there are reserve provisions under section 78 of NRSWA to allow government to charge utilities for the costs of making good long-term damage to streets due to reinstatements. The charge may be varied according to the nature of the street and the description and extent of the works. The importance of the long-term integrity of both carriageways and footways that are subject to excavation and reinstatement is emphasised.

The review covers national and international experience and is broken down into different headings applicable to reinstatement operations. Particular emphasis has been given to long-term performance of reinstatements and the adjacent highway and whether utility works can reduce the service life of an adjacent highway. Sections 5 to 10 cover different aspects of reinstatement practice in different countries as found from the extensive literature review.

5 Effect of reinstatements on pavement service life

Major research carried out both internationally and nationally on the effect of reinstatements on pavement service life is described in this section. The research is discussed separately for each country. A pavement is designed for a specific service life often taking into account whole life costs with the expectation that it will require some form of routine and/or structural maintenance during its life to keep it in good order. Hence, any premature maintenance undertaken is seen as detrimental to the service life of the pavement and is economically undesirable.

5.1 North America

5.1.1 Burlington, Vermont study

One of the first studies to investigate the impact of utility reinstatements was conducted in 1984 by a consulting firm for the city of Burlington, Vermont. The study aims were to assess the condition of reinstated (patched) and non-reinstated (non-patched) pavements (APWA, 1997 and Zeghal and Mohamed, 1999). This was based on visual surveys to calculate the pavement condition index and deflection measurements, using a Falling Weight Deflectometer (FWD), on randomly selected streets, which represented all pavement ages. Three methods were used to evaluate expected pavement performance. The first method gave a calculated rate of deterioration (as average loss of Pavement Condition Index, PCI, per year) for both reinstated and non-reinstated pavement sections (APWA, 1997). The report indicates that:

‘patched sections have a much steeper deterioration rate than non-patched sections, especially for segments with a high terminal PCI. For a terminal PCI of 70, the average life of patched sections was 11.6 years while the average life of unpatched sections was 20.1 years (a reduction factor of approximately 1.73).’

The second method involved using a least square linear regression between PCI and pavement age. By this method, reinstated sections reached a PCI value of 70 at the age of 12.1 years. The same for non-reinstated sections reached at 19.8 years, which is equivalent to a reduction factor of 1.64.
The third method was similar to the second one in relating pavement age to PCI using a third degree best-fit curve. The results indicated that the average life of reinstated sections was 8.5 years in comparison to the average life of 25.9 years for the non-reinstated pavements. This is equivalent to a reduction factor of just over three.

According to APWA (1997), the study did not show how good the curve fittings were or how adequate the limited data were in providing statistically significant conclusions.

5.1.2 Cincinnati study
Bodosci et al. (1995) and APWA (1997) reported on the impact of utility reinstatements on the performance of Cincinnati street pavements and document an early attempt to quantify the impact of excavations on the structural integrity of road pavements in the city of Cincinnati. The study did not target the impact of utility reinstatements on the performance of pavements specifically. The report, however, cites the following:

‘it is generally observed that the pavement sections in and around a cut generally fail at an accelerated pace. The resulting condition will have an influence on (i) the pavement life, (ii) pavement maintenance cost,... Presently, to maintain the street pavements with cuts at the same level as the surrounding pavement sections, cities are recovering a fixed amount from utility companies.’

The evaluation of structural condition of utility reinstatements and the surrounding pavement areas was carried out by a field technique, based on objective measurement of strength-deflection. The devices used to measure rebound deflections included Dynaflect (device similar to the FWD), Falling Weight Deflectometer (FWD) and a standard Benkleman Beam. The analysis of the results showed:

‘Based on objective evaluations, thirty of the thirty six cuts tested showed that the pavement surrounding the cuts had weakened to some degree, between one and six feet in lateral extent. That is, approximately 80% of the cuts tested showed damage. The remaining six cuts exhibited no apparent damage to the surrounding pavement. Age of the cuts may be a factor. Four of the seven cuts were between 1 and 2 years old, while two were 7 and 8 years old, respectively. The ages of the remaining cuts were unknown. This suggests that, in most cases, it may take several years for the damage to become evident.’

The study also showed that:

‘to restore the disturbed pavement to its original strength will require, under average conditions, the application of an overlay 1.75 inches thick.’

Bodosci et al. (1995) also presented a utility reinstatement management system, called Utility Cut Condition Index (UCCI), that was based on objective measurements of deflection and a subjective visual distress evaluation. The intended use of the management system was to identify conditions of utility reinstatements within a city and to assign priorities for their maintenance. This tool synthesises field evaluation procedures, cost management and policy issues that relate to pavement sections affected by utility reinstatements. A team of trained personnel had the task of conducting the distress surveys. In an analysis of 94 utility reinstatements located in bituminous and macadam pavements within Cincinnati, Ohio, the UCCI’s were computed for each reinstatement and statistical regression models were developed as a function of age for three levels of traffic (low, medium and high). The reinstatements were carried out by two main utility companies, namely Cincinnati Gas and Electric Company (CG&E) and Cincinnati Water Works (WW). The results indicated that:

‘for a given threshold value of UCCI (chosen to equal 65), cuts have an average life of 9 years when restored by CG&E and 7 years when restored by WW. This may be contrasted with the 15 to 20 years of life for a newly resurfaced pavement.’

5.1.3 Kansas City study
Terracon Consultants were commissioned by the Kansas City authorities to assess the effects of utility trench reinstatements on the structural capacity of the surrounding pavements (APWA, 1997). This involved carrying out FWD measurements to evaluate 24 sites of composite pavements with bituminous surfacing layer, which were selected by the city’s Public Works Department personnel to be representative of different levels of traffic, containing less than two-year old patched reinstatements.

Deflection results obtained from FWD measurements showed that the edges of the reinstatements had 50 - 65 per cent of the structural capacity of the centre of the reinstatement (the assessment method of structural capacity was not reported in the APWA review (1997)). The review also reports on the substantial subgrade softening occurring next to the reinstatements, in 35 per cent of the cases. The additional overlay needed to offset the structural deficiency within the 1.75 feet zone of influence was 1.5 inches (3.8mm).

5.1.4 Austin, Texas study
An engineering consultant firm was commissioned by the City of Austin to study the impact of utility trench reinstatements on the change in pavement life (APWA, 1997). This involved carrying out deflection measurements on and off the trench reinstatements using a Dynaflect. Special software was used to convert the deflection into strains at the base of the asphalt layer, and hence to calculate the fatigue life of the pavement.

The analysis showed that, in comparison to untouched pavements, 68 per cent of the measurements over trenches predicted reduced trench life, with 15 per cent predicting no change in pavement life and 17 per cent predicting increased pavement life. The range of actual decrease in pavement life varied from 2 to 40 per cent, with an overall average decrease of 15 per cent. The number of test sites was not reported in this review.
5.1.5 Santa Monica study

APWA (1997) reports on a study carried out by a consulting firm for the City of Santa Monica to determine the structural integrity of trenched pavements using a FWD. The results (as reported) showed that the average life of a pavement in Santa Monica would be reduced by a factor of 2.75 (64 per cent) due to utility reinstatements.

5.1.6 Sacramento study

In 1996, CHEC Consultants were commissioned by the City of Sacramento to study and quantify the extent of damage caused by utility reinstatements (as reported by APWA, 1997). A Dynaflect was used to measure deflections on and adjacent to reinstatements in streets paved with bituminous materials. This study distinguished between the transverse and longitudinal trenches.

It was found that, on average, longitudinally trenched pavements require an average of 39mm of bituminous overlay to provide an ‘adequate’ structural condition. The study also found that a zone of influence of 3.64 feet (1.1m) exists on both sides of a transverse trench reinstatement where pavement strength would be lost.

5.1.7 San Francisco study No. 1

The impact of utility reinstatements on the service life of San Francisco city streets (98 per cent of which were bituminous surfacings) was carried out by Tarakji (1995; 1997) of the San Francisco State University between 1992 - 1995, as commissioned by the Public Works Department for the city of San Francisco. This involved the analysis of the Pavement Condition Index (PCI) versus the age of the street for various numbers of utility reinstatements. The findings suggest that utility reinstatements have a detrimental effect on pavement life. The study (as reported by Zeghal and Mohamed, 1999) showed that:

‘increased levels of utility cuts accelerated the pavement ageing process. The analysis concluded that the service life of pavements will be reduced by 30% and 50% in streets with 3 to 9 cuts and streets with more than 9 cuts, respectively.’

5.1.8 San Francisco study No. 2

When the Tarakji (1995) study findings were challenged by the Construction Technology Laboratories (NVA, 2000), another study titled ‘The impact of excavation on San Francisco streets’ was conducted by a panel of pavement experts and a statistical consultant. The Department of Public Works initiated and completed the report in 1998. The study summarised by NVA (2000) showed that, on average, pavements with utility reinstatements had lower condition scores than pavements without reinstatements. Also, when the number of reinstatements increased, the condition scores decreased. This was confirmed for three scenarios, including the number of reinstatements per block, the number of reinstatements per area or the reinstatements as a percentage of area (all at a 95% confidence level). It was reported that:

5.1.9 San Francisco study No. 3

In a later study carried out by Chow and Troyan (1999), San Francisco’s Pavement Management and Mapping System (PMMS) was used to quantify damage from utility reinstatements. This involved data collected between 1984 to 1999 only on roads with complete construction histories, which were less than 20 years old. Two types of data were used in this study - pavement age and pavement condition, using yearly visual surveys. Pavement age was determined from the records of the last resurfacing. The condition rating of each road section was based on three criteria - ride comfort and smoothness of the surface, cracking (including reflective, block and fatigue) and ravelling (including the severity and extent of surface erosion from weathering and traffic). Hence, a pavement condition score was calculated as follows:

\[
\text{Condition score} = 100 - \text{ride score} - \text{cracking score} - \text{ravelling score}
\]

The condition score of a newly-paved street should ideally correspond to a score of 100. Excellent pavements would be expected to have a score of 80 to 100, with those in good condition earning a score of 60 to 79. A score of 40 to 59 would place the pavement in a fair condition; a score less than 40 would indicate poor performance.

The investigation looked at the relationship between pavement condition and the occurrence of trenches under the following three scenarios:

- the relationship between pavement condition and the existence of trenches;
- the relationship between the number of trenches and pavement condition; and
- the pavement age at which trench damage becomes negligible.
The study found that there was a linear relationship between the observed condition score and pavement age for pavements with and without trenches, though the degree of fit was better for pavements without trenches ($R^2 = 0.47$) than for those containing trenches ($R^2 = 0.29$). The research concluded that:

"trenching reduces pavement condition at certain ages. In general, trenching pavements before the age of 20 will damage the pavement prematurely. This damage decreases as the pavement ages."

The analysis quantified the damage for different pavement age categories in terms of the lost condition scores. For example, the analysis showed that, for less than 5-year old pavements, the damage caused by two trenches was equivalent to a loss of 9 condition points. The loss in condition for pavements of age 6 to 10 years for the same trenches was equivalent to 3 points. The damage became less as the streets became older.

### 5.1.10 Los Angeles study

The City of Los Angeles, Department of Public Works funded this study. It aimed to assess the effect of utility reinstatements on pavement life and rehabilitation costs using a combination of visual condition surveys, deflection and penetrometer testing on a total of 100 sections with utility reinstatements (fifty 'local' streets and fifty selected 'major' streets) and adjacent control sections (as reported by NVA, 2000). The results showed that the life of the selected streets with utility reinstatements was 16.5 years in comparison to the 25 years for the control sections (APWA, 1997). The calculated life of local streets with reinstatements was 28.5 years in comparison to 34.5 years for the control sections.

The deflection tests (APWA, 1997) also showed that:

"a considerable increase in deflection in and around the patching areas (reinstatements) and adjacent pavement edges as compared to the original pavement. This translates into weaker structural support for traffic and shorter pavement life span."

### 5.1.11 Union City, California Study

This study was funded by the City of Union City, California Department of Public Works to verify that Union City’s streets experience damage due to trench reinstatements and to quantify that damage in order to establish a fee to offset the cost of damage (as reported by NVA, 2000). The conclusions were that 68 per cent of the 16 evaluated streets showed a significant loss in strength from being sited in the zone of influence around the trench reinstatement area. The increase in deflection values within the zone of influence near a reinstatement ranged from 0 to 74 per cent. Also, the deflection tests carried out around transverse trenches showed that a zone of influence of 1.22 to 2.13 metres (4 to 7 feet) developed on each side of the trench or repair area. There was, however, no correlation between trench width and the magnitude of the damage.

### 5.1.12 Seattle, Washington study

This study was commissioned by the City of Seattle Transportation in 1999 to study the impact of utility reinstatements on street pavements, aiming to determine the extent of pavement degradation and costs associated with maintenance repair and rehabilitation due to the presence of utility reinstatements (NVA, 2000). The report applied two separate methodologies for the study. The first one relied on the overall condition index (OCI) to characterise performance. The study found that, despite using OCIs from two different survey data (1994 and 1997) for 300 pavement sections, "obvious trends defining the negative impact of utility cuts on pavement performance were not apparent."

The second methodology relied on deflection testing and overlay design to establish the impact of utility reinstatements on pavements, involving MicroPAVER condition surveys on 37 streets (nine asphalt, ten concrete and 18 composite sections). A preliminary screening using the maximum average deflection showed that the presence of utility reinstatements had an adverse impact on the pavement in 21 out of 37 cases (equivalent to 57 per cent). A statistical analysis of the data for both the asphalt and composite sections showed a worsening in the condition of streets (by 14 and 7 points, respectively). These results are reported to be significant at the 10 per cent level. Also, all nine asphalt sections required "additional overlay thickness as a result of the presence of utility cuts."

Out of the eighteen composite sections, eight sections also needed additional overlay thickness.

### 5.1.13 Oklahoma study

Research carried out into the residual life of aged interstate highway pavements in the United States has highlighted the importance of invasive measures in the performance assessment of existing pavements in addition to conventional non-destructive measures (Mooney et al., 2000). A forensic investigation of a 22.5km length of interstate highway in Oklahoma, consisting of multiple concrete overlays accumulated over a 40-year period is detailed. A thorough non-destructive investigation was carried out using FWD testing and Ground Penetrating Radar (GPR). This was followed by a detailed invasive investigation involving coring, drilling and sampling, laboratory testing and trenching.

