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ROAD HAUNCHES: A GUIDE TO RE-USABLE MATERIALS

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Prepared for: **County Surveyors Society**
Project: **Road Haunches: Re-use of Materials (WT/JE/CSS.ES/RP)**

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CONTENTS

FOREWORD

In 1991, the County Surveyors Society published a report entitled "Practical Guide to Haunching". This report gives practical advice for engineers and technicians working in Highway Maintenance and covers the investigation, design, supervision and testing required for the effective repair of haunches. It is a synopsis of a more detailed report published by the Transport Research Laboratory entitled "Road Haunches: A Guide to Maintenance Practice".

Following these publications, the County Surveyors Society commissioned the Transport Research Laboratory to investigate the re-use of materials for repairing haunches and to produce a guide for practising engineers and technicians.

This publication "Road Haunches: A Guide to Re-usable Materials" is based on the measured performance of re-usable materials in road trials over a period of two years. It incorporates and updates the design guidance given in the previous publications to make it a "stand alone" document. However, it is recommended that this report is used in conjunction with the previous publications because the engineering principles used in design and construction of haunches are equally applicable to virgin and re-usable materials.

An alternative approach for assessing structural maintenance needs from deflectograph measurements has evolved from this research project. The concept of using a Structural Strength Index (SSI) derived from deflection measurements could provide the option of reconstructing the haunch to extend the life of the road rather than carrying out a full overlay operation. In certain circumstances this strategy might provide an alternative maintenance solution on some roads for engineers working within tight financial constraints.

A complementary report by Earland (1995) describes the detailed studies of the road trials used to provide the data on which the guidance given in this document is based.

The research was guided by a Steering Committee whose members were:

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Cheshire County Council

M Roy (Chairman, May 1995 - April 1996),
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ROAD HAUNCHES: A GUIDE TO RE-USABLE MATERIALS

ABSTRACT

This Guide provides engineers with methods of repairing road haunches by re-using road materials or industrial by-products. The guidance given is based on the in-service performance of re-usable materials and recycling processes used in the foundation and structural layers of the haunch in three road trials. The performance of 22 test sections has been assessed over a period of two years in order to establish structural equivalences for the re-usable materials in terms of their engineering performance compared to that of crushed rock (Type 1) sub-base and bituminous roadbase control materials.

The steps required to produce a cost effective and successful design for haunch repair are detailed. They are based on a flow chart approach to assist the user design, plan and execute the various stages of haunch repair.

1. INTRODUCTION

The purpose of this Guide is to provide engineers with an option to repair haunches by re-using road materials or industrial by-products which may be untried or untested as far as the individual designer is concerned.

The guidance given in this report is based on tests during construction, laboratory measurements and the in-service performance of re-usable materials in road trials. Three trials were constructed in Gloucestershire, Leicestershire and Cheshire with 100m long test sections containing various re-usable materials and processes in the foundation and structural layers of the haunch. In total, 22 test sections and 6 control sections incorporating conventional materials were constructed.

The performance of the test sections has been assessed over a period of two years in relation to that of the control sections in order to establish a structural equivalence for re-usable materials in terms of their engineering performance compared to that of the consistent crushed rock (Type 1) sub-base and bituminous roadbase control materials. All the test sections were constructed according to the design guidance given in the County Surveyors Society Practical Guide for Haunching (1991). The trials will continue to be monitored to evaluate the longer-term performance of the materials and processes.

In this Guide, re-usable materials are recommended for the repair of haunches on roads carrying up to 10 million standard axles in one direction over a design life of 20 years.

The use of in-situ and plant recycling, alternative materials and industrial by-products can be a practical, cost effective and environmentally beneficial alternative to using conventional "standard" materials. However, before re-using a material for maintenance purposes it is important to consider the environmental benefits or drawbacks and the risk of early deterioration.

The current environmental issues affecting Highway Authorities are considered in Section 2 before giving detailed guidance on how to re-use materials for haunch repair.

The steps required to produce a cost effective and successful design for haunch repair are given in the Practical Guide for Haunching. They have been updated and incorporated into this Guide because it is important to follow these steps for both conventional and re-usable materials. This Guide is based on a flow chart approach to assist the user in carrying out the various stages of haunch repair. Guidance is also given on assessing the suitability of potentially re-usable or alternative materials.

A proforma is included (in Appendix 7) for users to provide feedback on their experience of re-using materials for haunch repair. This information is very valuable because it can be reviewed and incorporated, where appropriate, into future editions of this Design Guide.

2. ENVIRONMENTAL CONSIDERATIONS

This Section is included to help the maintenance engineer become aware of the environmental issues for Local Highway Authorities which are aimed at encouraging the re-use of road building materials and other wastes in road construction and maintenance.

2.1 SUSTAINABLE DEVELOPMENT

The Earth Summit in Rio De Janiero in 1992 placed an obligation on the 150 Governments attending to promote sustainable development to secure the future of our planet.

The conference produced a set of papers outlining their objectives, known as Agenda 21, setting out how countries should work towards sustainability. This involves reducing the use of finite resources, increasing energy efficiency, minimising waste and protecting the natural world. Agenda 21 is having considerable impact on local highway authorities around the world. Details are given in the document Agenda for Change (1993).

2.1.1 UK Strategy for Sustainable Development

The Government states that the aim should be to "recycle as far as is environmentally and economically justified" and that they are "committed to increasing significantly the level of use of recycled materials from the present position". Having outlined the existing difficulties for greater use, the suggested way forward is through broadening the specifications and increasing the technical scope for using secondary and recycled materials in roads. These changes should follow research into the technical feasibility and performance of the materials. The introduction of a Landfill Levy from demolition/construction may encourage more recycling of that material.

2.1.2 Minerals Planning Guidance

The Department of the Environment publication MPG6 (1994), Minerals Planning Guidance for Aggregate Provision sets out four objectives for sustainable development in relation to minerals planning. The first two are:

1. to conserve minerals as far as possible, whilst ensuring an adequate supply to meet the needs of society;
2. to minimise production of waste and to encourage efficient use of materials including appropriate use of high quality materials and recycling of wastes.

The Government believes that "traditional" aggregate sources are likely to become increasingly constrained and therefore alternative sources such as marine dredged aggregate, coastal super quarries and secondary aggregate must be considered and a gradual shift to these alternatives should occur. Recent research suggests that secondary aggregates count for up to 10 per cent of national aggregates consumption at present. MPG6 envisages this rising to 12 per cent by 2006 (0.53 billion tonnes).

MPG6 stresses the need to use all aggregate efficiently by minimising wastage and avoiding the use of higher grade material if lower grade will do. It suggests that whilst specifications for the use of material must have an adequate margin for safety, over-specification tends to occur; the most prevalent examples were for "fill, hardcore and capping layers in road construction where the DOT specification was exceeded or where better quality material was supplied more cheaply when lesser quality would have been sufficient". One of the main reasons for this is the relatively low cost of primary aggregate. In MPG6, the Government stated its intention to set up a research project to provide practical advice on specifications and measures to achieve greater use of secondary/recycled material.

2.2 WASTE MANAGEMENT

2.2.1 Environmental Protection Act 1990

The Environment Protection Act (1990) introduces strict controls over waste management activities for the protection of health and the environment. It also encourages the minimisation, reuse and recycling of waste and exempts from licensing control a whole range of wastes and activities where genuine recycling takes place.

2.2.2 Regulations

The Waste Management Licensing Regulations (1994) also extend and amend the provisions of Part 2 of the Environmental Protection Act 1990 taking account of the European "framework" directive number 91/156/EEC.

Deciding whether a substance is waste or not under the EC waste directive is not a simple matter. In order to be a waste substance or object, it must fall under one of the categories set out in Part 2 of Schedule 4 of the Regulations and be discarded, be intended to be discarded or be required to be discarded (being incapable of further use in their present form).

Therefore there are substances generated by Local Authorities which are a waste and others that are not. The first question that must be answered is "is the substance a waste?" Reference should be made to the regulations and to the circular for guidance on this matter. Secondly, if it is a waste, then a range of exemptions may apply. Such exemptions include:

a. spreading waste soil or compost on highway verges and the storage of such waste at the place where it is to be spread, provided that this results in ecological improvement (exemption number 7);

b. the manufacture from waste which arises from demolition and construction works of roadstone or aggregate, the treatment of waste soil or rock which when treated is to be spread on land in accordance with exemption 7 above and the storage of these wastes at the place where the activity is to be carried out provided that the total amount treated at that place does not exceed 100 tonnes and the total quantity of waste stored does not exceed 50,000 tonnes in the case of roadstone from road planings and in any other case 20,000 tonnes (exemption number 13);

c. the storage in a secure place on any premises of waste articles (e.g., aggregate/kerb stones) which are to be used for construction work which are capable of being used in their existing state - maximum quantity 100 tonnes for a maximum 12 months (exemption number 17);

d. the storage on a site of waste which arises from demolition and construction provided it is suitable for relevant work which will be carried on at that site, or if it is not produced on the site, it must be used within three months of deposit (exemption number 19).

In the case of bituminous planings, up to 50,000 tonnes can be stored for up to three months.

There is an over-riding requirement that any activity should be carried out in such a manner as not to cause pollution of the environment or harm to human health and the operator must comply with the Waste Management Duty of Care (1991).

2.2.3 Materials from mines and quarries

Waste materials that originate from "processing" quarry materials will be classified as controlled waste. Other "as dug" materials such as quarry overburden, china clay waste and slate waste will not be a controlled "Directive" waste and will not fall within the regulations for the time being. It should be noted, however, that this is under review and certain mine and quarry wastes may become subject to the regulations in future.

This is a complicated area of law and engineers are advised to discuss the matter with the Waste Regulation Authority in order to clarify the interpretation of the waste definition in respect of any particular material and what controls and restrictions, if any, apply.

3. PROCEDURE FOR HAUNCH REPAIR

Haunch deterioration occurs principally due to a weakness of the carriageway edge. In some instances that may be caused by the failure or absence of a drainage system or by the presence of a leaking water supply which softens the underlying layers and allows the pavement to deteriorate. Frequently, deterioration is caused by vehicles over-running the edge of the carriageway on narrow rural roads.

First it is necessary to identify the damaged haunch then determine the extent and severity of the deterioration. Guidance on how to do this is given in Section 4.

The next stage is to evaluate the structural designs for the various materials available for the haunch repair. The design thicknesses depend on the bearing capacity of the subgrade, the materials available for carrying out the repairs and the traffic that the road is expected to carry. Design guidance is given in Section 8 and information about materials in Sections 6 and 7.

When the use of non-traditional materials or the re-use or recycling of existing materials is being considered, it might be necessary to carry out additional assessments. However, the extra testing, if required, should be balanced against the potential financial savings associated with re-using materials as well as the environmental benefits that should also be realised.

A glossary of terms used in this Guide is given in Appendix 1.

The Guide sets out the various steps necessary to design and carry out a haunch repair using traditional or re-usable materials.

4. ASSESSMENT OF HAUNCH CONDITION

A defective haunch can be identified from safety inspections, routine visual inspections (like CHART or MARCH) or from deflection measurements.

Sites should be identified for maintenance on the basis of:-

a) Location

b) Length of deterioration

c) Width of deterioration

d) Type and severity of deterioration

e) Condition of the drainage

f) Condition of the verge and adjacent carriageway

The possible reasons for the deterioration should be investigated and the cause should be corrected as part of the repair procedure.

Flow chart A, given in Figure 1, outlines the steps required to assess the haunch and indicates the strategy for examining the re-use of materials for repairing the haunch.

As part of the research study, Young (1992) carried out a comprehensive review of equipment and methods for assessing the condition and construction of haunches.

4.1 VISUAL INSPECTIONS

Regular safety inspections or more detailed routine visual condition surveys will determine areas of haunch deterioration or vehicle overrun. Then, depending on the severity of the problem and the class of road, the plan of action for remedial work can be programmed.

Visual signs of haunch deterioration are rutting, cracking or crazing in the nearside wheelpath together with deterioration of the section of road between the wheelpath and the edge. Damage to the edge of the carriageway and the