The pavement layer profiles deduced from non-destructive test results alone failed to show a significantly weakened subsurface concrete layer that was revealed during invasive testing. Mechanistic analysis of the perceived pavement and actual pavement layer profiles revealed a significant difference in fatigue life. The study concluded that reliance on non-destructive testing alone for pavement analysis and rehabilitation design would result in significant errors in determining residual life.

### 5.2 Canada

In a recent comprehensive study in Ottawa-Carleton Canada, the cost and impact of utility trenching on the long-term performance of an urban road network was investigated (Lee and Lauter, 1999 and 2000). The results
from a two-year study on the impact of utility trenching on an urban flexible road network are presented with respect to pavement roughness, pavement surface distress, structural carrying capacity, pavement life cycle, rehabilitation and maintenance requirements, and the costs associated with these impacts. The field data were collected from over 50 urban roads and 35 rural roads, over 700 urban and 580 rural road sections amounting to a total of 170km urban and 600km rural road lengths.

Pavement performance and life-cycle relationships were developed using modified methodologies to address concerns raised by reviews carried out by Construction Technology Laboratories Inc. and the National Research Council of Canada, on utility trenching studies to date.

The study found that the use of a composite Pavement Quality Index (PQI) performance model, which combined the pavement surface distress, structural adequacy and pavement roughness performance criteria, provided a significantly superior model for analysing the impacts of utility reinstatements on the present and future loss of serviceability. This model was used to determine the impact of trenching on the pavement service life.

In the Ottawa-Carleton study, normalised individual pavement section life cycles, composite pavement quality indicators, and performance prediction models calibrated with numerous years of field data were used in the life cycle and pavement performance determination.

Results from this study indicate that utility trenching shortens the lifecycle of urban pavements by 7.8 per cent when trenching impacts are spread over the pavement surface area of the entire urban road system. A reduction in pavement surface life of 32.4 per cent is calculated when the trenching impacts are proportioned back to just the trenching area involved.

Results from pavement life cycle relationships developed in this study, indicate that road sections with longer pavement life cycles will experience higher life cycle losses due to the effects of utility trenching compared to road sections with shorter life cycles. Utility trenched areas were estimated to occupy about 24.1 per cent of the total urban pavement surface.

Non-destructive pavement deflection testing results indicated that utility trenching had a significantly negative impact on the fatigue structural carrying capacity of the pavement within the trenched areas. The results of this study indicated that, on average, utility trenching reduces the fatigue structural carrying capacity of the pavement in the trenched areas by 8.5 per cent. This would require pavement strengthening within the trench with about 32mm of hot rolled asphalt to restore the fatigue structural carrying capacity lost due to trenching. The cost to restore the fatigue load carrying capacity of the trenched areas back to the same level as the areas not affected was found to be the largest component of the total costs attributed to trenching.

Based on the structural carrying capacity and pavement roughness profile analyses, the impact of the utility trenching was found to extend beyond the edge of the trenches by an average of 0.55m for the trenches studied. Using the conservative assumption that the zone of influence at the bottom of trench is zero, a zone of influence extending 30 per cent of the depth beyond the edge of trench width was calculated.

This study did not quantify the cumulative impact of utility trenching on the loss of pavement life between rehabilitation cycles. It was, however, considered that some of the pavement areas where trench impacts were still evident had undergone more than one cycle of resurfacing. When the life cycle lost equation was developed using the ‘snapshot in time’ condition survey of the pavement condition, the mitigating impacts of all rehabilitation works resulted in reduced distresses, more structural strength and less pavement roughness in the trench areas than otherwise had resurfacing works not been carried out.

5.3 United Kingdom

5.3.1 TRL study around Southampton and West Sussex
This study consisted of a structural and visual assessment of in-service trenches and newly constructed trenches, reinstated to the requirements of PUSWA and the Model Agreement 1974, prior to the introduction of the New Roads and Street Works Act 1991, over a three to four year monitoring period (Burtwell and Hurst, 1995). This study examined the effects of the presence of services on road performance on eight sites in Southampton and six sites in West Sussex, using deflection measurements by FWD and visual condition assessment of service deterioration monitored over time.

The results of deflection analysis showed that where an untrenched control was available, the trench was always weaker than the control and, in most cases, the wheelpath adjacent to the trench was also weaker. The trench was often weaker than the adjacent wheelpath. Although most sites showed a trend towards improved strength with time, the rate at which trenches became stiffer was lower than the control wheelpaths.

The results also showed that many of the failures were found near the ends of the trench. It was concluded that poor compaction at the ends of trenches was the likely cause of this failure perhaps due to the difficulty in using equipment in the more confined area. It was also recognised that there were three planes of potential weakness at the trench ends compared with only two in the centre of the trench. This provided some evidence to support the view that long-term damage to the road by reinstatements could occur, particularly when they were not constructed to the requirements of PUSWA and the Model Agreement 1974. For example, using significantly different sub-base constructions in trenches to that found in the road, such as granular sub-base instead of lean concrete, could weaken the existing construction.

The study also found that the quality of reinstatement material in the transverse trenches also affects the deformation of the pavement along the wheelpaths. One road where part of the original DBM sub-base was replaced by Type 1 showed vertical deformation by as much as 12mm along the nearside wheelpath after 34 months. The same trench was reinstated by lean concrete on the opposite carriageway, which showed settlement levels in the wheelpaths ranging from 4 - 8mm.
It was also concluded that a reinstatement remained weak if a temporary reinstatement was carried out prior to a permanent reinstatement whereas a first time reinstatement generally showed better performance.

5.3.2 TRL study in Lincolnshire
In a follow up study to that carried out in Southampton and West Sussex, TRL was commissioned by the Department of Transport (now Highways Agency) to determine the effect of longitudinal trench reinstatements on the deterioration of all classes of road in Lincolnshire (Burtwell and Howe, 1996). Although these trenches were reinstated to local specifications, prior to the introduction of the HAUC Code of Practice Specification (DoT et al., 1992), the measurements were compared to a number of performance requirements over the HAUC guarantee period, namely surface depression, surface crowning and cumulative settlement as indicators of structural integrity.

It was found that the deterioration of an existing pavement, as a consequence of a longitudinal trench, was influenced by the width and depth of the trench for a given level of trafficking. The deflection results in four out of seven trenches indicated a significant deterioration in performance immediately after trenching. Also, the greatest settlement was found to occur during the first nine to fifteen months. On the narrow trenches the surface depression limit was not exceeded on the lightly-trafficked sites, although there was non-compliance on the more heavily-trafficked sites. On trenches wider than 900mm, which were heavily trafficked, the trench depth directly influenced the surface depression. Trenches wider than 1.4m and trenches deeper than 2.7m produced the greatest surface depression and cumulative settlement, particularly in the wheelpath adjacent to the trench. Higher traffic loading (>2msa) caused greater damage, particularly in terms of wheelpath rutting immediately after trenching. The standard of compaction and type of backfill also influenced the performance of the trench and the road. Many of the trenches exhibited deterioration of the bituminous surfacing material, which was mainly attributable to poor workmanship and poor compaction.

5.3.3 TRL study in the Pavement Test Facility (PTF)
A comprehensive study commissioned by the Department of Transport (now Highways Agency) and the National Joint Utilities Group (NJUG) was carried out by TRL. The objective of the study was to examine the effects of eight trench reinstatements, built to the draft SWP134 Specification, on the long-term performance of a Type 3 pavement (road) and the effects of traffic loads on buried pipes (Burtwell and Blackman, 1997).

The study was conducted as a trial at TRL’s Pavement Test Facility (PTF) designed to determine the structural performance of granular and foamed concrete backfill materials and their effects on overall pavement performance, pipes and the wetting up of the subgrade. The test sections within the PTF pit were all constructed on uniform clay subgrade in order to eliminate any variation in the construction of the pavement. Eight trenches were excavated and reinstated in the constructed pavement.

Also, the test sections were in a fully temperature controlled environment without any fluctuating temperatures or adverse weather conditions (hot or cold). This meant that the trafficking of the pavement and reinstatements were carried out at a reasonably constant temperature. This provided the confidence to isolate the behaviour of each trench within the pavement and its interaction within the pavement. A typical Gaussian distribution of trafficking, at 11.5 tonne axle load, was applied across each of the trenches. Performance measurements - deflection, strain, stress, profile and rut depths - were carried out at simulated 6 monthly intervals over a simulated 4.5 year test period.

The observations throughout the whole process indicated that the standard of workmanship in excavating and reinstating the trenches was typical of current utility practice carried out in regular operational conditions. The overall standard of the pavement construction, trench excavation and the various stages of pipe laying and full reinstatement were, in most cases, undertaken at the lower tolerances of the requirements of the Specification.

The study was undertaken in controlled conditions where no weathering effects were included. The subgrade was of uniform strength and the Type 3 pavement was not aged in terms of its actual life, being only two years old under simulation when it was trenched.

The results showed that, within the HAUC guarantee period, no consequential damage was observed using either granular or foamed concrete backfill material and no permanent maintenance was required to the trenches or the original pavement. No significant changes were found in the deflection, visual deterioration on the control or trenched sections. The majority of settlement could be attributed to the horizontal movement of the bituminous material rather than the increase in settlement of the backfill materials.

After a simulated two years of trafficking on the built pavement and a simulated 2½ years of reinstatement and pavement trafficking, the good performance of the trenches and the pavement indicated that sustained sound performance was likely to be achieved throughout the remaining life of the pavement. Also, the subgrade strain measurements showed no significant differences in the trenched and untreated sections.

The performance of the pavement and trenches showed that the Specification was robust, if not conservative, and that if the specification was adhered to in every respect, good performance would be expected both from the trenches and the adjacent pavement.

5.3.4 University of Southampton study
During the period 1985-1988, a field study of the long-term settlement characteristics of some 120 reinstated utility trenches was carried out in and around Southampton City by the University of Southampton and was funded by the Engineering and Physical Science Research Council, EPSRC (Fleming and Cooper, 1995). The site work covered an area of some 300km², including heavily used major traffic routes – often with complicated historical substructures – old and new residential routes, and rural
routes which included busy commuter routes as well as scenic and quiet country routes. The study focused on trenches that were accessible before their reinstatements were carried out, to allow some measurement of the trench dimensions of the in-situ and/or imported materials. The work involved measurement of surface profile across the trench using a profile beam and classification of the backfill quality.

The sequential monitoring of reinstatements showed the settlement process. Immediate profile measurements in eight of the trenches prior to trafficking showed no perceptible downward (i.e. less than 1mm) movement. The larger magnitudes of the settlement occurred with increasing trafficking. The reinstatements in subgrade Class A roads maintained a higher rate of settlement for a longer period than Class B and C roads. The rate of average settlement varied considerably depending on the age of the trench. Data showed that 83 per cent of trenches less than six months old had a rate of settlement greater than 2mm/month. In the second half of the year, only 35 per cent maintained the same level of settlement (in contrast to 74 per cent that had a settlement greater than 1mm/month). Over one third of the trenches were still settling at the rate of 1mm/month after 12 months.

The assessment of backfill quality was based on material type and level of compaction achieved. It appeared that 40 per cent of the trenches analysed were backfilled with imported granular materials, predominantly wet mix. A further 50 per cent used selected in-situ as-dug materials (predominantly stiff gravelly clay), with the remaining 10 per cent using both in either two distinct layers of approximately equal thickness, or in some cases a mixture of these materials.

A comparison of the performance of trenches reinstated with selected ‘as-dug’ materials with that of the traditional Type 1 backfill material showed that the average settlement is greater when ‘as-dug’ materials are used – this difference tended to increase with time, showing the time-dependent consolidation of the predominantly clay fill. A comparison of the density in the reinstatements showed that, in the wheelpaths, it was generally higher than that found between wheelpaths, confirming the progressive compaction of the sub-base layers due to trafficking.

The workmanship in these site observations proved to be a valuable addition to the study of such uncontrolled phenomenon. It was found that, in the majority of cases, good practices of compaction were not complied with, the principal deviation being caused by an attempt to compact the backfill in one lift and then applying as many passes as possible to overcome the problem of layer thickness. The adequate support of trench sides was virtually non-existent, which led to settlement of adjacent carriageway and significant over break in poorer ground conditions. Selection of suitable backfill varied enormously and, quite often, the original demolished pavement surface layers and cobble-sized fragments of concrete were included.

The quality of temporary surfacing materials was also investigated in the study. They varied significantly from a very plastic material that would bleed under loading, to a very stiff almost brittle material that would crack or deteriorate very quickly.

It was concluded that good workmanship was the key to good performance of reinstatements.

6 Specification requirements for reinstatements

Research carried out both internationally and nationally on specification requirements for reinstatements is described in this section. The work is discussed separately for each country.

6.1 North America

In an effort to reduce unnecessary damage to pavement service life, under Open Pavement Cut Policy, Monroe County in New York requires all utility crossings to be bored (Monroe DoT, 2001). However, open trenching to County highways may be considered if any of the following conditions are met:

1. Major maintenance or roadway improvements are scheduled for the highway within the following three-year period.
2. The road was last resurfaced or surface treated at least five years earlier.
3. The road was reconstructed at least 10 years earlier.
4. Roads that are in poor structural condition and have been approved for open trenching by the County Superintendent of Highways.

All open trenching is required to be saw cut (45° to 90° to the edge of the pavement) and reconstructed in accordance with the Department’s pavement restoration and/ or paved shoulder restoration details.

Similar arrangements are also in place in other US Counties. In Tempe County in Arizona, all utilities crossing existing City streets must be bored or punched, unless permission to open a trench has been given in writing by the City Engineer or his authorised representative (Snyder, 2001).

6.2 Canada

Despite trench reinstatements being carried out to specified design and construction practices, there appears to be poor performance in some cases, leading to disagreements and litigation between the city authorities and utility providers. A review carried out by Khogali and Mohamed (1999) of the preliminary engineering analysis and consultation with stakeholders (highway authorities and utilities) showed that:

‘the absence of a sufficient engineering practice has been the main cause behind current restoration problems. There are instances where design and construction specifications set forth by city engineers were not adhered to, which many believe is the reason behind the reported premature failures. Nonetheless, the review of many existing restoration practices indicates that even when such specifications are
followed, performance of restored utility cuts remain unsatisfactory. Analysis of current practices indicates that existing technical specifications cannot guarantee adequate performance. Accordingly, management systems developed to enforce these specifications were not fruitful.’