A

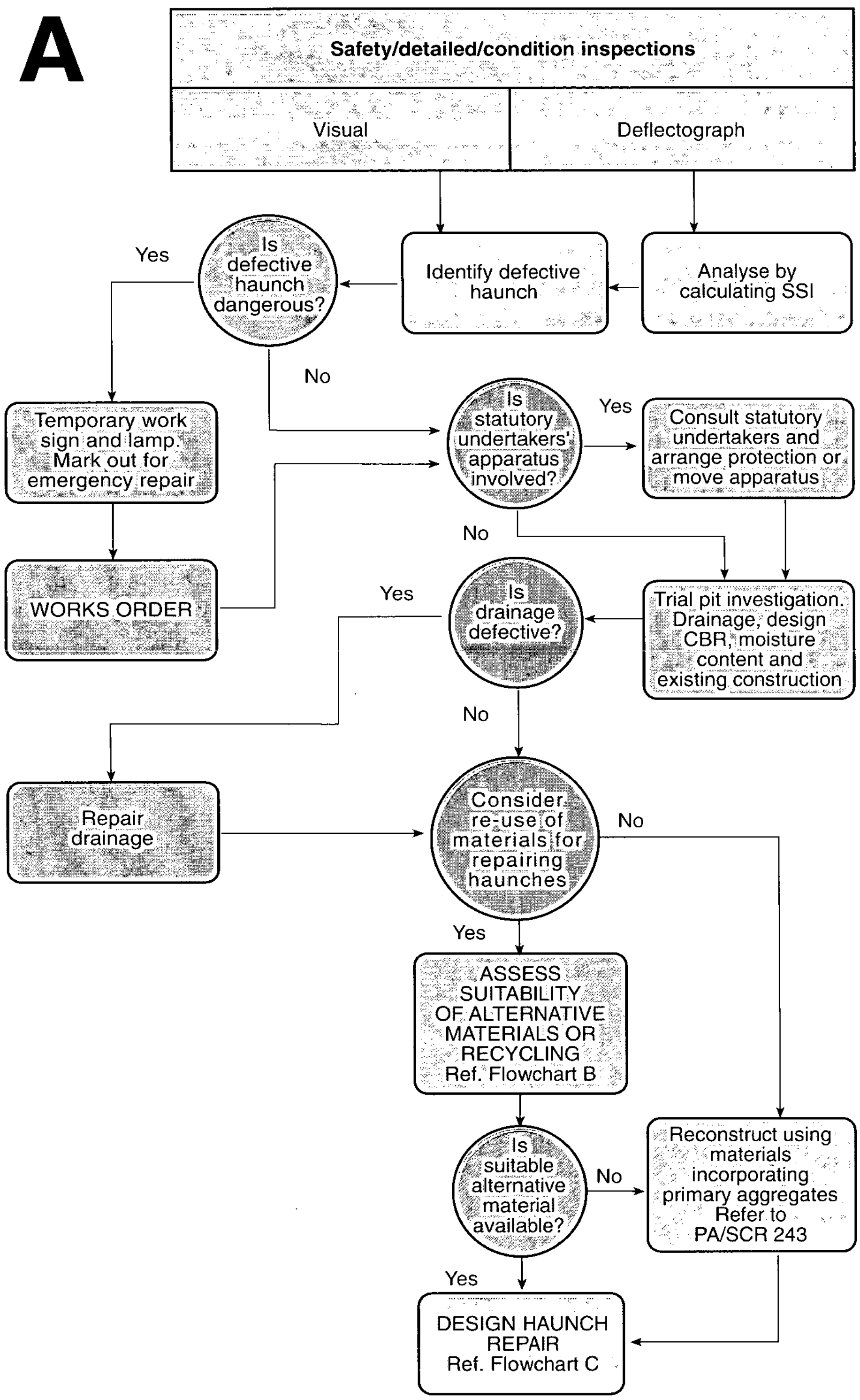

Fig.1 Assessment of haunch condition

adjacent verge should be taken into account when assessing the need for haunch repair. On many unkerbed roads deterioration could be in the form of potholes, general disintegration of the road edge or depressions in the road surface which can retain standing water.

The extent of deformation should be measured as the depth of rut below a 2 metre straight edge. Where the rutting is between 10mm and 20mm with some cracking, remedial measures should be considered, particularly if overrun damage is also present. Where the rutting exceeds 20mm and particularly if cracking or crazing is present, the area should be repaired as soon as possible.

4.2 DEFLECTION SURVEYS AND STRUCTURAL STRENGTH INDEX

If a deflectograph survey is available, it can be used to identify haunches which are in poorer structural condition relative to the rest of the road and a haunch repair may offer an alternative maintenance treatment to carrying out a full width overlay on the basis of results from a conventional deflectograph survey.

In the course of the research study to assess the structural performance of re-usable materials used for repairing haunches, the concept of a Structural Strength Index (SSI) was developed by Young (1994) to analyse deflectograph measurements on the test sections. Essentially, SSI is the ratio between individual deflections in the nearside wheelpath over the deteriorated haunch (Dh) and the average deflection in the offside wheelpath over the section being considered (Δ Ds).

$$SSI = 1 - Dh/\Delta Ds$$

Although it is not necessary to calculate SSI for routine assessment of haunches, the principle can be used to determine whether repair of the haunch alone or in combination with a thin overlay would provide the required residual life for the complete carriageway. The SSI approach provides the option of reconstructing the haunch to extend the life of the road rather than carrying out a full overlay operation. In certain circumstances this strategy might provide an alternative more economic maintenance solution.

Conventional structural strengthening recommendations derived from routine analyses of deflectograph measurements are usually based on the 85th percentile value of the higher deflections from the nearside or offside wheelpath for the section of road surveyed. Often the deflection in the nearside wheelpath is larger than that in the offside wheelpath and therefore the recommended strengthening is generally based on the condition in the wheelpath nearer to the edge of the road.

The following approach is recommended when considering the maintenance requirements for carriageways for which the deflectograph measurements indicate the need for overlay. It should be borne in mind that recommendations based on results from a deflectograph survey should be evaluated in conjunction with the visual condition survey.

Assuming that the deflectograph and visual condition measurements are compatible and that remedial work is considered necessary, the first stage in the evaluation is to compare the relative deflection levels measured in the two wheelpaths. If the deflections in the nearside wheelpath are generally higher than those in the offside wheelpath, it is recommended that the survey is reprocessed using the offside deflections only to determine what, if any, strengthening is required for the centre section of the road.

If an overlay is not required for the centre section of the road or if the addition of a new wearing course would give sufficient future life, then it is worth considering strengthening the carriageway by means of a haunch reconstruction alone or in conjunction with a new wearing course instead of a full strengthening overlay. A new wearing course would also improve the surface profile and skid resistance.

A similar approach could be used with deflection beam measurements or with the output from other equipment that can be used to measure the condition of the nearside and offside wheelpaths independently.

4.3 TEMPORARY WORKS

If the defective haunch is a hazard to safety in respect of Citizen's Charter performance indicators, it may be necessary to undertake emergency repairs prior to the detailed investigation. The information listed in Section 4.0 should be recorded prior to this emergency work being carried out.

It is essential to consult Statutory Undertakers before carrying out emergency repairs or a trial pit investigation so that apparatus can be protected or moved.

4.4 STATUTORY UNDERTAKERS

Where repairs or widening of the carriageway are envisaged it is essential to notify the Statutory Undertakers of the proposed work to establish whether their apparatus is affected. A minimum thickness of cover to their apparatus is required by Statutory Undertakers dependent on whether it is in the carriageway, footway or verge. The cost of protection or moving their apparatus can often be a major cost of the haunch repair.

4.5 TRIAL PIT INVESTIGATION

A site investigation should include a trial pit in the form of a transverse slit trench to examine the full depth of construction and any variations across the road. Alternatively, if this is not possible cores should be taken through the bituminous layers.

A trial pit has the advantage of exposing all the pavement layers and allows an accurate assessment to be made of the condition of the granular layers and of the sub-grade. A schematic section of a haunch is shown in Figure 2 and indicates the points to investigate. The investigation must include an assessment of the strength of the underlying sub-grade, measured as the equilibrium California Bearing Ratio (CBR), the condition of the drainage and the type of construction and layer thickness of the carriageway.

The CBR of the sub-grade is a key parameter for the design of the haunch foundation. The assessment should relate to the moisture content expected to be present under the reconstructed haunch when an equilibrium condition has been reached. The CBR can be determined by laboratory testing but the preferred method is to make an assessment from the range of equilibrium CBR values for various soil types shown in Table 1.

4.6 DRAINAGE

Ineffective drainage in the road and verge leads to softening of the sub-grade and deterioration of the road pavement; the cause should be investigated and corrected.

The design of remedial work should consider:-

a) the control of the water content in the sub-grade at formation level,

b) the reduction of the ingress of water from the verge or through the carriageway construction,

c) the avoidance of a haunch construction likely to form a water-trapping barrier between the existing carriageway and the verge,

It should be borne in mind that some materials, both re-usable and conventional, are more susceptible to deterioration through migration of moisture than others.