In this regard, a series of performance based best-practice guidelines were developed that took into account the specifics of the site conditions, including conventional and innovative construction materials, environmental conditions, and local construction practice and expertise. These guidelines were thought to form a sound basis for developing an effective management system for utility works.

6.3 United Kingdom

6.3.1 Northern Ireland study of telecommunication ducts

Research carried out at the Highway Engineering Research Centre (HERC), University of Ulster has shown that a utility may be the party at fault in trench reinstatements since ducts have been installed at shallow depths of cover without fully realising the implications of doing so (Woodside et al., 1997). In laboratory conditions, representing the burial of telecommunication ducts, research has shown that ducts installed under current specifications employed by many utilities may undergo excessive deflections, in turn resulting in unacceptable surface depressions upon loading. Some of these may not occur until after the guarantee period has expired. The referenced paper presents results of a simulated traffic loading on a reinstated trench containing twin telecom ducts at different burial depths. It was found that ducts buried at cover depths less than 350mm suffered more than the 5 per cent deformation limit. Yet, a burial depth of 250mm is common in footway reinstatements.

6.3.2 TRL study of various utility trenches

TRL was commissioned by the then Department of Environment, Transport and the Regions (DETR) to identify any problems found nationally following the introduction of the New Roads and Street Works Specification for the reinstatement of openings in the highway (Spong, 1997, Burtwell and Spong, 1999 and Amor et al., 1998). The criteria for the study included the investigation of compliance with Specification, the standards of workmanship, long-term performance within minimum guarantee periods and any possible consequential damage to the road pavement caused by the works. Work commenced in 1993 by setting up sample studies and monitoring programmes in several Highway Authority areas in co-operation with the National Joint Utilities Group (NJUG) comprising Electricity, Gas, Water, Telecom, Mercury Telecommunications and Cable TV.

The observed working practices of utility operatives were compared with the Specification’s requirements. In the second observation stage, follow-up visits were made to these sites, to assess the early-life performance of the reinstated trenches against the performance requirements and compactive effort described in the Specification. The sites were aged between 8 and 21 months when visited. The general impression, gained from the site visits, was that most of the utility companies and their contractors were trying to comply with the Specification’s requirements, but there were some variations in working standards.

Results indicated that about 29 per cent of the sites were found to be reinstated to incorrect design options: 18 per cent of the sites containing layers of incorrect thickness and 11 per cent of sites containing incorrect materials for the chosen design options. This means that the structural integrity of three out of ten trenches could be compromised by the selection of a weaker design than that specified. Surface deterioration, e.g. cracking, was assessed during the second visit to the reinstatement sites. 82 per cent of the sites were found to be in ‘good’ condition or ‘very good’ condition, the age of the sites being between nine and 12 months at the time of this visit. The most common defect present in the sites of ‘adequate’ or ‘poor’ quality (amounting to nine per cent of the sites) was edge depression and the likelihood of further deterioration was considered to be significant (TRL reinstatement study for DETR, 2001).

As far as the long-term performance of the reinstatements is concerned, compactive effort is generally accepted, amongst highway engineers, as being the most important factor. A comparison of the observed compactive effort and the Specification showed that only 3.3 per cent of the sites, where observations were made, contained all layers with the correct thickness and received the correct compactive effort. Insufficient passes, which occurred in about 71 per cent of the failed sites, were the most common failure.

6.3.3 Environmental streetscape improvements

The Commission for Architecture and the Built Environment (CABE) champions better quality design in the urban environment. With support from the Office of the Deputy Prime Minister (ODPM), CABE commissioned Alan Baxter & Associates with assistance from EDAW to investigate the reasons for failure to deliver a sustained and progressive improvement to English streetscape despite the proliferation of official guidance and environmental schemes to improve streets. Unlike previous studies, the resulting report ‘Paving the Way’ (CABE, 2002) does not seek to provide design guidance. Rather it uses case studies from, for example, 12 towns and cities in England (e.g. London, Nottingham, Leeds, Aylesbury, Dunstable) and three European towns, Marseille (France), Copenhagen (Denmark) and Freiburg (Germany) to examine the decision-making and management processes influencing the design and maintenance of England’s streets. By considering the overall regulatory framework of guidance and management which sets the parameters for design solutions and compliance, the report suggests that there are other factors influencing the delivery of good quality design.

To quote the report:

‘The research highlights the institutional and cultural barriers, which hinder the realisation of successful and coherent street improvements.'
Irrespective of the quality of the design solution, long-term success is undermined by the following factors:

- The failure of utility companies to acknowledge their responsibilities in maintaining quality landscapes.

The report goes on to add that:

‘To improve street design, improvements must be made across the regulatory framework. These changes are entirely achievable under current statutory arrangements.

Successful streetscapes are also dependent on changing the management cultures in those bodies and professions responsible for street works.’

7 Developments in reinstatement practice

Research carried out both internationally and nationally on developments in reinstatement practice is described in this section. The work is discussed separately for each country.

7.1 North America

7.1.1 Brooklyn Union Gas/Consolidated Edison Company of New York laboratory study

This full-scale laboratory study, as reported by Todres and Baker (1996), aims to compare performance of trimback and non-trimback repairs, poorly- and well-compacted backfill and an evaluation of moisture intrusion. The trial included 12 trench reinstatements, 6 trimback and 6 non-trimback sections (each having an equal dimension of 3 ft \(\times\) 3 ft \(\times\) 3 ft) in a paved area at the contractors’ facility. Each reinstatement was subjected to 2.5 million repeated loading by means of a hydraulic ram applying an approximately 10,000 lb load (approx. 4.5 tonnes) on a 1 foot square (0.093 metres) contact area, i.e. a loading pressure of around 480kPa.

The results showed no failures with the well-compacted repairs - five of the six patches deflected less than 2.5mm. All the poorly-compacted repairs showed deflections greater than 6mm (with four exceeding 10mm). The poorly-compacted backfills with both trimback and no trimback repairs behaved similarly, within the statistical limits of the number of data points. The conclusions reached in this study emphasise the critical role of compaction in producing stability and good performance of the pavement surfacing layers.

7.1.2 Consolidated Edison Company of New York laboratory study

This full-scale laboratory study, as reported by Todres and Baker (1996), involved simulating a full-depth asphalt surfacing (5mm of surface course and 150mm of binder course) resting on a sand silt subgrade which was constructed in a 2.7m diameter and 1.5m deep soil box. Openings of 0.9m \(\times\) 1.2m \(\times\) 1.1m deep were excavated and then backfilled with a sand blended material to simulate that used in Westchester County. The loading system was similar to that used in the Brooklyn Union Gas study except that the loading was approx. 4 tonnes and the load was applied by rolling rubber pads to simulate tyre contacts. The variables studied were trimback, no trimback, good compaction versus poor compaction of the backfill and the use or no use of a patented metallic reinforcement grid for the asphalt patch. Deformations were monitored at different stages of the load cycles. The maximum deformation registered after 40,000 cycles was less than 9.5mm for all but one reinstatement which gave a value of 12.5mm (with low backfill density, trimback and using the metallic reinforcement grid).

The results showed that compaction is the most important element in ensuring sound performance with no particular advantage being gained in using a trimback repair. Also, the asphalt reinforcement was not effective in bridging poorly-compacted backfill.

7.1.3 Southern California Gas Company studies

In a research study into the best engineering practice of utility reinstatements in asphalt pavements, Todres (1999) reviews three field trials carried out for Southern California Gas Company in 1989, 1990 and 1992-96. One of the objectives of the 1989 trial (archival study), carried out by ARE Inc., was to revisit the site that had been constructed three to six years earlier to evaluate the soil compaction level existing in the trench. In evaluating the settlement information, it was found that a backfill density of 90 per cent modified Proctor maximum was the boundary between a pass/fail for settlement performance. Above 90 per cent, there were no failures, with the maximum settlement being approximately 3mm, whereas at densities below 90 per cent, although some trenches also showed zero settlement, they were generally greater than 3mm, with a significant percentage greater than 9.5mm or 12.7mm.

The research did not find any functional relationship between density and settlement. Reinstatements with trimbacks (T-sections) were thought to improve performance (NVA, 2000) but quantitative information was not available, thus recommending additional studies to be carried out.

In the 1990 field trial (Carson Street study), 16 trench reinstatements were placed in the wheelpath of a heavily-trafficked lane carrying a significant proportion of lorries and buses (Todres, 1999). The existing pavement was in reasonably good condition, with few cracks and no previous trench reinstatements. The reinstatements were designed to allow the investigation to be carried out into the effects of backfill density (low, medium and high, targets being 85 per cent, 90 per cent and 95 per cent modified Proctor maximum, respectively) and repair configuration (standard and trimback sections) on the performance of the reinstatements. The research also included comparisons of hot-mix and cold-mix bituminous surfacing materials. Profile and deflection monitoring was carried out over a two-year period after completion using a
straightedge and wedge device and a Falling Weight Deflectometer (FWD) respectively (no FWD measurements were reported in this paper).

The main findings are:

- No significant difference was observed in the performance of standard and trimback section repairs that were surfaced with hot-mix asphalt.
- The cold-mix asphalt patches did not perform well in terms of surface deflection, but it was not certain whether this was an inherent problem with the mix, or the result of the lower patch densities generally achieved.
- Backfill density of at least 85 to 90 per cent modified Proctor gave acceptable performance, regardless of reinstatement geometry (standard or trimback sections).

In the 1992-1996 trial (Florence Avenue study), construction was completed in 1992 and monitoring took place between 1992-94. The site was re-visited in 1996 (Tordes, 1999). A total of 18 reinstatements were made in the wheelpath of a pavement with an average daily traffic of 3200 vehicles, including a reasonable number of lorries. The existing pavement did not have any visible damage in 1992 but had suffered fatigue cracking in the wheelpaths. FWD measurements were made on the reinstatements, in the nearside wheelpath and on undisturbed pavement (although not reported in this study). Similar results were reported to those of the second trial in 1990.

Another APWA (1996) report addresses the need for co-ordination and regulation of utility operations as a valuable community resource. It reviews the issues involved and includes examples of North American practices to improve co-ordination efforts. Khogali and Mohamed (1999) view the co-ordination between the utilities and road authorities not to be effective in managing schemes. They make a few recommendations to reduce confusion about reinstatement issues, namely a joint venture approach for investigating future solutions, development of performance-based specifications as well as considerations given to the requirements of improvements to management procedures.

### 7.1.4 FHWA field guide

A field guide was produced by the US Department of Transport (FHWA, 1996) which focuses on utility excavation and restoration operations in a timely and safe manner to minimise disruption of traffic and commerce. This guide highlights proper procedures, precautions, work steps, methods, equipment and materials. Despite the diversity in the structure and size of local governments, the guide recognises that local governments retain the ultimate responsibility, regardless of who does the works. It is also recognised that government agencies, utility companies and contractors must do everything possible to ensure that reinstatements are carried out correctly and safely with minimal disruption of traffic and without leaving behind a defective pavement.

### 7.2 Canada

The adverse effects of utility reinstatements on the integrity of city streets have been a major concern for Canadian municipalities. Research carried out by the National Research Council of Canada (NRCC), Institute for Research in Construction (IRC) (Baer, 1998) indicates that patches over utility reinstatements last little more than three years before they deteriorate. According to this report, in some cities, road crews return up to five times in the first year or two after a reinstatement, to repair the patch while the trench settles. Phair (2000) reports on the findings after utility deregulation, where it was not uncommon to have 15 or 20 different companies cutting into and patching a stretch of road, each using a slightly different reinstatement method. Due to the high cost of such reinstatements to municipalities, in some cities such as Los Angeles, utilities are now being forced to maintain the integrity of the road surface for the life of the road.

In response to this challenge, IRC assembled, at a cost of £1 million, a consortium of municipalities and utilities in 1998 called the Utility Cuts Consortium (including the National Research Council of Canada and US Army Corps of Engineers) that is dedicated to finding new ways to handle utility reinstatements. The multi-year research program aimed to yield practical, cost-effective solutions for dealing with the damage done by utility reinstatements, whilst addressing the concerns of municipalities, utility providers, materials suppliers and equipment manufacturers. This was to involve laboratory tests, analytical modelling, designed to evaluate the entire road structure and better predict the effects of traffic and thermal and moisture-induced loading and fully instrumented field trials. No preliminary findings have been reported from this study to date.

In an earlier study carried out in Canada in 1995, seven different types of backfill material to water-main trenches were considered. The backfill materials included native clay, sand with and without insulation layers, two controlled low-strength materials, expanded shale lightweight aggregate, and bottom ash from a local coal-fired generating station. An innovative insulated backfill material was also developed using chipped-up plastic yoghurt and margarine containers collected by the Regional Ottawa-Carleton Municipality’s recycling program. The research was aimed at showing the efficiencies and deficiencies of each kind of material. The results showed that some materials such as clay are good insulators but the road containing them could settle. Cementitious materials, on the other hand, support the roads but promote frost penetration deeper into the trench.

A review of road trenching and reinstatements on regional roads in Ottawa, Canada and their impact on cyclists carried out by the Regional Municipality of Ottawa-Carleton was reported in an internet article (RMOC, 1998) which stated that:

> ‘road cuts are often reinstated poorly and cause permanent damage to the roadway structure, decreasing the time before it must be rebuilt. While the utility work is being done and after the road has been ‘restored’ cyclist traffic may be subjected to an unpleasant, unrideable and even dangerous road surface.’
The study reports on selected poorly-treated temporary reinstatements remaining in place, in some cases even longer than a month, before proper reinstatements were carried out. In some cases, the uneven reinstatements were left to vehicular traffic to further consolidate the compaction. The study also reports on metal plates temporarily placed over openings in Toronto causing slipperiness for cyclists in the rain. Their sharp nearside edge was also a potential danger, which caused flat tyres and falls from bicycles.

### 7.3 United Kingdom

A non-technical article in Surveyor (1997a) draws attention to concerns by highway authorities about the reinstatements of cable TV trenches. The article makes reference to a report that highlights research, carried out by the University of Ulster, claiming that the telecommunication ducts were not installed deeply enough and were at risk from failure. The article also gives the results of the coring study carried out by authorities around the country in 1996 showing that almost 70 per cent of excavations and reinstatements failed to meet the criteria in the Specification. This may be partially due to the fact that there are no set standards for cover depth above these ducts. The results of trials carried out in Birmingham City on reinstatements were discussed (Surveyor, 1997a), which showed that up to 60 per cent were defective.

Feedback from NJUG members’ own coring work shows a success rate in the 60-80 per cent range (Surveyor, 1998). This article also shows the results of a coring study carried out by the London Borough of Fulham and Hammersmith on 100 carriageway sites two years into the NRSWA era as reinstatements approached the end of the two-year guarantee period. The study was repeated two years later. The results showed that the number of surface profile failures decreased, but visual and depth checks on the cores showed that 90 per cent were out of specification. The article also points out that out of one third of the sites that had passed their routine NRSWA inspection procedures, about 60 per cent ‘would benefit from remedial action’.

The lack of suitable training for all operatives in the field is also of concern. A news brief in Surveyor (1997b) indicated that by March 1997, up to three quarters of the operatives needed to be trained and registered before the August deadline, as laid down by the NRSWA 1991 Act. A spokesperson for NJUG indicated that

‘because the register only recorded successful candidates by name, it was difficult to collate information about where the missing operatives might be working.

We are in a position where we don’t know how many trained operatives there should be or where they are.’

This points to the possibility that some reinstatements could have been carried out by non-qualified operatives.

The desire to further improve utility works and highway works resulted in the preparation of Best Practice Guidance (The Stationery Office, 2001). It aims to draw the attention of Undertakers and Highway Authorities and that of road users in general to examples of best practice in all aspects of street works and highway works.

#### 7.3.1 Performance of edge cutting and sealant methods

In 1998/99 and 1999/2000, UK Water Industry Research Ltd (UKWIR) commissioned TRL to investigate the long-term performance of various cutting methods and sealing products used in the highway environment with their potential use for water industry (Lloyds, 1998; Lloyds and Spong, 1998; Amor and Burtwell, 1999; Amor and Burtwell, 2001). The tensile and shear strength properties of a number of proprietary products, available in the market, had not been fully explored and their role in the long-term performance of trench reinstatements therefore needed to be identified. Depending on the type of edge cutting, different sealant methods and products were identified from a market survey and from a questionnaire based survey within the water industry.

Best practice guidelines for edge cutting and sealant methods are recommended such as the use of a hand-held saw for the cutting of openings in highways as it causes minimal damage to the surrounding pavement and avoids the use of extensive trimback. The use of a jackhammer for the cutting of openings in highways is not recommended unless the joints are first sawn. The equipment causes damage to the surrounding pavement and extensive trimback is required particularly in cold weather when the asphalt is likely to be more brittle. The study also identified the need to exercise caution in selecting edge sealants for use in carriageway and footway environments. Some products were found to be better suited to trafficked situations than others. Their tensile and shear strengths dictate the suitability for waterproofing of joints and load transfer respectively.

#### 7.3.2 Performance of telecommunication manhole chambers

Carson Industries Ltd commissioned TRL to study the long-term performance of trenches containing a series of stacked rectangular telecommunication chambers, 900mm deep, surrounded by four different backfill or bedding materials (Zohrabi, 2001). The installation included a chamber surrounded by foamed concrete with a narrow backfill surround (less than 100mm) which was designed for confined spaces. Two other chambers were surrounded by a standard 150mm wide lean mix concrete, which was hand compacted due to inadequate surrounding space for a vibrotamper to operate. A further chamber was designed to simulate the worst case scenario; having hand-tamped Type 1 sub-base material as surround and bedding.

All four installations were subjected to a simulated traffic loading representing 20 years trafficking (500,000 passes) of an industrial estate distributor road (UK Class 4) using a super-single 4 tonne maximum wheel load applied both on and offset from the centreline on the material adjacent to the chambers where the trafficking effect was considered to be the most severe. The settlement measured on three installations surrounded by foamed concrete and
lean mix concrete showed that they met the HAUC performance criteria. The chamber reinstated representing lower quality bedding and surround using Type 1 sub-base material showed severe cracking along the off-centre trafficking path of the poor installation with reinstatement settlements of about 28mm, more than that allowed by the Specification intervention level. The general conclusion of the worst case installation is that hand tamping of even good quality Type 1 material in confined spaces does not replicate the degree of compaction that could be achieved by a conventional vibrotamper. The latter would require special attachments to the shoe to extend it for use in confined areas at greater depths.

7.3.3 Performance of access drainage chambers
In another trial, TRL was commissioned to study the performance of a particular design of circular access chambers (Crabb and Todd, 1999). The chambers had a telescopic section attached to the cast iron frame that is inserted through a gasket into the main body of the chamber. The principal feature was that the cover and frame could move to accommodate settlement and movement of the adjacent carriageway reinstatement.

The original concept allowed for the frame to be set directly into the carriageway construction with only the lower bound layers for support. Convention would have a concrete slab cast beneath the frame thereby enabling wheel loads to be more widely spread into the trench wall and backfill. This experiment was devised in order to compare the performance of three types of chamber installations, two with differently detailed reinforced concrete slabs and the third without a slab as originally specified.

The chambers were subjected to both super-single 4 tonne and twin wheel 5.75 tonne maximum wheel loads applied both on and offset from the centreline. The loading set-up represented a combination of the worst possible patterns that a reinstatement could be subjected to.

Precise levelling and profiling of the full reinstatement showed that, although the chamber with no slab settled more than the two chambers with the concrete slabs, they all met the pavement performance criteria for settlement limits set out by Specification. The general conclusion was that good workmanship was the key to achieving the performance criteria.

7.3.4 Efficiency of the reinstatement process
In an attempt to improve methods for excavating and reinstating street works, a new process for minimising the costs and increasing the efficiency of road excavation was developed by OnSite, the contracting division of South Staffordshire Water (Surveyor, 2000). OnSite’s Ex-Frame system was designed in collaboration with contractors, materials specialists, and utility companies. It controls the dimensions of excavations, enables excavation and backfilling to the required depth, and reduces total reinstatement cost. Its first component is a saw cut guiding frame, which allows straight clean cuts to be made through existing bituminous material. The surface is broken out after all the edges have been cut. The next step is to install the ExFrame edge protection frame, which currently has three standard sizes, though frames can be made of non-standard sizes. The frame is lightweight but durable and ensures compliance with the requirements of the Specification by providing guides and levels for backfilling and permanent reinstatement. One company has observed a greatly reduced reinstatement failure rate since it started using the ExFrame process.

7.3.5 Northern Ireland
Due to the large volume of road openings in Northern Ireland (currently around 900 openings per week, which is more than twice as many as in 1992) as reported by the Northern Ireland Audit Office (NIAO, 2001), the need for a rigorous inspection system was identified in order to check that utility work was completed in accordance with prescribed performance standards.

NIAO noted that:

‘some Section Offices within Roads Service appear to have a significant problem with regards to reinstatement work carried out by Water Service. In particular.... inadequate response from Water Service when notified of defective reinstatements..... the vast majority of reinstatements were temporary, many of which were never made permanent and remain defective.’

The results of a coring study supplied by the Roads Service to NIAO revealed that there was an upward trend in the overall failure rate of cores from about 38 per cent in 1996 to 44 per cent in 2000 (NIAO, 2001).

In respect of the long-term impacts of street works, the NIAO (2001) report highlights the Roads Service’s concern that:

’strieworks, especially those involving multiple openings, result in the need for a road to be strengthened at an earlier date than would have been otherwise necessary if it had remained undisturbed. Studies in the United States of America in a number of major cities have shown that no matter how good the utility repair, trenching reduced the life of a road between 15 and 30 per cent and the damage from utility excavations extended three feet either side of the trench. In NIAO’s view, this is a potentially serious matter because of the existing doubt about the long-term performance implications of the trenches themselves, consequent damage to the road structure and further disruption to the road user.’

8 Performance of alternative reinstatement materials
Research carried out internationally and nationally on the performance of alternative reinstatement materials is described in this section. The work is discussed separately for each country as for other sections in Part 1 of the report. The papers reviewed in section 7: Developments in reinstatement practice of Part 1 are primarily about the best engineering methods for reinstatements and the structural
quality of trenches. Section 8 is concerned with the performance of reinstatement surfacing materials and materials used as backfill and sub-base in the trench.

8.1 Australia
The Department of Road Transport in conjunction with the Australian Road Research Board (ARRB) conducted a series of full-scale pavement tests using the ARRB Accelerated Loading Facility on the South East Highway near Adelaide (Statton and Kadar, 1991). The aim of the trial was to test the relative performance of alternative forms of asphalt rehabilitation. An existing section of distressed pavement was repaired using a variety of thin overlay treatments and various thickness of asphalt reinstatement. A total of 17 loading experiments were conducted. The relative performance of the treatments was measured in terms of their resistance to surface deformation and crack propagation.

Preliminary analysis has provided a ranking of deformation resistance of all asphalt materials used with some modified binders displaying significant advantages over conventional C170 bitumen. Comparative overlay experiments clearly demonstrated a significant extension in treatment life through use of a modified binder in the asphalt overlay.

8.2 United Kingdom

8.2.1 Permanent Cold-lay Surfacing Materials (PCSMs)
The effect of Polymer Modified Emulsions (PMEs) on the stiffness and permanent deformation characteristics of Emulsified Bitumen Macadams (EBMs) investigated at Liverpool University are given in this paper (Khalid and Eta, 1997). Conventional and polymer modified EBMs have been developed for potential use in reinstatement works as Permanent Cold-lay Surfacing Materials (PCSMs). The specification criteria suggested by the Highway Authorities and Utilities Committee (HAUC) were used to ascertain the suitability of the EBMs for reinstatement works. The conventional and selected modified EBMs, together with equivalent hot-applied mixes developed in accordance with the HAUC equivalency criteria, were then used in a laboratory study to assess their fatigue behaviour. Controlled stress centre-point bending fatigue tests were carried out to arrive at fatigue life/strain relationships for both the hot and cold-lay mix varieties. The BISAR-PC Program developed by Shell was used to model typical flexible pavement constructions in order to study the materials’ response to traffic loading. The resulting strains were used to predict pavement lives with the candidate cold-lay materials. Structural support values for the EBMs, which can be used in pavement design, were then computed from the resulting fatigue lives.

The analysis revealed that the conventional EBMs had relatively low support values that would lead to a poor long-term performance. However, the modified EBMs were found to have the potential of giving an equal, or even better performance than the equivalent hot-applied materials.

8.2.2 Cold-mix thin asphalt surfacings
This paper (Robinson, 1997) describes the development of Cold Mix/Cold Lay asphalt mixtures incorporating Bitumen Emulsion and their suitability for trench reinstatements. It demonstrates their engineering properties and enhanced workability characteristics compared to their hot-mix counterparts, thus making them suitable for the trench reinstatement market. The importance of relating cold-mix design to expected performance in the field is covered in the paper. Typical data, including elastic stiffness, dynamic creep and residual voids obtained on field cores, are presented. Stiffness data obtained from major road trials in 1994 showed that the developed stiffness of the cold mixture over the two-year approval period exceeded the HAUC requirements. This provided the confidence to carry out machine laying trials involving Tarmac in 1994 and 1995. The 1994 trial involved laying three strips with a gap graded cold mixture incorporating a fluxed emulsion at three different binder contents to act as a benchmark. The subsequent trial in 1995, involved graded materials laid on a quarry road, subjected to heavy delivery vehicles that did not show any obvious signs of deterioration over an 18-month period. Energy saving aspects are also benefits to be considered should cold mixtures gain commercial acceptance in the UK.

The research showed that for a 10 per cent share of the total hot surface course market, this would yield a saving of 271 million Mega Joules (MJ) per year (Robinson, 1997). Also, the paper showed that adopting a cold-mix production process for this share of the market would save approximately 12 million cubic metres of carbon dioxide emissions per year.

The paper concludes that cold asphalt mixtures are a technically viable alternative to ‘hot’ materials and suggests that utility contractors will increasingly adopt them in the years ahead for reinstatement works. Growth in machine-laid cold mixtures will depend largely on how quickly a specification is developed.

8.2.3 Cementitious backfill
The research carried out by the University of Birmingham for National Power Plc, UK (Ghataora et al., 2000 and Ghataora and Alobaidi, 2000) follows the TRL’s study of defects in trench reinstatements, which is quoted to show that, in 90 per cent of cases, the compaction level of Type 1 backfill was incorrect and, in 50 per cent of cases, compaction was insufficient. In an attempt to investigate the use of materials requiring little or no compaction, this paper reports the results of field trials conducted on PFA:sand:cement, Lytag:cement, and Type 1 granular material. It first surveys the results of some earlier tests conducted from 1980 onwards. Before the field study, a large-scale laboratory model trench, made of plywood and perspex, was filled with the mixes chosen for the trials, and compression tests were conducted. The field trial was conducted to compare the behaviour of the two artificial materials and conventional Type 1 granular sub-base backfill. Surface profiles were measured after trench reinstatements, using a two-dimensional profile-measuring device. Core samples
from trial trenches were recovered one year after replacement, and their elastic moduli were measured. FWD tests were conducted one year after trench construction, to study the effects of various backfill materials on trench performance.

The trench backfill materials complied with the NRSWA Specification. Field trials showed that, although Lytag backfill performed better than Type 1 granular sub-base in terms of having lesser long-term settlement (less elastic deformation and permanent deformation), both materials showed settlements that were below the requirements of the Specifications (ranging 2-5mm in Type 1 material). A cost estimate of the backfill materials suggested that, although the Aardelite backfill performs similarly to granular sub-base, in the long term it may be a cheaper option as it requires little or no maintenance.

8.2.4 Northern Ireland

In a study carried out by Shaat and Al-Gassas (1994) at the Queen’s University of Belfast and supported by the DoE in Northern Ireland, reinstatement excavations by public utilities are considered as major factors, in addition to the effects of heavy traffic and the environment, that can cause serious damage to urban road pavements. Such damage was considered to be largely due to the inevitable settlement of traditional granular backfill as a result of inadequate compaction of irregular and pocketed trench sides. The authors believed that there was no way to compact both unbound or bound materials into undercut pockets and voids in trench sides of existing structures without consequential surface settlement and surface irregularities on the adjacent pavement surfaces. The paper also comments on over-specifying reinstatement standards by some highway authorities on pavements that were constructed prior to 1950, which had deteriorated stiffness, thus resulting in stronger reinstatements than the adjacent existing surfaces. It is the authors’ belief that incorporating a higher stiffness reinstatement would result in a differential stiffness condition on the pavement with the reinstatement having a longer service life than the untreated pavement. In an attempt to obtain reinstatement stiffness similar to those of the adjacent pavement, the paper examines the possibility of using different recipes of cement-bound materials to improve the backfilling and reinstatement of such excavations in different pavement stiffness conditions. This work is undertaken by carrying out some initial FWD measurements in a series of untreated flexible and rigid pavements. No FWD measurements were reported on the trenched pavements.