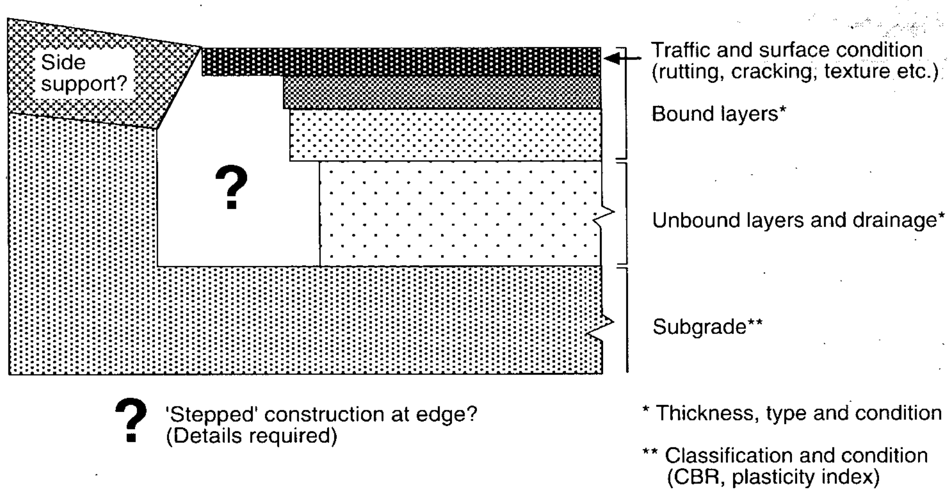

Fig.2 Schematic section showing required information

TABLE 1

Equilibrium CBR Values

Soil Type	Plasticity Index	Design CBR (%)
Plastic clay	50 or greater	Less than 2
Silty clay	40	2
Silty clay	30	3
Sandy clay	20	3
Sandy clay	10	Less than 2
Silt	-	Less than 2
Sand (poorly graded)	-	7*
Sand (well graded)	-	10*
Sandy gravel (well graded)	-	15*

Note: * Indicates estimated values assuming some probability of material saturating in service.

The use of bituminous material in the Foundation Platform may avoid the need to excavate below the level at which water would be encountered. Alternatively a permeable granular material can be used to avoid in-service build up of excessive pore pressures in the voids. In some instances it may be sufficient to provide a filter drain to lower the level of the water table under the road to achieve an improvement in the pavement performance.

4.7 RE-USE OF MATERIALS

In order to decide whether to re-use a material for repairing the haunch, it is necessary to consider the economic viability as well as the environmental benefit. To do this, the availability, suitability and cost of the potential materials must be determined together with the design options and layer thicknesses from which the quantities of material can be calculated.

In practice, the assessment of materials and the structural design should be carried out in parallel so that the various options can be considered together. The recommended approaches to do this are described in Sections 4 to 8 of this Guide.

5. ROAD CATEGORIES

It is first necessary to determine the traffic category of the road because this forms the basis for structural design for the haunch repairs. The road type category depends on the amount of commercial traffic to be carried in one lane, or one direction, over a 20 year design life. The categories are given in Table 2 and are the same as those specified for the HAUC specification for reinstatement of openings in highways (1992). This approach allows the Engineer to take advantage of the available information on local traffic conditions.

Guidance on how to assess the traffic levels is given in Section 8.2 and Appendix 5 of this Guide.

TABLE 2

Road Type Categories

Road Type Category	Traffic Design Standard (Million standard axles)
1	More than 10 up to 30
2	More than 2.5 up to 10
3	More than 0.5 up to 2.5
4	Up to 0.5

6. MATERIALS FOR REPAIRING HAUNCHES

Environmental strategies in National and Local Government are encouraging the re-use and recycling of materials for road construction and maintenance. Careful consideration should therefore be given to employing re-usable, recycled or alternative materials for the foundation and structural layers of haunches on Type 2, 3 and 4 roads (design life less than 10 msa) in place of primary aggregates.

As part of the research study into the reuse of materials for repairing haunches, a review of past practice of using alternative materials for haunch repair was carried out by Potter and Langdale (1993). Many materials had been used and in general their performance was considered to be satisfactory based mainly on subjective judgement. However, the materials were rarely required to comply with a specification and reliance was often placed on the contractors experience to achieve good results.

6.1 TRADITIONAL MATERIALS

For the more heavily trafficked category Type 1 roads, with a design life requirement of between 10 and 30 msa, it is recommended that the materials comply with the requirements in TRL Report PA/SCR243 (1994).

The materials recommended for haunch repair in the TRL Report PA/SCR243 (1994) and the CSS Report ENG/1/91 (1991) are given in Appendix 2.

6.2 RE-USABLE MATERIALS

It is recognised that potentially, there is a broad suite of non-standard materials available which may perform equally well within the design parameters. Examples could include re-usable road materials, secondary aggregates, marginal materials, industrial by-products or recycled materials, mixed in-place or processed off-site. These alternative materials may be available from sources local to the point of use or be required to accord with environmental conservation objectives.

Re-usable materials and processes that could be employed for reconstructing haunches can be considered to fall into one of four categories. These categories are listed in Table 3 and show the materials that were included in the road trials.

The principal objective of the road trials was to establish the structural equivalence of the alternative materials in terms of their engineering performance when compared with conventional control materials in test sections designed in accordance with the requirements of the CSS "Practical guide to haunching" (1991).

The conventional unbound control materials used in the trials were consistent crushed rock sub-base conforming to

TABLE 3

Categories of materials used in haunching trials

Granular	Granular -Bituminous	Bituminous-bound	Cement-bound
Processed aggregates	Bituminous planings	Plant-recycled planings with foamed bitumen	No-fines concrete
Quarry waste	Granulated bituminous materials	Plant-rejuvenated planings	In-situ recycling with cement
Slate		In-situ recycling with foamed bitumen	In-situ cement-stabilised gravel
China clay Stent *		In-situ rejuvenated planings	
Crushed kerbstones			
As-dug sand and gravel			
Furnace bottom ash			

* Stent is the granite overburden that has to be extracted before mining of china clay sand.

the Specification for Highway Works (SHW) (1991), Clause 803, Granular sub-base material Type 1. In the revision of SHW in August 1994, the granular material is permitted to contain up to 12.5 per cent by mass of natural sand which passes the 5mm BS sieve. It should be noted that in the trials the performance of Type 1 sub-base containing 12.5 per cent of natural sand has not been assessed in the haunching situation.

7. ASSESSING THE SUITABILITY OF ALTERNATIVE MATERIALS

Flow chart B, given in Figure 3, illustrates the process of assessing the suitability of re-usable, recycled and alternative materials for use as foundation or structural layers in haunch reconstruction for category Type 2, 3 and 4 roads.

7.1 LEACHATES

Leachates can be produced by the action of water on materials containing certain chemical compounds. If these leachates subsequently infiltrate ground water systems and rivers they may present a danger to plants and crops, fish and other animals. Research projects are in progress to investigate the production of leachates from construction materials and the potential for movement of the leachates through the ground into watercourses.

In many instances, materials that are considered for re-use in haunches have already been used in road or other civil engineering construction works and are known not to produce hazardous leachates. If materials are produced as a by-product from a chemical, incineration or other process, they might produce leachates when exposed to water. Any material suspected of producing hazardous leachates should be investigated before being used in foundation or structural layers of a haunch. The user should also be satisfied that the material is chemically stable and inert.

In cases of doubt, material suppliers should be asked to provide a chemical analysis of the product and a written assurance that potentially hazardous leachates will not be produced. This information should be confirmed by the Waste Management Division of the Local Authority. If information is not available from the supplier, then the material should not be used until on-going research investigating leachates and their movement has produced more information on which to base decisions or until organisations like the National Rivers Authority or the Department of the Environment gives assurance that the material presents no environmental hazard.

Bituminous planings, or road arisings such as tar-bound slag pitching, obtained from some sources could contain tar, either in the form of coating on old tar-based macadams or in surface dressing, pitch bitumen, asphalt etc. and this might be of concern regarding potential leachate problems. However, tests on bituminous planings reclaimed from minor roads of unknown history have shown that potential leaching from this material was not likely to be a problem. Also, bituminous planings have been used extensively in embankments, capping and sub-bases without any reported leachate problems. On the basis of the present information, it is considered that the presence of tar in bituminous arisings should not be harmful to the environment if they are used to repair road haunches.

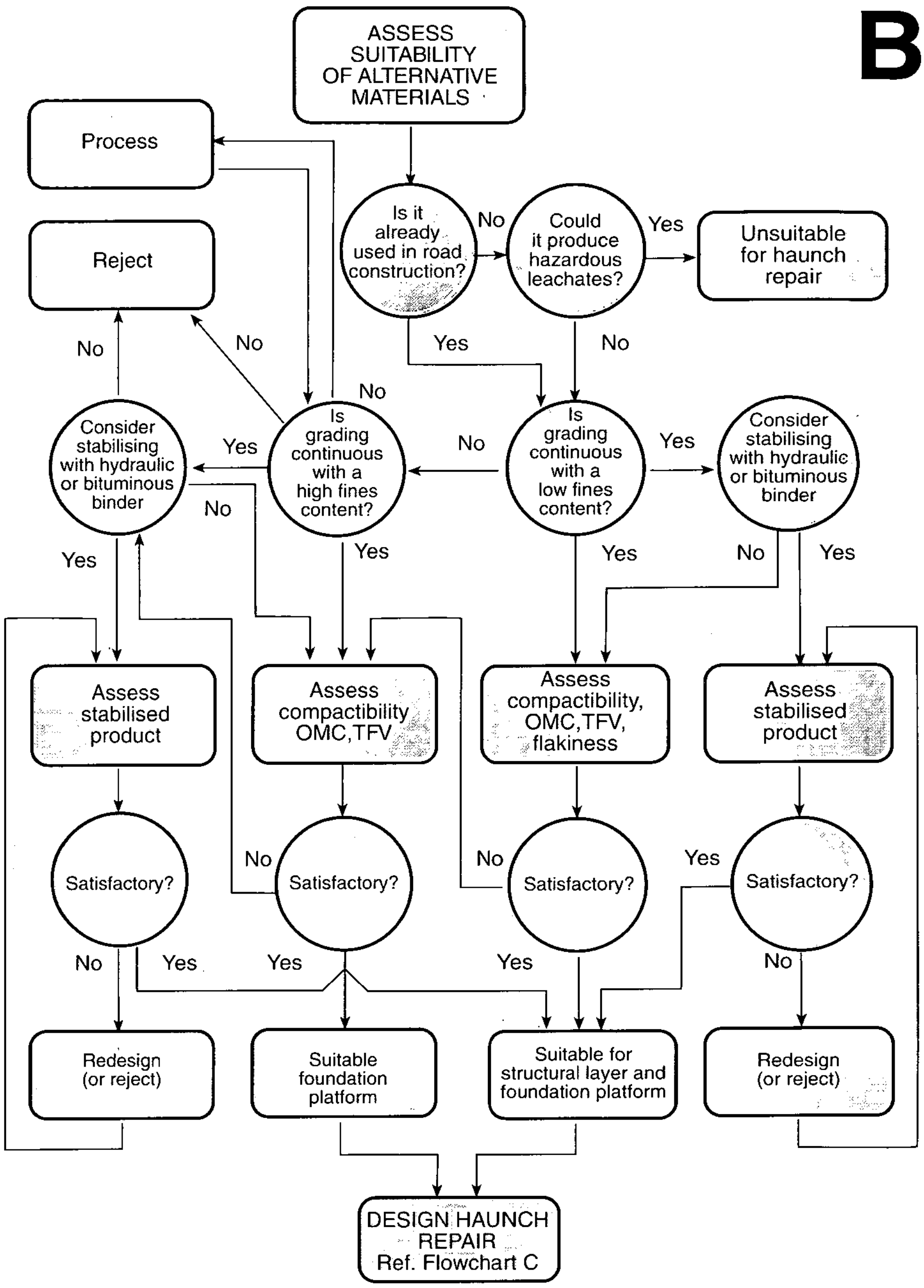

Fig.3 Assessing suitability of alternative materials

7.2 GRANULAR MATERIALS

Granular materials that have been used before or are the product from some other process generally have more variable properties than new materials produced for use as road aggregate. However, such materials should give satisfactory performance in haunch repairs provided that they comply with basic engineering requirements.

For use in the Structural Course, re-usable granular materials are specified by their performance characteristics. The materials must achieve a minimum value of equivalent modulus of 100MPa measured on top of the compacted Structural Course using the plate bearing test described in TRL Report PA\SCR243. This should be achievable using materials that have a continuous grading with a low fines content and with a maximum particle size appropriate to the required layer thickness. In addition, the particles should be crushed and should not crush further during compaction. This should enable the material to be compacted satisfactorily giving good mechanical stability and low air voids. Re-usable granular materials that achieve an equivalent modulus of 100MPa after placement are classed as Category A materials.

For the Foundation Platform, the thickness of the layers can be balanced against the quality of the re-usable material.

Consequently, the requirements are more relaxed and lower minimum values of equivalent modulus measured on top of the compacted Foundation Platform can be permitted. Materials achieving a value in excess of 70MPa are classed as Category B re-usable granular materials and those having an equivalent modulus in excess of 50MPa are classed as Category C materials.

The plate bearing test values measured in the field are also influenced by the subgrade conditions and these should be taken into account when the tests are being conducted.

As a first evaluation to assess a source of previously unused material to check whether it is likely to achieve the recommended plate bearing values on site, laboratory tests can be carried out to determine the particle size distribution, flakiness, compactibility, optimum moisture content and possible degradation during compaction. The suggested values of some of these properties for re-usable materials for use in the Structural Course or Foundation Platform are given in Appendix 3.

If the materials are to be used in locations prone to freezing their frost susceptibility and soundness should also be taken into consideration. The soundness of aggregates can be determined by the magnesium sulphate soundness test which is a requirement for Type 1 sub-base. It classifies the resistance of aggregates to deterioration under freeze thaw conditions. However, it is recommended that re-usable aggregates are used only on Type 2, 3 and 4 roads for haunch repairs and for this application the magnesium sulphate soundness test is not considered to be essential.

The laboratory measurements that were made on the materials used in the haunch trials are also presented in Appendix 3.

Materials that do not display all of the component requirement values for every test in Appendix 3 could still nevertheless give the required equivalent modulus values in the field. Local experience with such materials should be taken into consideration and it is recommended that plate bearing tests be carried out on a trial section of the material(s). For example, although furnace bottom ash (FBA) has a low ten per cent fines value, after placement in a haunch it achieved an average plate bearing value of about 60MPa.

Flowchart B gives an option of stabilising the granular materials with hydraulic or bituminous binders for use in the Structural and Foundation layers. The stabilisation process can be carried out in-situ or in a suitable plant and can be of benefit by reducing the required thickness of the layers. This is discussed in Section 8, Haunch Design.

7.3 GRANULAR-BITUMINOUS MATERIALS

Granular-bituminous materials comprise bituminous planings, bituminous materials rejected from construction sites, surplus or cooled production material or the materials produced when mixing plants are first started up. If such materials have been stockpiled it might be necessary to break up and grade the material to separate any larger pieces which have been formed by the smaller particles adhering together. Satisfactory compaction relies on a good particle size distribution.

Ideally, the bituminous planings should be obtained from the haunch site to minimise transportation costs. Bituminous arisings are composed of high quality aggregates and therefore it can be assumed that they comply with the particle strength and flakiness values recommended in Appendix 3. Guidance is given in Section 9 regarding placement and compaction of granular-bituminous materials.