9 Performance of trenchless technology

Research carried out both internationally and nationally on the performance of trenchless technology for excavation and reinstatement is described in this section. The work is discussed separately for each country as for other sections in Part 1 of the report. Trenchless techniques are an alternative to ‘open cut’ methods where the layout of existing underground pipes and cables permit their effective use.

9.1 United Kingdom

In a comparison between traditional trenching practice and trenchless technology, Rogers (1996) outlines the primary causes of short-term and long-term ground displacements caused by trenching and pipe-bursting, and briefly presents methods of ground movement prediction for individual practical cases. It is argued that subsurface ground displacements due to pipe bursting tend to be localised, and dissipate rapidly away from the bursting operation. The original equilibrium tends to be restored with time and surface trafficking, thus reducing any displacements induced in adjacent services or structures. In contrast, trenches create discontinuities in an overlying road structure and reduce road life. The author notes:

‘while it is possible to damage the surroundings using the pipe-bursting technique, the potential for damage is considerably reduced in comparison with trenching and can be removed altogether by sensible design and precautions.’

Based on experimental data, the author suggested that for normal pipe-bursting operations:

‘consideration of temporary displacement to an adjacent service or structure need only be made if it lies within approximately 2-3 diameters of the replaced pipe, with significant permanent displacements occurring only closer to the pipe. Where large volumes of soil are to be displaced (e.g. for significant upsizing) more careful consideration will be required.’

The 2-3 diameter threshold will, of course, depend on the size of the pipe within a minor road and how close the pipe within the unbound layer is to the bound layer. There may be only one pipe diameter of soil between the pipe and the bound layer, in which case there is a possibility for surface cracking if the bound layers are relatively thin and/or weak.

9.1.1 Northern Ireland

In a report by the Northern Ireland Audit Office (NIAO, 2001) regarding trench openings by utilities, the Code of Practice for Co-ordination is highlighted, which is reported to encourage utilities to consider the use of trenchless techniques where practicable:

‘These techniques, such as pipe-bursting and guided boring, have many advantages. For example, they only require an opening at the start and finish points rather than opening the whole road. Not only does this reduce the extent of excavation and hence the need for reinstatement, it minimises disruption to traffic..... However, if not used in appropriate circumstances, these techniques can present road authorities with some problems. For example, pipe bursting can cause surface heave, which distorts the overlying road. The only remedy is conventional excavation and reinstatement.’

Recognising the attractiveness of the trenchless methods in causing minimum disturbance to the public and having
low impact on the environment. Khogali and Mohamed (1999) point out some potential obstacles to their use. These include the risk of construction failures due to unexpected underground obstacles, absence of maps or drawings to provide accurate underground information, high initial cost and a short history of proven success.

10 Economic measures against long-term damage

During recent years, many innovative techniques have been developed for rehabilitation of distressed pavement structures. Studies on the cost effectiveness of various rehabilitation strategies, for pavements that have reached a particular stage of their functional and economic life, have created a new generation of civil engineering technologies. However, the direct economic evaluation of the impact of utility reinstatements would require an in-depth evaluation of surface deterioration created by such operations. Environmental disbenefit and disruption are also two factors involved in the economic evaluation and together with other social factors such as loss of amenity may not be easily quantifiable. In the absence of specific guidelines for assessing the cost impact of utility trenching, different cities around the world have developed their own fee structures and payment schedules, payable by utility companies, which in the majority of cases relate to the size of the reinstatements.

Major research carried out both internationally and nationally on financial measures to safeguard the highway against long-term damage is described in this section. The research is discussed separately for each country. The fees reported for North America and Canada were in Dollars and have been converted to UK Sterling at an approximate rate of £1.0 = $1.50 for both countries.

10.1 North America

10.1.1 Santa Ana, California

A comprehensive review of a proposed trench excavation fee (also termed trench cut fee in the USA) by the Santa Ana City was carried out by Alvarez (2000). Several questions were raised regarding the trench excavation fee.

City having the policing power to impose a trench cut fee?

It was argued that under Article XI, section 7 of California Constitution that:

‘a city may make and enforce with its limits all local, police, sanitary and other ordinances and regulations not in conflict with general law.’

Article XI, section 5 of California Constitution enabled:

‘charter cities to enact laws with regard to any matters which are deemed local or municipal affairs.’

Under section 200 of Article II of the Charter of the City of Santa Ana:

‘within constitutional and legal limits, the City shall have the power to make and enforce all laws and regulations in respect to its municipal affairs.’

Article XI, section 9 of the California Constitution prescribed that:

‘corporations which establish and operate works for supplying light, water, power, heat, transportation or means of communication, to residents of a municipal corporation shall establish and operate such services upon conditions and under regulations that municipal corporation may prescribe under its law.’

The review concluded that the California Constitution combined with the Charter of the City of Santa Ana granted the City the right:

‘to adopt reasonable regulations regarding its right-of-ways, which reasonable regulations would include the imposition of a trench cut fee.’

Several questions were also raised and answered in this review, including the following:

The difference between the trench excavation fee and a tax?

The response was that this fee is not a tax as the purpose is not to enhance the revenue or to be used as general funds, but the objective would be to pay for ‘more frequent and more expensive street resurfacing caused by trench cuts’.

Is the trench excavation fee in violation of franchise agreements?

It was argued that a franchise is a ‘privilege granted to an individual or a corporation to use the property of a governmental body’. The government agency grants them:

‘to enable an entity to provide vital services with some degree of permanence and stability’. 

In response to the proposed trench fee ordinance by the City, the utility industry also proposed a model ordinance, aiming:

‘to ensure that City is protected from poor workmanship in trench cuts, create a co-ordinating committee and create a ‘penalty’ fee to deter trench cuts in streets repaved less than 3 years prior.’

The study did not propose actual fee rates for trench reinstatements.

10.1.2 Burlington, Vermont

The 1984 Burlington study (APWA, 1997) on the long-term effects of trench reinstatements on pavement structures (see Chapter 5) estimated an additional overlay of 19 to 38mm to be necessary to ‘compensate for patch induced pavement weakness.’ The extra costs attributing to utility trench reinstatements averaged over the 87 miles of streets in the City amounted to £2500 per km (£4,000 per mile). The City proposed a fee of £71.77 - £78.87 per square metre (£6.67 - £7.33 per square foot) for all reinstatements to be recovered from utility companies. The proposal was taken to court (APWA, 1997) by two utility companies and later settled out of court.
10.1.3 Cincinnati

The Bodocsi et al. (1995) study for the City of Cincinnati found that reinstatements in concrete pavements did not need additional strengthening. Based on the maximum deflection measurements in and around the reinstatements within asphalt pavements and on the control sections, the study found that an additional overlay of 29mm was needed. For a reinstatement with an average size of 1.2m by 1.5m, the cost of strengthening was estimated to be at least £630. Based on limited data, the report also showed that the total cost for the City of Cincinnati due to approximately 6000 openings in asphalt pavement per year could amount to a recoverable cost of £1.3M (an average of £216 per opening).

10.1.4 Los Angeles

To safeguard an acceptable performance criterion for utility reinstatements, some city authorities in the United States have introduced a trenching fee. In 1996-97, the city of Los Angeles Mayor proposed a street-trenching fee (Cal Tax News, 1996). According to the Mayor, the fee was to be based on the amount of trenching, and the age and condition of the street. The city intended to resurface some 200km (300 miles) of city streets in 1997. It was thought that the street trench fee would encourage better planning and co-ordination of resurfacing work. Meanwhile, in San Diego, the City Council’s Rules Committee deferred consideration of amendments to the city’s Right-of-Way Ordinance until there was a study on whether utility trench reinstatements were a factor in long-term deterioration of city streets.

In a recent survey of various highway authorities’ utility fee programme, NVA (2000) reports on the 1996 study conducted for the City of Los Angeles which showed a fee schedule per reinstated area and differentiated between ‘major roads’ and ‘local roads’ as a function of the pavement age. The fee for a major road varied from £101.14 per square metre (£9.40 per square foot) to £67.47 per square metre (£6.27 per square foot) for a 15 year old pavement to £67.47 per square metre (£6.27 per square foot) for a 10-15 year old pavement. In comparison, the fee for a local road varied from £37.34 per square metre (£3.47 per square foot) for a 1-5 year old pavement to £7.64 per square metre (£2.33 per linear foot) which doubled to £15.28 per square metre (£4.66 per linear foot) for a transverse reinstatement of the same age. In comparison, a longitudinal reinstatement in a pavement older than 15 years only required a trenching fee of £2.20 per metre (£0.67 per linear foot), which again doubled to £4.36 per metre (£1.33 per linear foot) for a transverse reinstatement within the same age pavement. The City of Sacramento is required to prepare a five-year repaving schedule. Similarly, utility companies are also required to prepare and submit a five-year utility master plan.

10.1.5 Santa Monica

City of Santa Monica (1998) reports on the development of a telecommunication master plan in 1997 that included drafting right-of-way management standards. The purpose of this master plan was to co-ordinate construction with different road users, avoiding repetitive street trenching whenever possible to prevent unnecessary financial burden to the taxpayers due to reinstatement degradation of the pavement. This approach ensured the long-term structural integrity, ride quality and aesthetic properties of the existing infrastructure, enhancing competition among telecommunications providers and promoting potential partnerships between the City and private utility companies.

As part of the process of developing final standards and goals, the City commissioned a study of appropriate utility trench reinstatement methods and appropriate fee structures for utility permit plans, inspection and use of the public right-of-way. No information has been provided on the current level of fees within the City. APWA (1997) reports on an earlier study by a consulting firm to assess the average extra yearly cost of patching for the City of Santa Monica which proposed a fee of £14.31 per square metre (£1.33 per square foot) of excavation to ‘compensate for street damage costs.’ The APWA (1997) report does not provide a date for this study; hence no current fee rate is available.

10.1.6 Sacramento

A later study carried out by NVA (2000) differentiated between longitudinal and transverse trench reinstatements in setting fees for Sacramento that was a function of the pavement age. The fee level for a longitudinal reinstatement in a pavement that was less than five years old was set at £7.64 per metre (£2.33 per linear foot) which doubled to £15.28 per metre (£4.66 per linear foot) for a transverse reinstatement of the same age. In comparison, a longitudinal reinstatement in a pavement older than 15 years only required a trenching fee of £2.20 per metre (£0.67 per linear foot), which again doubled to £4.36 per metre (£1.33 per linear foot) for a transverse reinstatement within the same age pavement.

The City of Sacramento is required to prepare a five-year repaving schedule. Similarly, utility companies are also required to prepare and submit a five-year utility master plan.

10.1.7 San Francisco

In a statistical study of trenched pavement conditions (see Section 5.1.9), carried out by Chow and Troyan (1999), it was found that pavement condition, due to utility excavations, becomes statistically significant for each reinstatement group up to the age of 20. The study suggested that an appropriate cut off date for assessing pavement restoration fees should be 20 years. The study also found that if trench excavation could not be postponed, the cost of the pavement damage should be commensurate with the loss in the pavement condition, as shown in Section 5.1.9 of this report.

A 1998 study carried out by JBS Energy, Inc. for the City of San Francisco (NVA, 2000), attempted to determine the total costs of re-paving due to excavation in City streets and to devise a method to reasonably allocate the cost among all utility companies.

The computed costs did not include excavation in concrete streets, costs of routine maintenance or repainting...
associated with excavation or litigation costs resulting from excavation. It also did not include any public user costs (i.e. delay or vehicle maintenance costs). The actual computed re-paving costs associated with excavation activities range from £37.66 to £60.15 per square metre (£3.50 to £5.59 per square foot). Based on this, the Department of Public Works proposed a fee schedule as a function of the age of the street. The amount of fee ranged from £25 per square metre (£2.33 per square foot) for 0-5 years (since last re-paving) to £7 per square metre (£0.67 per square foot) for 16-20 years (since last re-paving). It was claimed that this fee schedule would not fully recover the cost of re-paving determined in this study, but it was considered ‘reasonable and defensible.’

10.1.8 Union City, California
NVA (2000) reports on an economic study for trench fee evaluation for the City of Union City in 1998. The study was based on the loss in strength defined in terms of additional asphalt thickness at the time of rehabilitation, ranging from 0 to 75mm in thickness with an average of 33mm. The cost consequence of a trench at the time of rehabilitation of a pavement was estimated to be at least £37.89 per metre (£11.53 per linear foot) without consideration of life cycle costing.

10.1.9 Seattle
The development of the fee schedule in Seattle was based on the deflection testing approach, requiring additional overlay thickness in utility reinstated areas in comparison to control sections (NVA, 2000). In addition, the City’s maintenance policy indicated that:

‘10% of the pavement surface area had to be covered with low severity utility cuts before an overlay was required.’

Hence, a fee of £126.97 per square metre (£11.80 per square foot) (based on a minimum overlay of 50mm for construction reasons) was recommended. This included all engineering design, material and contract costs. Hence, the costs incurred by the public and businesses and the health and safety implications were not included.

10.2 Canada

10.2.1 Gander
In Gander, Canada, utilities are required to leave a deposit cheque for £300 ($500) with the Town Office for each reinstatement pending the complete reinstatement of the street. This deposit is held for 12 months, then refunded with interest. All work performed is subject to inspection and approval by the Town Authorities. Any undue settlement requiring repair by the street authorities within one year of the completion of the project is at the contractor’s expense (Gander, 2001).

10.2.2 Ottawa-Carleton
In a recent comprehensive study carried out by Lee and Lauter (1999), the economic impact of utility excavations were investigated. A sliding scale table was prepared that quantified the costing of trenching impacts using the number of years since the last rehabilitation was developed (based on an average life cycle of 12.7 years for the urban network). The costs ranged from a high of £15.63 per square metre for pavements that were resurfaced less than two years prior to the trenching works, to a low of £2.88 per square metre for pavements resurfaced more than 10 years prior to the trenching works.

These figures assumed that costs associated with the reduction in pavement life cycle and the pavement strengthening requirements are set to zero when the pavement age is more than 10 years rather than 12.7 years.

10.3 Republic of Ireland

Having regard to the need to ‘safeguard recently renewed road and pavement surfaces’, the Dublin Corporation (2001) document, called ‘Directions for the control and management of road works in Dublin City’, sites Section 13 of the Roads Act, 1993 which imposes a ‘responsibility on the road authority for the maintenance and construction of public roads.’ Subsection 7, as cited by the above document, provides the following:

‘A Road Authority may do all such things as arise out of or are consequential on or are necessary or expedient for the performance of its functions under this act or otherwise in relation to public roads or ancillary thereto.’

According to the Dublin Corporation (2001) document, these provisions:

‘empower a road authority to take whatever actions it considers necessary to maintain and manage the roads within its functional area.’

The following is implemented under Section 2.3.1 of the document:

‘A mandatory charge will be imposed on all utilities/companies intending to excavate roads, which have been overlaid within the past five years. The charge will be equivalent to the cost of overlaying half the carriageway for the full length of the roadworks.’

Dublin Corporation (2001) provides a list of streets overlaid in the previous five years (1997 - 2000) to make it clearer for those carrying out excavations.

10.4 Northern Ireland

Currently in Northern Ireland, there is no financial recompense from the utilities for any long-term damage to the roads. The NIAO (2001) report highlights the provisions of Article 38 of the 1995 Order, under which:

‘the Department may, through regulations, require a utility to contribute to the cost of making good long-term damage to a road.’

One of the aims of the 1995 Order is ‘to minimise disruption and delays to road users’, which can give rise to significant economic costs. For example a recent report,
sponsored by the Pipe Jacking Association (Brady et al., 2001), stated that the current annual cost of traffic and public disruption in England and Wales could be approaching £2 billion. Whilst the cost in Northern Ireland is not of the same magnitude, the figure helps to focus attention on the impact of street works. It also highlights the importance of monitoring the effectiveness of the current legislation to ensure that its objectives are met. Roads Service has yet to undertake any assessment of its impact on road users. However, in the report ‘Structural Maintenance of Roads’ (NIAO No.15, Session 1999-2000 (29 June 2000)), a recommendation was made that consideration should be given to reporting the impact of street works on the condition of the network of roads and footpaths.

10.5 Europe
In the European cities described in the report ‘Paving the Way’ (CABE, 2002), various methods are employed to control street work activities. In Marseille, statutory undertakers have to seek permission before undertaking works, and then pay rent during the period of intervention - thereby effectively renting underground space. In Copenhagen, a permit must be applied for to use both private and communal roads for installation of services. In Freiburg, a fee is paid by the utility company to the city for opening up works and a bond of two per cent of the contract price is retained by the city to fund repairs if reinstatement works are inadequately completed. The report (CABE, 2002) states that:

‘This tighter control mechanism could provide lessons for UK practice in curbing the excesses of utility companies’ interventions.’

Amongst the challenges for improvement in English regulation and policy cited in the report is:

‘Regulation of utility companies’ works – Local authorities need greater powers, including the ability to levy charges for occupation of the street and to impose fines for inadequate reinstatements by utility companies.’

The key recommendations from the report include:

‘4. Local authorities should introduce cross-sectoral management of streets with the aim of establishing an integrated approach to the public realm. .................

9. Principles of lane rental and overcharging systems for utility works in the street should be extended nationally if current projects increase street quality and reduce disruption.’

11 Discussion
The literature review has highlighted factors about how the pavement may be affected by excavation and reinstatement of trenches, all of which have been found in the studies cited in this report:

- Multiple reinstatements have a greater tendency to deterioration than single reinstatements.
- A reinstatement can affect the life of the surrounding pavement. The parts of the pavement thus influenced are generally termed the ‘zone of influence’. This zone can vary in width, is dependent on the depth of the excavation and is measured from each edge of the reinstatement. For example, an excavation and reinstatement of one square metre and one metre deep will have a zone of influence about 1.0 to 1.5 metres from each side of the reinstatement.
- In general, a trench and its zone of influence will remain weaker than a control (untrenched) area during its life.
- The width and depth of a trench affects the rate of deterioration of the adjacent pavement for a given traffic loading.
- Good reinstatement performance is most likely to occur when a specification is adhered to and good practice is employed throughout the excavation and reinstatement process. Nevertheless, surface damage or environmental disbenefits may also occur.
- Inadequate compaction is the most common problem contributing to the structural failure of reinstatements and deterioration of the adjacent pavement. The ends of reinstatements where plant has to operate in confined areas are most at risk from inadequate compaction.
- Cold-mix repairs do not generally perform well in terms of surface deflection. However, the addition of a modified binder in the asphalt surfacing will significantly extend the life of the reinstatement and that of the adjacent pavement.
- Emulsified bitumen macadams (EBMs) have the potential to produce an equal or better performance than equivalent hot-applied materials.
- ‘Pipe bursting’ can cause ground displacement and heave if used in poor ground conditions and could cause cracking in the pavement surface if the pipe or cable installation is too close to the surface.
- Certain types of subsurface weakening may not be revealed by non-destructive investigation techniques. Supplementary invasive testing may therefore sometimes be required.
- The failure of utility companies to acknowledge their responsibilities in maintaining quality landscapes is undermining and hindering the long-term success of coherent street improvements.
- A tighter control mechanism could assist in curbing utility companies’ street work activities. Greater local authority powers, including the ability to levy charges for occupation of the street and to impose fines for inadequate reinstatements by utility companies, might be a way forward.

Evidence from North America and Canada practice may not be considered by practitioners to be generally applicable to UK highways. However, all utility companies and state authorities outside the UK operate very similar excavation and reinstatement specifications to those
employed in the UK in respect of excavation techniques, backfill materials and compaction plant. Due to the vastness of the North American continent and varying ground conditions, each state has a specification for excavation and reinstatement of openings in the highway rather than a national specification.

The UK Water Industry Research Ltd (UKWIR) has been collaborating with AWWARF (AWWA Research Foundation), USA on common operational research for a number of years. For example, a Workshop, sponsored jointly by UKWIR and AWWARF, held on 29th to 31st May 2002, addressed the issues surrounding the location of multi-utility buried pipes and appurtenances. Delegates at the workshop represented a wide spectrum of research sponsors (including Transco), users, providers, equipment manufacturers and contractors from the UK, North America and the Netherlands. Outputs culminated in sixteen outline research proposals for joint funding by both UKWIR and AWWARF on state-of the art technologies, the limitations of current technologies, cost and performance specifications for asset management and maintenance, regulatory issues and standards and specifications.

Furthermore, a jointly sponsored project by UKWIR and WERF (Wastewater and Environmental Research Foundation), USA has recently been awarded to Black and Veatch to investigate surface water source control (Sustainable Urban Drainage Systems (SUDS)). Other collaborative research programmes include bodies such as KIWA and STOWA of the Netherlands, Ondeo and Vivendi of France, TZW of Germany, CRC-Water Quality of Australia, WRC of South Africa and UKWIR from the UK.

To increase knowledge on long-term performance of reinstated trenches and their adjacent pavements, further evidence of existing reinstatement and adjacent pavement performance needs to be gathered and analysed. With the implementation of the new Specification, practices should continue to improve but the presence of reinstatements may in itself result in the need for premature maintenance intervention.

Finally, whilst some evidence concerning surface deterioration is given in the reviewed reports and papers they provide little research evidence about the environmental disbenefits of trenched carriageways, footways and cycle tracks. Further investigation of this aspect is needed.

12 Conclusions

The main conclusions from the review of national and international reports on the long-term performance of reinstatements and their effect on pavement performance and service life are:

1 Effect of Reinstatements on Pavement Service Life
   (Section 5)

   - The majority of research studies, under field conditions, showed that sections of a pavement with reinstatements had a much greater deterioration rate than zones with no reinstatements (control). Most of these studies used a combination of visual condition surveys and some form of deflection (stiffness) testing to compare the trenched sections with the zones of influence and the untrenched control zones (APWA studies in Burlington of Vermont, Cincinnati, Kansas City, Austin, Santa Monica, Sacramento and San Francisco).
   - Two studies (by APWA in Burlington, Vermont and Seattle) showed that the average life of sections with reinstatements was around 60 per cent of that for control sections (without reinstatements). Another study showed 68 per cent reduced pavement life due to the presence of reinstatements whilst 17 per cent showed increased pavement life and 15 per cent predicted no change in pavement life (APWA study in Austin, Texas).
   - In the majority of cases, there appeared to be a weakened zone (zone of influence) around the areas with reinstatements, varying from around 1.0 to 1.5 metres from the trench (APWA studies in Sacramento, Union City and Kansas City plus Ottawa-Carleton Canada study). One study showed that the edges of the reinstatements had 50 - 65 per cent of the structural capacity of the centre of the reinstatement (APWA study in Kansas City).
   - The deterioration rate of trenched pavements depends on the number of trenches within them: those containing more than one trench had a faster deterioration rate than those that only contained a single trench. For example, one study showed that the service life of pavements reduced by 30 per cent with three to nine reinstatements and 50 per cent with more than nine reinstatements, respectively (APWA San Francisco No. 1 study).
   - From the reports and papers reviewed, the adverse effects of trenching were considered to be a problem only in bituminous surfaces. Concrete pavements did not appear to be affected by trenching (Bodocsi et al. study for the City of Cincinnati).
   - The results of deflection analysis on trench reinstatements, carried out prior to the introduction of the 1992 NRSWA Specification, showed that where an untrenched control was available, the trench was always weaker than the control and, in most cases, the wheelpath close to the trench was also weaker. The trench was often weaker than the adjacent wheelpath with failures frequently occurring near the ends of the trench. Poor compaction at the ends of trenches was the likely cause of failure perhaps due to the difficulty in using compaction equipment in the more confined area (TRL study around Southampton and West Sussex).
   - In a field study of trenches in Lincolnshire (reinstated to local specification prior to the introduction of the Specification), it was found that the deterioration of an existing pavement, as a consequence of a longitudinal trench, was influenced by the width and depth of the trench for a given level of trafficking. The results indicated that, in four out of seven trenches, there was a significant deterioration in performance immediately after trenching. Also, the greatest settlement was found to occur during the first nine to fifteen months. In the narrow trenches, the surface depression limit was not
exceeded on the lightly trafficked sites, although non-compliance occurred on the more heavily-trafficked sites. In trenches wider than 900mm, which were heavily trafficked, the trench depth directly influenced the amount of surface depression (TRL study in Lincolnshire).

- The results of a simulation study at the TRL Pavement Test Facility in a Type 3 road showed that, within the two-year HAUC guarantee period, no consequential damage was observed using either granular or foamed concrete backfill in four reinstatements and no permanent maintenance was required to the trenches or the original pavement. The subgrade was of uniform strength and the Type 3 pavement was not aged in terms of its actual life, being only two years old under simulation when it was trenched. No significant changes were found in the deflection, visual deterioration in the control (untrenched) or trenched sections. The observations throughout the whole process indicated that the standard of workmanship in excavating and reinstating the trenches was typical of current utility practice carried out in regular operational conditions albeit at the low end of the Specification in certain respects. The good performance of the trenches and the pavement indicated that sustained sound performance was likely to be achieved throughout the remaining life of the pavement. However, this study was undertaken in controlled conditions where no weathering effects were included and trafficking was only carried out for an additional six months beyond the two-year guarantee period (TRL study in the PTF).

- In a field analysis of newly reinstated trenches in the UK, it was found that the rate of settlement was greater than 2mm/month in the majority of the trenches less than six months old. In the second half of the year, only 35 per cent maintained the same level of settlement (in contrast to 74 per cent that had a settlement 1 and 2mm per month). Over one third of the trenches were still settling at the rate of 1mm/month after 12 months (University of Southampton).

- With the implementation of the 2002 revision to the Specification, practices should continue to improve but surface deterioration and environmental damage may still occur.

2 Specification Requirements for Reinstatements (Section 6)

- In some instances, absence of adequate engineering practice is seen as the main cause behind current restoration problems in Canada. It has been shown that current engineering standards are not always adhered to which in turn produced premature failures. Even when specifications are followed, the performance of restored utility reinstatements remains unsatisfactory. Analysis of current practices indicates that existing technical specifications cannot guarantee adequate performance. To redress the situation, performance based best-practice guidelines were developed that took into account the specifics of the site conditions including conventional and innovative construction materials, environmental conditions and local construction practice (Khogali and Mohamed study for NRC Canada).

- In assessing the early-life performance of reinstated trenches against the performance requirements, it was shown that the structural integrity of at least 30 per cent of trenches could be compromised by the selection of a weaker design than that specified. Insufficient compaction passes, which occurred in over 70 per cent of the cases, was the most common failure (TRL reinstatement study for DETR, 2001).

- Surface deterioration, e.g. cracking, was assessed during a number of visits to reinstatement sites. The majority of sites were found to be in good condition or very good condition, the age of the sites being between 9 and 12 months at the time of this visit. The most common defect present in the sites of ‘adequate’ or ‘poor’ quality (amounting to 9 per cent of the sites) was edge depression. The likelihood of further deterioration was considered to be significant (TRL reinstatement study for DETR, 2001).

- In the majority of studies, good workmanship was the key to achieving the performance criteria. A large-scale study of manhole chamber installations in a pavement showed that chambers reinstated to the NRSWA Specification did not suffer any adverse effects but the one installation that replicated poor workmanship failed (TRL study for Uponor Ltd).

- The failure of utility companies to acknowledge their responsibilities in maintaining quality landscapes is undermining and hindering the long-term success of coherent street improvements. Successful streetscapes are also dependent on changing the management cultures in those bodies and professions responsible for street works (Commission for Architecture & the Built Environment (CABE), 2002).

3 Developments in Reinstatement Practice (Section 7)

- Good compaction was the most important element of performance when patches were subjected to simulated trafficking up to 2.5msa (Brooklyn Union Gas/Consolidated Edison Co. of New York).

- Backfill densities in excess of 85 per cent Proctor did not show any reinstatement failures (Southern California Gas - Carson Street and Florence Avenue studies).