Plate bearing tests results on granular-bituminous materials should be interpreted with caution if the measurements are being carried out in hot weather because the stiffness of the bitumen can reduce as it is being loaded and cause plastic deformation. Alternatively, site measurements of CBR of granular-bituminous materials can be made indirectly using a dynamic cone penetrometer. Using the TRL dynamic cone penetrometer (Jones and Rolt 1991), the measurements on the materials used in the trials indicate that the granular-bituminous materials have performed satisfactorily when the rate of penetration was not less than 8 blows per 100mm. It should be borne in mind that a calibration may be required to obtain a measure of CBR.

7.4 BITUMINOUS-BOUND MATERIALS

7.4.1 Hot in-plant recycling

The Department of Transport guidance on Maintenance of Bituminous Roads (HD 31/94; 1995) permits the use of up to 30 per cent of reclaimed bituminous materials in recycled hot rolled asphalt and coated macadam for basecourse and roadbase on trunk roads and motorways provided that the recycled materials comply with the Specification for Highway Works (MCHW 1). Also permitted is the inclusion of up to 10 per cent of reclaimed material in hot rolled asphalt wearing course; for this, it is a requirement that the recovered penetration of the binder in the reclaimed material must exceed 15 pen. For haunch repair on Type 1 roads, the use of the same maximum percentages of reclaimed bituminous materials is recommended.

Generally, the limitation of the quantity of reclaimed material that can be used in the mix is governed by the consistency of the reclaim material, its grading, binder content and binder penetration if it is to comply with the specification.

For haunch repairs on category Type 2, 3 and 4 roads, it is suggested that the maximum percentage of reclaimed material used in mixtures for the Foundation Platform or the Structural Course is limited only by the requirement to comply with the appropriate specification for new hot-mixed bituminous material. Bituminous mixes containing up to 60 per cent of reclaim have been produced successfully as roadbase materials (Potter and Mercer 1995).

7.4.2 Cold in-plant recycling

Cold in-plant recycling using foamed bitumen binder can be used for the Structural Course and the Foundation Platform. Although the material has a storage life of several weeks, it is important to ensure that it is protected adequately from the weather when stored on site in order to maintain a consistent moisture content at the value required to achieve good compaction.

It is suggested that the quality of the material is assessed on the basis of compliance with the values proposed in Appendix 4 for relative in-situ density, moisture content, stiffness modulus, bitumen content and particle size distribution. The number of samples will depend on the size of the job. For haunch repairs in excess of 100 linear metres, it is suggested that samples are taken from successive 100m sections.

Ideally, it is desirable to test samples extracted from the road immediately after compaction. However, it has often proved difficult to core the material before it is fully cured and therefore it is recommended to take samples from the full depth of the layer prior to compaction.

Tests on samples that have been extracted by coring after a few months in service have shown that the materials have attained similar stiffness and fatigue characteristics to those of conventional hot-mix bituminous materials. However, cold recycled materials using foamed bitumen are vulnerable to distress in early life until the strength has developed. Consequently, these materials have to be protected with a sufficient cover of conventional bituminous surfacing appropriate to the traffic to be carried whilst they are curing.

7.4.3 Cold in-situ recycling

Cold in-situ recycling using foamed bitumen binder is carried out using specialised recycling machinery for haunch repairs. Generally, the Structural Course and Foundation Platform will be constructed together. It is therefore necessary that samples of the existing construction are taken to the full depth of the materials to be recycled in order to produce the mix design.

It is suggested that the quality of the material is assessed on the basis of compliance with suggested values given in Appendix 4 for relative in-situ density, moisture content, stiffness modulus, bitumen content and particle size distribution. It is recommended that samples are taken from each 100m section of recycled haunch from the full depth of the layer just prior to compaction.

Where ground water tables are high or the bearing capacity of the subgrade is less than 2 per cent CBR, cold in-situ recycling using foamed bitumen is not recommended.

In the trials, 100 pen foamed bitumen binder was applied at a rate of 4 per cent by weight with 2 per cent of Portland cement to facilitate bitumen adhesion.

7.5 CEMENT-BOUND MATERIALS

7.5.1 Cold in-situ recycling

The process of cold in-situ recycling using hydraulic (cementitious) binders is suitable for haunch reconstruction with the Structural Course and the Foundation Platform recycled as one layer.

The existing construction must be sampled to determine the thickness and quality of material in order to produce a suitable mix design. It is suggested that the mixture is designed to have a compressive strength of 4.5N/mm^2 measured on cubes at 7 days. The strength needs to be sufficient to support the traffic loading but weak enough to minimise the formation of wide shrinkage cracks which might result in reflection cracks at the road surface. Subject to the presence of suitable material in the existing haunch, higher compressive strength values can be achieved in accordance with the requirements for CBM3 and CBM2.

Appendix 4 sets out the recommended values for the assessment of in-situ recycled materials using cementitious binders.

Recycled cement-bound materials can be considered to have a comparable performance to new cement-bound materials having the same grading, density and strength.

7.5.2 No fines concrete

No fines concrete is suitable for use in haunch repairs particularly in areas with a high water table or where free drainage of the road foundation is important. The no fines concrete used in the trials was supplied according to Clause 2603 in the Specification for Highway Works (MCHW1 1991).

8. HAUNCH DESIGN

After the cause of the haunch defects has been established and the availability of materials confirmed, the remedial work should be designed in accordance with Flow Chart C given in Figure 4. The selection of materials to be used for the haunch repair should be made by following the steps in Flow Chart B (Figure 3) and the guidance given in Section 6.

For Type 2 roads, the Structural Course must comprise a bound material and therefore re-usable granular or granular-bituminous materials are recommended for use only in