- Deterioration in the surfacing material was evident within three years in poorly reinstated trenches with several remedial repairs being carried out (National Research Council of Canada (NRCC), Institute for Research in Construction (IRC)).

- Suggestions for better co-ordination of street works included improved performance specifications and management where co-ordination was not seen to be effective in managing schemes. This resulted in a collaborative project between street authorities and utilities on guidelines for best practice in trench reinstatement (NIAO - Audit review).
Poor quality reinstatements of utility excavations were problems for cyclists when poor interim reinstatements had not been made permanent in a reasonable timescale (Regional Municipality of Ottawa-Carleton, Canada).

A reinstatement remained weak if an interim reinstatement was carried out prior to the permanent reinstatement, whereas a first time reinstatement generally showed better performance (TRL study around Southampton and West Sussex).

Best practice guidelines for edge cutting and sealant methods recommended the use of tools to minimise ground vibration and disturbance, such as hand held saws, thus discouraging the use of jackhammers. Greater importance was given to waterproofing of joints (TRL study for UKWIR).

4 Performance of Alternative Reinstatement Materials (Section 8)

A good degree of performance was obtained by using different forms of pavement cold-lay surfacing materials with varying degrees of bitumen content in the reinstatements. Comparative overlay experiments clearly demonstrated a significant extension in treatment life through the use of a modified binder in the asphalt overlay (Robinson - UK).

Cold mix repairs do not generally perform well in terms of surface deflection. However, the addition of a modified binder in the asphalt surfacing significantly extends the life of the reinstatement and that of the adjacent pavement. (Southern California Gas - Florence Avenue study).

Conventional Emulsified Bitumen Macadams (EBMs) have relatively low support values that might lead to a poor long-term performance. However, the modified EBMs were found to have the potential of giving an equal, or even better performance than the equivalent hot-applied materials. The developed stiffness of the cold mixture over a two-year approval period exceeded the HAUC requirements (Khalid and Eta - UK).

A review of alternative materials used in trench reinstatements in the UK showed that the average settlement is greater when as-dug materials are used (versus conventional Type 1 aggregates). This difference tended to increase with time perhaps due to the time-dependent consolidation of the predominantly clay fill (University of Southampton study).

Field trials were conducted to compare the behaviour of two artificial materials, PFA:sand:cement and Lytag:cement with conventional Type 1 aggregate. All materials were reinstated in accordance with the HAUC Specification. Results showed that, although the Lytag backfill performed better in terms of long-term settlement than the Type 1 granular sub-base, both materials showed settlements that were worse than the performance requirements of the Specification. This clearly demonstrates the importance of complying with the reinstatement specification (University of Birmingham study for National Power plc).

5 Performance of Trenchless Technology (Section 9)

The primary causes of short-term and long-term ground displacements caused by ‘pipe-bursting’ were found to be subsurface ground displacements, although these tend to be localised and dissipated rapidly away from the bursting area. The original equilibrium tends to be restored with time and surface trafficking, thus reducing any displacements induced in adjacent services or structures. In contrast, trenches create discontinuities in an overlying road structure and reduce road life. Where there is only one pipe diameter of soil between the pipe and the bound layer there is a possibility for surface cracking if the bound layers are relatively thin and/or weak (Rogers, 1996).

Pipe-bursting and guided boring only require an opening at the start and finish points rather than opening the whole road. Not only does this reduce the extent of excavation and hence the need for reinstatement, it also minimises disruption to traffic. However, if used in inappropriate circumstances, these techniques can present road authorities with some problems. For example, pipe bursting can cause surface heave, which distorts the overlying road. The only remedy is conventional excavation and reinstatement (Northern Ireland Audit Office, 2001).

Trenchless methods cause minimum disturbance to the public and have a low impact on the environment. Nevertheless, there are some potential obstacles to their use which include the risk of construction failures due to unexpected underground obstacles, absence of maps or drawings to provide accurate underground information, high initial cost and a short history of proven success (Khogali and Mohamed, 1999).

6 Economic Measures against Long-term Damage (Section 10)

From an examination of case studies in the USA, the addition of overlays was found to be the most appropriate measure to reduce the adverse effects of trenching on the pavement life. In most cases, the overlay thickness varied, but for practical and construction reasons, an average of around 40-50mm was estimated (studies in Cincinnati, Kansas City and Sacramento). Legislation empowered the street authorities to impose additional charges to utilities by means of a fee to cover the additional overlays needed (Santa Ana, California as an example).

From a review of one city’s legislation, reasonable regulations regarding right-of-ways are adopted, which includes the imposition of a trench excavation fee (Santa Ana, California).

In general, trenching a pavement before an age of 20 years damages the pavement prematurely. This damage decreases as the pavement ages. Hence, an appropriate cut off date for assessing the pavement restoration fee was considered to be 20 years. One study showed that, if trench excavation could not be postponed, the cost of the pavement damage should be commensurate with the loss in the pavement condition (APWA San Francisco No. 3 study).
• The cities of Santa Monica and Sacramento, USA have adopted a utility master plan (e.g. for a five year period) to be produced by utilities. A five-year repaving schedule is then prepared. In Santa Monica, the master plan included drafting right-of-way management standards with a view to co-ordinating construction with different road users, thus avoiding repetitive street trenching whenever possible (Santa Monica and Sacramento).

• Legislation in Ireland allows the street authorities to impose a mandatory charge on all utilities/companies intending to excavate roads, which have been overlaid within the previous five years. The charge is equivalent to the cost of overlaying half the carriageway for the full length of the road works (Dublin Corporation Directions, 2001).

• The form of charging varied between case studies. In most cases, the level of fee depended on the age of the pavement to be trenched (in some cases calculated since the last resurfacing). Some distinguished between major and local roads in determining the level of additional fees chargeable to utilities and others based the fee on the trench orientation (longitudinal versus transverse). Some charged per opening and others per square area or length of an opening (various cases as discussed in Chapter 10).

• The extra costs attributed to utility trench reinstatements in the USA case studies varied greatly, ranging from £15 - £100 per square metre, depending on the age of the pavement. For example, a flat rate of around £10 to £30 per metre length of excavation was prescribed and, in one case, an average value of around £200 per opening was prescribed. These costs did not account for any whole-life cycle costing considerations nor the costs incurred by the public and businesses (various cases as discussed in Chapter 10).

• Invasive investigation, such as the use of coring, and non-destructive techniques such as deflection measurements using the Falling Weight Deflectometer (FWD), were recommended to determine pavement condition. The pavement layer profile deduced from non-destructive measurements alone failed to reveal a significantly weakened subsurface layer that was subsequently revealed during invasive testing (Mooney et al. study in Oklahoma).

• A tighter control mechanism could assist in curbing utility companies’ street work activities. Local authorities need greater powers, including the ability to levy charges for occupation of the street and to impose fines for inadequate reinstatements by utility companies (Commission for Architecture & the Built Environment (CABE), 2002).

13 Acknowledgements

The authors wish to thank the Steering Committee members for their support and encouragement during the research programme. They would also like to thank personal contacts in the UK, Ireland, USA and Canada and elsewhere and the TRL Library Services for their assistance in collating the necessary reports and papers for review.

14 References


San Francisco (1998). The blue ribbon panel on pavement damage, the impact of excavation on San Francisco streets. The Department of Public Works, City and Council of San Francisco.


## Appendix A: Summary table for the reviewed literature

### Table A1 Summary of the reviewed documents

<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>Issuing body</th>
<th>Authors</th>
<th>Sponsor</th>
<th>Study</th>
<th>Type of study</th>
<th>Visual survey/deflection</th>
<th>Pavement settlement</th>
<th>Reinst. Practice/specs.</th>
<th>Costs</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>APWA 1996</td>
<td>Todres and Baker</td>
<td>Brooklyn Union Gas/Consolidated Edison Co. of New York</td>
<td>Comparing performance of trimback and non-trimback repairs, backfill compaction and moisture intrusion.</td>
<td>Lab</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Good performance was found in well-compacted repairs subjected to up to 2.5msa simulated traffic. Trimback and non-trimback behaved similarly.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>APWA 1996</td>
<td>Todres and Baker</td>
<td>Consolidated Edison Co. of New York</td>
<td>Simulating the behaviour of reinstatements in a full depth asphalt resting on a sandy silt subgrade.</td>
<td>Lab</td>
<td>X</td>
<td></td>
<td></td>
<td>Good compaction is the most important element of performance. Trimback and non-trimback behaved similarly. Asphalt reinforcement mesh ineffective in bridging poorly compacted backfill.</td>
<td></td>
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<tr>
<td>3</td>
<td>APWA 1999</td>
<td>Todres</td>
<td>Southern California Gas</td>
<td>Archival study: Revisiting reinstatements carried out.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Backfill densities above 90% Proctor did not show any failures. Trimback and non-trimback behaved similarly.</td>
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<td>4</td>
<td>APWA 1999</td>
<td>Todres</td>
<td>Southern California Gas</td>
<td>Carson street: Revisiting reinstatements carried out.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Backfill densities above 85% Proctor behaved well. Trimback and non-trimback behaved similarly.</td>
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<td>APWA 1999</td>
<td>Todres</td>
<td>Southern California Gas</td>
<td>Florence Avenue: Revisiting reinstatements carried out.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Backfill densities above 85% Proctor behaved well. Trimback and non-trimback behaved similarly. Cold mix repairs did not perform well.</td>
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<td>6</td>
<td>APWA 1996</td>
<td>Unknown</td>
<td>APWA</td>
<td>Excavation in the right of way.</td>
<td>Desktop</td>
<td></td>
<td></td>
<td>X</td>
<td>Emphasis on co-ordination of street works.</td>
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<tr>
<td>8</td>
<td>Canadian Consulting Engineer</td>
<td>Baer</td>
<td>None</td>
<td>Asphalt on city streets.</td>
<td>Desktop</td>
<td></td>
<td></td>
<td>X</td>
<td>Report on the poor quality of reinstatements; deterioration evident within three years.</td>
<td></td>
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<tr>
<td>Ref. No.</td>
<td>Issuing body</td>
<td>Authors</td>
<td>Sponsor</td>
<td>Study</td>
<td>Type of study</td>
<td>Visual survey/deflection</td>
<td>Pavement life</td>
<td>Reinst. Practice/specs.</td>
<td>Costs</td>
<td>Findings</td>
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<td>ENR, Canada</td>
<td>Phair</td>
<td>US Corp of Engineers, NRC Canada</td>
<td>Utility Cut Consortium.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Details of a collaborative project between street authorities and utilities on guidelines for the selection and best practice in trench reinstatement.</td>
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<td>10</td>
<td>Regional Municipality of Ottawa</td>
<td>None</td>
<td>Regional Municipality of Ottawa</td>
<td>Road cut hazards to cyclists.</td>
<td>Desktop</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Poor reinstatement of utility excavations, in particular their inappropriateness to cyclists.</td>
</tr>
<tr>
<td>11</td>
<td>TRL Limited</td>
<td>Burtwell et al.</td>
<td>UKWIR</td>
<td>Performance of edge cutting and sealant.</td>
<td>Lab/ field/desktop</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Best practice guidelines for edge cutting and sealant methods recommended (such as hand held saws). The use of jackhammer not advised. Importance of waterproofing pointed out.</td>
<td></td>
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<tr>
<td>12</td>
<td>TRL Limited</td>
<td>Burtwell and Spong</td>
<td>DTLR</td>
<td>Effectiveness of the utility reinstatement specification.</td>
<td>Desktop/field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Assessing the early-life performance of the reinstated trenches against the performance requirements. Structural integrity of three out of ten trenches could be compromised by the selection of a weaker design than that specified. Insufficient number of passes, which occurred in about 71 per cent of the failed sites, was the most common failure.</td>
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<td>13</td>
<td>TRL Limited</td>
<td>Zohrabi Carson Industries Ltd</td>
<td>Performance of manhole chambers under traffic loading.</td>
<td>Full scale lab</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Reinstatement using four different backfills – one reinstatement, which replicated poor workmanship involved hand compacting Type I backfill and failed. The other three reinstatements passed the requirements of the NRSWA Specification.</td>
<td></td>
<td></td>
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<tr>
<td>14</td>
<td>TRL Limited</td>
<td>Crabb and Todd</td>
<td>Uponor Ltd</td>
<td>Performance of access drainage chambers.</td>
<td>Full scale lab</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Good workmanship in installing the drainage chamber was the key to achieving the required performance criteria.</td>
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<tr>
<td>15</td>
<td>NIAO</td>
<td>Not specified</td>
<td>NIAO</td>
<td>Road openings by utilities.</td>
<td>Audit review</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Poor reinstatement often attributed to an interim reinstatement that is not made permanent. Lack of co-ordination; increasing failure rate in extracted cores. Shortened life of pavements with more than one trench in them. Charging for improvement may be an option.</td>
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<td>16</td>
<td>APWA 1999 Congress</td>
<td>Khogali and Mohamed</td>
<td>NRC Canada</td>
<td>Issues surrounding managing utility reinstatements.</td>
<td>Desktop</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Absence of sufficient engineering practice was the main cause of current restoration problems; current engineering standards were not adhered to; perform ance based best-practice guidelines proposed.</td>
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<td>17</td>
<td>APWA</td>
<td>Zeghal and Mohamed; APWA (1997)</td>
<td>APWA</td>
<td>Burlington, Vermont study.</td>
<td>Field</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>Sections with reinstatements have a much steeper deterioration rate than sections without reinstatements. Average life of sections with reinstatements was 11.6 years whilst the average life of sections without reinstatements was 20.1 years. The extra costs attributing to utility trench reinstatements averaged over the 87 miles of streets in the City amounted to £4,000 per mile. The City proposed a fee of £71.77 - £78.87 per square metre.</td>
</tr>
<tr>
<td>18</td>
<td>APWA</td>
<td>Bodosci et al. and APWA (1997)</td>
<td>APWA and Cincinnati</td>
<td>Cincinnati study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Patched sections have a faster deterioration rate than non-patched sections. Approximately 80 per cent of the reinstatements showed weakening around the patched area. Total cost of 6000 openings in asphalt pavement per year amounted to £1.3M (an average of £216 per opening).</td>
</tr>
<tr>
<td>19</td>
<td>APWA</td>
<td>APWA (1997)</td>
<td>APWA</td>
<td>Kansas City study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Edges of the reinstatements had 50 - 65 per cent of the structural capacity of the centre of the reinstatement.</td>
</tr>
<tr>
<td>20</td>
<td>APWA</td>
<td>APWA (1997)</td>
<td>APWA</td>
<td>Austin, Texas study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>In comparison to un-trenched pavements, 68 per cent of the measurements over trenches predicted reduced trench life, with 15 per cent predicting no change in pavement life and 17 per cent indicating increased pavement life.</td>
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<tr>
<td>21</td>
<td>APWA</td>
<td>APWA</td>
<td>APWA</td>
<td>Santa Monica study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Average life of a pavement in Santa Monica was reduced by a factor of 2.75 (64 per cent) due to utility reinstatements. A fee of £14.31 per square metre of excavation was proposed in an earlier study (undated).</td>
</tr>
<tr>
<td>22</td>
<td>APWA</td>
<td>APWA</td>
<td>APWA</td>
<td>Sacramento study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Longitudinally trenched pavements required an average of 39mm of bituminous overlay to provide an 'adequate' structural condition. A zone of influence of 1.1m exists on both sides of a transverse trench reinstatement. The fee for a longitudinal reinstatement in a pavement less than 5 years old was £7.64 per metre, which doubled to £15.28 per metre for a transverse reinstatement of the same age. A longitudinal reinstatement in a pavement older than 15 years required a fee of £2.20 per metre which again doubled to £4.36 per metre for a transverse reinstatement within the same aged pavement.</td>
</tr>
<tr>
<td>23</td>
<td>APWA</td>
<td>APWA</td>
<td>APWA</td>
<td>San Francisco (study No. 1).</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Service lives of pavements were reduced by 30 per cent and 50 per cent in streets with three to nine cuts and streets with more than nine cuts, respectively.</td>
</tr>
<tr>
<td>24</td>
<td>APWA</td>
<td>NVA</td>
<td>APWA</td>
<td>Carried out by San Francisco APWA and a panel of experts (study No. 2).</td>
<td>Desktop/ field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Street cuts disrupt surface integrity, which creates surface roughness. Surface roughness reduces pavement strength and allows the entry of moisture, which accelerates long-term deterioration. The actual computed re-paving costs associated with excavation activities range from £37.66 to £60.15 per square metre.</td>
</tr>
<tr>
<td>Ref. No.</td>
<td>Issuing body</td>
<td>Authors</td>
<td>Sponsor</td>
<td>Study</td>
<td>Type of study</td>
<td>Visual survey/deflection</td>
<td>Pavement life</td>
<td>Reinst. Practice/specs.</td>
<td>Costs</td>
<td>Findings</td>
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<tr>
<td>25</td>
<td>TRB</td>
<td>Chow and Troyan</td>
<td>APWA</td>
<td>Using a pavement management system to determine cost and impact of utility trenching in San Francisco (study No. 3).</td>
<td>Desktop/field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Trenching reduces pavement condition at certain ages. In general, trenching pavement before the age of 20 years will damage the pavement prematurely. This damage decreases as the pavement ages. An appropriate cut off date for assessing pavement restoration fee should be 20 years. The study also found that if trench excavation could not be postponed, the cost of the pavement damage should be commensurate with the loss in the pavement condition.</td>
</tr>
<tr>
<td>26</td>
<td>APWA</td>
<td>APWA (1997) and NVA (2000)</td>
<td>APWA</td>
<td>Los Angeles study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>There was a considerable increase in deflection in and around the reinstated areas and adjacent pavement edges compared to the original pavement. The fee for a major road varied from £101.14 per square metre for 1-5 year old pavement to £67.47 per square metre for a 10-15 year old one. In comparison, the fee for a local road varied from £37.34 per square metre for a 1-5 year old pavement to £24.64 per square metre for a 20-25 year old one.</td>
</tr>
<tr>
<td>27</td>
<td>APWA</td>
<td>NVA (2000)</td>
<td>APWA</td>
<td>Union City, California Study.</td>
<td>Field</td>
<td>X</td>
<td></td>
<td></td>
<td>68 per cent of the 16 evaluated streets showed a significant loss in strength as a result of being close to the trench reinstatement area. The cost consequence of a trench at time of rehabilitation of pavement was estimated to be at least £37.89 per metre without consideration of life cycle costing.</td>
<td></td>
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<tr>
<td>Ref. No.</td>
<td>Issuing body</td>
<td>Authors</td>
<td>Sponsor</td>
<td>Study</td>
<td>Type of study</td>
<td>Visual survey/deflection</td>
<td>Pavement life</td>
<td>Reinst. Practice/specs.</td>
<td>Costs</td>
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<td>28</td>
<td>APWA</td>
<td>NVA</td>
<td>APWA</td>
<td>Seattle, Washington study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Method one used an overall condition index (OCI) to characterise performance. Obvious trends defining the negative impact of utility cuts on pavement performance were not apparent. Method two used deflection testing and overlay design, which found that the presence of utility reinstatements had an adverse impact on the pavement in 21 out of 37 cases (equivalent to 57 per cent). A fee of £126.47 per square metre (based on a minimum overlay of 50mm for constructability reasons) was recommended which included all engineering design, material and contract costs. However, the costs incurred by the public and businesses and the health and safety implications were not included.</td>
</tr>
<tr>
<td>29</td>
<td>ASCE</td>
<td>Mooney et al.</td>
<td>Not available</td>
<td>Oklahoma study.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Emphasis on invasive measures such as coring in addition to non-destructive measures, such as the FWD. The pavement profile deduced from non-destructive test results alone failed to reveal a significantly weakened subsurface concrete layer that was revealed during invasive testing.</td>
</tr>
<tr>
<td>30</td>
<td>TRR article &amp; Ainley Group report</td>
<td>Lee and Lauter</td>
<td>Regional Municipality of Ottawa-Carleton, Canada</td>
<td>Impact of utility trenching on the long-term performance of an urban road network in Canada.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Results from this study indicate that utility trenching shortens the lifecycle of urban pavements by 7.8 per cent when trenching impacts are spread over the pavement surface area of the entire urban road system. A reduction in pavement surface life of 32.4 per cent is calculated when the trenching impacts are proportioned back to just the trenching area involved.</td>
</tr>
</tbody>
</table>
### Table A1 (Continued) Summary of the reviewed documents

<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>Issuing body</th>
<th>Authors</th>
<th>Sponsor</th>
<th>Study</th>
<th>Type of study</th>
<th>Visual survey/ Deflection</th>
<th>Pavement settlement</th>
<th>Reinst. Practice/ Pavement specs.</th>
<th>Costs</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>TRL Limited</td>
<td>Burtwell and Hurst</td>
<td>Highways Agency</td>
<td>TRL study around Southampton and West Sussex.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>The costs ranged from a high of £15.63 per square metre for pavements that were resurfaced less than 2 years prior to the trenching works to a low of £2.88 per square metre for pavements resurfaced more than 10 years prior to the trenching works. FWD deflection testing showed that where an un-trenched control was available, the trench was always weaker than the control and, in most cases, the wheelpath adjacent to the trench was also weaker. The trench was often weaker than the adjacent wheelpath. Many of the failures that occurred in this study were found near the ends of the trench. Poor compaction at the ends of trenches was the likely cause of failure perhaps due to the difficulty in using equipment in the more confined area. A reinstatement remained weak if an interim reinstatement was carried out prior to a permanent reinstatement whereas a first time reinstatement generally showed better performance.</td>
</tr>
<tr>
<td>32</td>
<td>TRL Limited</td>
<td>Burtwell and Howe</td>
<td>Highways Agency and CSS</td>
<td>TRL study in Lincolnshire.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Deterioration of an existing pavement as a consequence of a longitudinal trench was influenced by the width and depth of the trench for a given level of trafficking. In four out of seven trenches deflection tests indicated a significant deterioration in performance immediately after trenching. Also, the greatest settlement was found to occur during the first nine to fifteen months.</td>
</tr>
<tr>
<td>Ref. No.</td>
<td>Issuing body</td>
<td>Authors</td>
<td>Sponsor</td>
<td>Study</td>
<td>Type of study</td>
<td>Visual survey/ settlement</td>
<td>Pavement life</td>
<td>Reinst. Practice/ specs.</td>
<td>Costs</td>
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<tr>
<td>33</td>
<td>TRL Limited</td>
<td>Burtwell and Blackman</td>
<td>Highways Agency/NJUG</td>
<td>TRL study in the PTF</td>
<td>Lab (simulated)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Within the HAUC guarantee period, no consequential damage was observed using either backfill material and no permanent maintenance was required to the trenches or the original pavement. The majority of settlement could be attributed to the horizontal movement of the bituminous material rather than the increase in settlement of the backfill materials.</td>
</tr>
<tr>
<td>34</td>
<td>Dublin Corporation</td>
<td>Road works management in Dublin City</td>
<td>Spec.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A mandatory charge is to be imposed on all utilities/companies intending to excavate roads, overlaid within the past five years – the charge is equivalent to the cost of overlaying half the carriageway for the full length of the road works.</td>
</tr>
<tr>
<td>35</td>
<td>Proc. ICE and Cooper</td>
<td>Fleming and EPSRC</td>
<td>University of Southampton study</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>83 per cent of trenches less than six months old had a rate of settlement greater than 2mm/month. In the second half of the year, only 35 per cent maintained the same level of settlement (in contrast to 74 per cent that had a settlement greater than 1mm/month). Over one third of the trenches were still settling at the rate of 1mm/month after 12 months. The average settlement is greater when as-dug materials are used (versus conventional Type 1); this difference tended to increase with time (perhaps due to the time-dependent consolidation of the predominantly clay fill).</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>APWA 2000 street and technology conference</td>
<td>Alvarez</td>
<td>City of Santa Ana, California</td>
<td>Analysis of proposed trench cut fee ordinance</td>
<td>Desktop</td>
<td>X</td>
<td></td>
<td></td>
<td>This report reviews the legal aspects of imposing a trench excavation fee. It states that the City has the policing power to impose a trench excavation fee. Also, it allows the City to adopt reasonable regulations regarding its right-of-ways, which would include the imposition of a trench excavation fee. Fee levels not given.</td>
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<tr>
<td>Ref. No.</td>
<td>Issuing body</td>
<td>Authors</td>
<td>Sponsor</td>
<td>Study</td>
<td>Type of study</td>
<td>Visual survey/ settlement</td>
<td>Pavement life</td>
<td>Reinst. Practice/ specs.</td>
<td>Costs</td>
<td>Findings</td>
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<tr>
<td>37</td>
<td>ARRB</td>
<td>Statton and Kadar</td>
<td>ARRB</td>
<td>The relative performance of alternative forms of asphalt rehabilitation.</td>
<td>Lab</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Comparative overlay experiments clearly demonstrated a significant extension in treatment life through use of a modified binder in the asphalt overlay.</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>2nd Europ. Symposium Leeds</td>
<td>Khalid and Eta</td>
<td>Not available</td>
<td>Structural support value for emulsified bitumen Macadams in reinstatements.</td>
<td>Lab</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Conventional EBMs had relatively low support values that could lead to a poor long-term performance. However, the modified EBMs were found to have the potential of giving an equal, or even better performance than the equivalent hot-applied materials.</td>
<td></td>
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<tr>
<td>39</td>
<td>2nd Europ. Symposium Leeds</td>
<td>Robinson</td>
<td>Not available</td>
<td>Performance of Cold-mix thin asphalt surfacings in reinstatements.</td>
<td>Lab</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>The developed stiffness of the cold mixture over two-year approval period exceeded the HAUC requirements.</td>
<td></td>
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<tr>
<td>40</td>
<td>Highways and Transportation</td>
<td>Ghataora et al. National Power Plc, UK and Ghataora and Alobaidi</td>
<td></td>
<td>Suitability of cementitious backfill for trench reinstatements.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Field trials were conducted to compare the behaviour of the two artificial materials (PFA:sand:cement, Lytag:cement) and the conventional Type 1 sub-base that were reinstated in accordance with specifications. Results showed that although Lytag backfill performed better than Type 1 granular sub-base in terms of having lesser long-term settlement (less elastic deformation and permanent deformation), both materials showed settlements that were below the requirements of the Specifications (ranged from 2-5mm in Type 1 sub-base material).</td>
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<tr>
<td>41</td>
<td>4th Int Conf. NRC</td>
<td>Shaat and Al-Gassas</td>
<td>DoE, NI</td>
<td>Using different recipes of cement-bound materials to improve the backfilling.</td>
<td>Field</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>This experiment examined the possibility of using different recipes of cement-bound materials to improve the backfilling and reinstatement of such excavations in different pavement stiffness conditions.</td>
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</table>
Abstract

This report is Part 1 of a two-part study of the long-term performance of reinstated trenches and their adjacent pavements. It contains a review of national and international research carried out on reinstatements in footways and carriageways over the last decade, including UK research since the introduction of the NRSWA Specification (HMSO, 1992). The main aim of the review is to assess whether the rate of deterioration of the reinstatements is higher than the adjacent pavement and whether the presence of the existing reinstatements has had an effect on the life of the adjacent pavement. The report presents evidence as to whether non-compliance with the Specification and variation in the quality of workmanship, materials and methods have had any significant effects on the service lives of pavements. In some cases, authors have made general qualitative deductions to evaluate the likelihood of long-term damage that may result from reinstatements in the highway. To increase knowledge on long-term performance of reinstated trenches and their adjacent pavements, further evidence of existing reinstatement and adjacent pavement performance would need to be gathered and analysed. With the implementation of the 2002 edition of the Specification, practices should continue to improve but the presence of reinstatements may in itself result in the need for premature maintenance intervention. Finally, whilst some evidence concerning surface deterioration is given in the reviewed reports and papers they provide little research evidence about the environmental disbenefits of trenched carriageways, footways and cycle tracks. Further investigation of this aspect is needed.

Related publications


TRL516 Mitigating the disruption caused by utility street works by K C Brady, M Burtwell and J C Thomson. 2001 (price £35, code H)

TRL197 Trench reinstatement trial at TRL’s Pavement Test Facility by M Burtwell and D I Blackman. 1997 (price £50, code L)

CT34.2 Streetworks and reinstatement update (1996-2000) Current Topics in Transport: selected abstracts from TRL Library’s database (price £20)

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