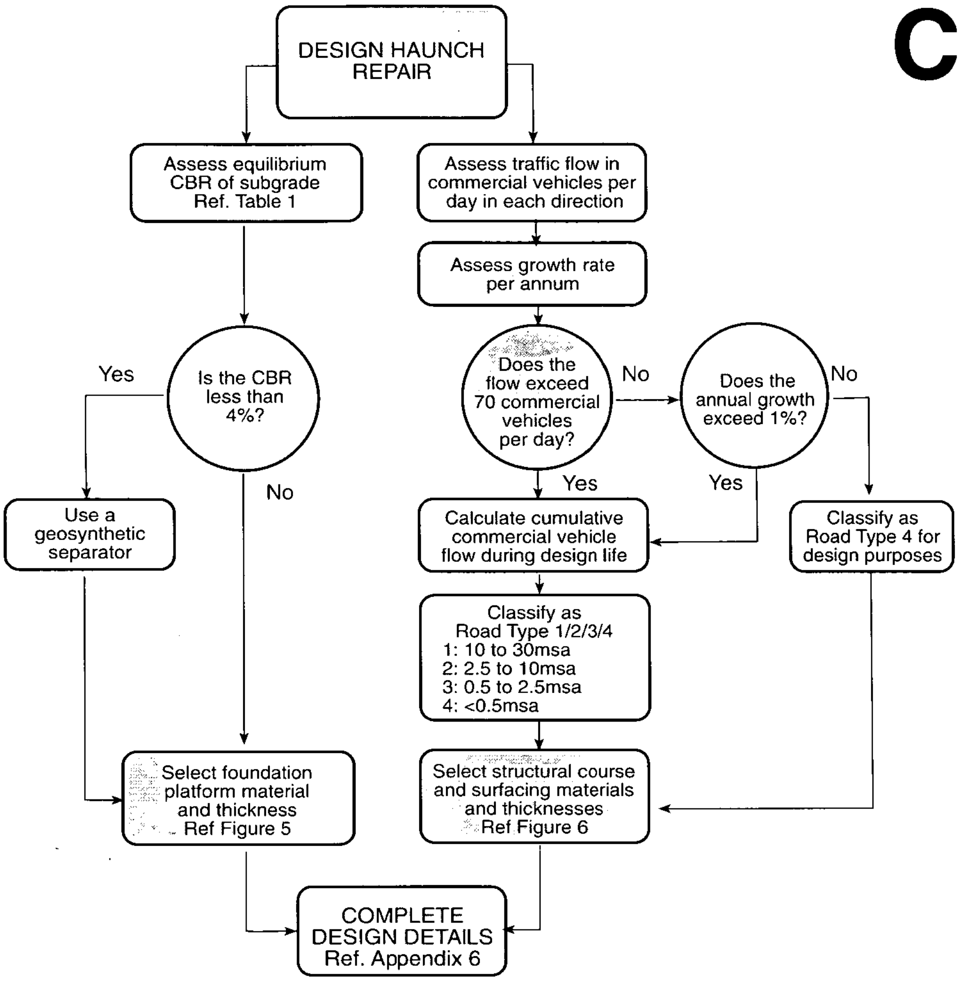

Fig.4 Structural design of haunch

the Foundation Platform. For Type 3 and 4 roads, granular or granular-bituminous re-usable materials are permitted for both the Foundation Platform and the Structural Course. Consequently, it is anticipated that if a suitable source of re-usable material is identified then it is likely to be used for both layers.

In the trials, generally the same material was used for both the Foundation Platform and the Structural Course. However, in this Guide, the thickness designs for the Foundation Platform and the Structural Course are considered separately to allow for the use of re-usable unbound materials in the Foundation Platform of Type 2 roads.

After two years in service in the trials, several re-usable materials are performing at least as well as their equivalent control materials according to transient deflection measurements and visual condition surveys. It is recommended, therefore, that these materials are installed to the same thicknesses as recommended for crushed rock Type 1 sub-base.

Some of the materials investigated however, are not performing as well as the equivalent control sections. For these materials either thicker layers are recommended or it is advised that they should not be used for the Structural Course until further performance data are available.

If the haunch deterioration is caused by frequent over-running of the road edge, road widening or kerbing should be considered as part of the haunch remedial works particularly if the over-running has been a continuing problem.

For design purposes, the pavement structure is divided into three layers on top of the subgrade as shown in Table 4.

The design of the haunch repair must consider:-

1) the materials to be used in the Foundation Platform and Structural Course which can influence the layer thickness
2) the thickness of the Foundation Platform which is dependent upon the bearing capacity of the underlying subgrade and the materials employed
3) the thickness of the Structural and Wearing Courses which are dependent upon the volume of traffic to be carried and the materials employed

TABLE 4

Haunch Construction Layers

Construction layer	Purpose	Material
Surfacing Layer(s)	Safe, durable, even running surface	Bituminous
Structural Course	Main stress distributing element	Bituminous or hydraulically bound, granular or granular-bituminous
Foundation Platform	Compaction platform for Structural Course	Bituminous or hydraulically bound, granular or granular-bituminous

8.1 DESIGN OF FOUNDATION PLATFORM

The thickness of the Foundation Platform depends on the bearing capacity of the underlying subgrade which must be assessed in relation to the equilibrium CBR (refer to Table 1 if measured data is not available). Where the CBR is 2 per cent or less, it is recommended that a geosynthetic separation membrane is laid at the bottom of the Foundation Platform. Where the CBR is between 2 and 4 per cent, the use of a geosynthetic separation membrane should be considered.

8.1.1 Traditional materials

The thickness of the Foundation Platform constructed using traditional fully crushed unbound granular Type 1 sub-base or bituminous basecourse materials is determined directly from Figure 5. Experience has shown that traditional fully crushed granular Type 1 sub-base could achieve an equivalent modulus in excess of 100MPa measured by the plate bearing test method. Consequently, a plate bearing requirement was not specified for traditional materials. However, for other granular materials, a requirement of 100MPa was specified in the TRL Report PA/SCR243 if they were intended to be used in the Foundation Platform at the same thickness as traditional Type 1 sub-base. In August 1994, the Specification for Highway Works (MCHW1) permitted the inclusion of up to 12.5 per cent of natural sand in Type 1 sub-base and these materials have not been evaluated in the road trials. It is important therefore, that granular materials installed at thicknesses according to Figure 5 have an equivalent modulus of at least 100MPa measured using the plate bearing test on top of the Foundation Platform after compaction. By complying with the requirements given in Appendix 3, Table A3.2, the materials should provide the required equivalent modulus.

No-fines concrete can also be used in the Foundation Platform. However, on the basis of visual condition and deflection surveys made on the trials, it is recommended that no-fines concrete is used only on Type 4 roads at a thickness 50 per cent greater than for conventional hot-mix bituminous materials. Recommended thicknesses for the Foundation Platform are given in Table 5.

8.1.2 Re-usable materials

In Section 7.2 re-usable granular materials were classified in terms of the equivalent modulus value that was measured using the plate bearing test on top of the finished layer.

For granular-bituminous materials and re-usable granular materials that are able to give an equivalent modulus of 100MPa measured on the surface of the Foundation Platform, the material is classified as Category A granular material and the recommended thicknesses are the same as those for the traditional fully crushed granular materials.

Re-usable granular materials that can give an equivalent modulus of 70MPa are classified as Category B and the recommended thicknesses of the Foundation Platform are approximately 25 per cent thicker than traditional materials to take account of the greater variability in their properties and of their in-service performance in the haunching trials.

Those materials achieving a lower mean equivalent modulus of 50MPa are classified as Category C and they need to be approximately 50 per cent thicker. Furnace bottom ash (FBA) used in the trials had a low Ten-per-cent Fines Value although it achieved a mean equivalent modulus of 60MPa but with considerable variability. After 2 years in service on a Type 4 road it has an equivalence of about 0.65 in comparison to the control Type 1 sub-base material on the basis of deflection measurements and the suggested thickness of Foundation Platform in Table 5 reflects the performance to date. It is advised that Category C granular materials should be used only on Type 4 roads until further performance data are available.

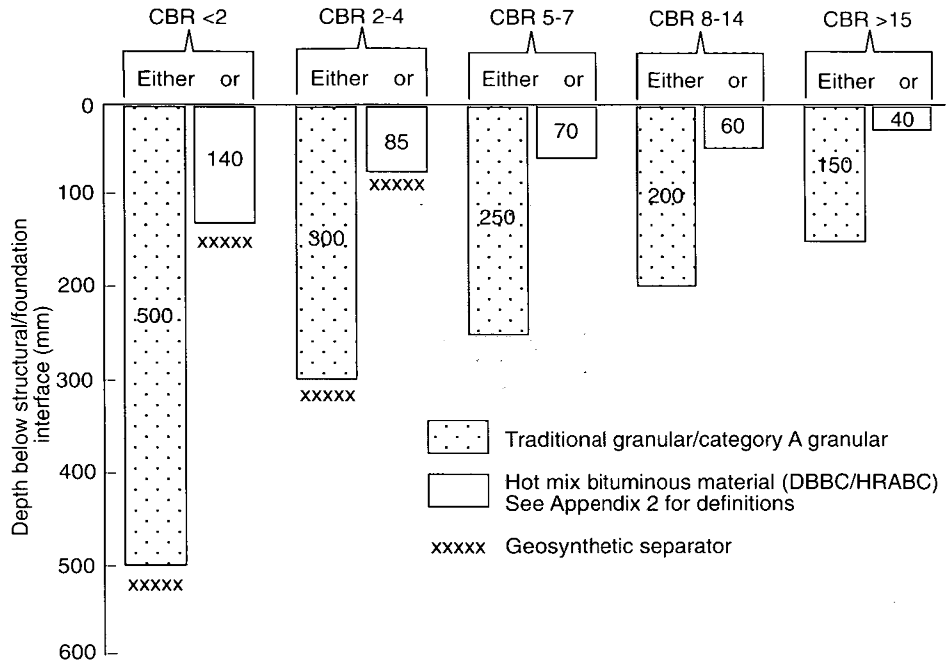

Fig.5 Thickness of foundation platform for traditional materials

The plate bearing equivalent modulus values of the materials used in the trials are given in Appendix 3, Table A3.5.

In the road trial on a subgrade of 5-7 per cent CBR, the performance after 2 years in service of cold in-plant recycled bituminous planings using foamed bitumen binder is similar to 100 pen DBM when used in the Structural Course. For Foundation Platforms constructed using in-plant recycled bituminous material with foamed bitumen binder on subgrades with a CBR greater than 5 per cent, it is recommended that the thickness of the recycled material should be the same as that for hot-mix bituminous materials. For subgrades with a lower CBR, an equivalence factor of 0.7 relative to 100 pen DBM is suggested to take account of the slower rate of gain in strength relative to hot-mix materials and to give sufficient support at the road edge for immediate construction of the Structural Course.

The performance of cold recycled bituminous planings with foamed bitumen on sites with a CBR less than 2 per cent is not known and although a thickness of 200mm is proposed in Table 5 it is suggested that the material is not used on such subgrades until performance data become available. Also, it is recommended that cold recycled bituminous planings are not used on sites with high water tables.

The performance of planings rejuvenated with a proprietary rejuvenator in a screw mixing plant was only slightly better than untreated bituminous planings. Consequently, the recommended thicknesses for these materials are only slightly less than for bituminous planings.

Recommended design thicknesses of the Foundation Platform for re-usable and alternative granular and granular-bituminous materials are given in Table 5.

When in-situ cold recycling is used to repair the haunch, the Foundation Platform and the lower Structural Course are produced together as one layer and the design for this technique is given in Section 8.3.3.

8.2 ASSESSMENT OF TRAFFIC

The commercial vehicle loading expressed as the number of standard axles is used to establish the category of road for the design of the pavement structure. All traffic assessments should have been made for the purposes of the New Roads and Streetworks Act (1991) but if this has not yet been done the commercial flow of vehicles should be available from traffic survey information for most major routes together with their rate of growth. Where necessary, advice should be obtained from the Traffic Management Division of the Highway Authority to determine a reasonable flow of vehicles and growth rate.

If the traffic flow is less than 70 commercial vehicles per day in one direction with less than 1 per cent per year growth rate, the road can be considered to be Type 4 for the pavement design.

For traffic flows in excess of 70 commercial vehicles per day in the direction where the haunch needs treatment, it will be necessary to calculate the cumulative traffic for a recommended design life of 20 years. Preferably, the cumulative traffic should be calculated in accord with the full

TABLE 5

Thickness of Foundation Platform for re-usable materials

Re-usable material	Recommended thickness of Foundation Platform (mm)				
	CBR <2*	CBR 2-4	CBR 5-7	CBR 8-14	CBR >15
Category A granular material (100MPa equivalent modulus Appendix 3, Table A3.2)	500	300	250	200	150
Category B granular material (70MPa equivalent modulus Appendix 3, Table A3.2)	625	375	315	250	190
Category C granular material (50MPa equivalent modulus. Appendix 3, Table A3.2). Type 4 roads only	750	450	375	300	225
Granulated bituminous materials complying with recommendations in Appendix 3	500	300	250	200	150
Bituminous planings complying with recommendations in Appendix 3	500	300	250	200	150
Cold in-plant recycled bituminous planings with foamed bitumen	200	120	70	60	40
Cold in-plant rejuvenated bituminous planings	460	280	235	185	140
No fines concrete (recommended for use on Type 4 roads only)	210	130	105	90	60

* Recommended to install geosynthetic separation layer

traffic assessment given in the Department of Transport Design Manual for Roads and Bridges, Volume 7, HD24/94. The use of the full method is recommended because the proportions of the different traffic categories are likely to be different on local authority roads from those on trunk roads and motorways, particularly at the lighter trafficked end of the spectrum. This approach is also recommended in the CSS Pavement Design Manual (1994).

Appendix 5 gives values of vehicle growth factors and wear factors to enable a full traffic assessment to be made for a 20 year design life.

If it is not considered appropriate to do a full traffic assessment then a simple equation can be used as a broad brush approach to determine the road Type category. However, if the calculation yields a value close to a road Type category boundary then it is recommended that the higher category is used for design unless a full assessment is made. The traffic assessment equation is as follows:

$$msa = 9000 \times AADF$$

where msa is the cumulative msa for 20 year life

AADF is the average annual daily flow of commercial vehicles in one direction

The equation assumes a 20 year design life and a default growth rate of 2 per cent giving a wear factor of 1.25. The distribution of commercial vehicles is assumed to be:

- 50 per cent of 2 axle rigid
- 10 per cent of 3 axle rigid
- 10 per cent of 4 axle rigid
- 10 per cent of 3 axle artic
- 20 per cent of PSV

Recent research (Potter and Mercer, 1995) has identified that commercial vehicles fitted with super single wheels cause more wear to the pavement structure than those with conventional dual wheels carrying the same axle load. Although the type of wheel is not normally taken into account when calculating design traffic loading, if the haunch site is located where such vehicles are used some allowance should be made in the msa calculations. Although equivalencies are not yet available, it is recommended that if the calculated msa provides a value that is approaching the upper limit of a road Type traffic category, the haunch should be designed for the next road category for heavier traffic.

8.3 DESIGN OF STRUCTURAL COURSE AND SURFACING LAYERS

A typical standard construction detail for haunching work is shown in Appendix 6.

The thickness of the Structural Course and surfacing layers depends on the road Type given in Table 2. The surfacing layer(s) for all road Types are constructed using the appropriate hot-mix bituminous material specified in Figure 6. For the Structural Course, various materials can be used depending on road Type.

For road Type 1 recommended materials are:

1. Conventional hot rolled asphalt or dense bitumen macadam
2. Recycled conventional hot-mix materials containing up to 30 per cent reclaimed bituminous material

For road Type 2:

1. The materials for road Type 1
2. Cold in-plant recycled bituminous material using foamed bitumen binder
3. Cold in-situ recycling using cementitious or foamed bitumen binder

For road Type 3:

1. The materials for road Types 1 and 2
2. Cold in-plant rejuvenated planings using a proprietary rejuvenator
3. Category A unbound granular or granular-bituminous materials

For road Type 4:

1. The materials for road Types 1,2 and 3
2. No fines concrete
3. Slate or furnace bottom ash

8.3.1 Traditional materials

For traditional hot-mix bituminous materials and Type 1 granular sub-base, the thickness of the Structural Course is determined from Figure 6 for the different categories of road. Hot rolled asphalt basecourse (HRABC) or dense bitumen macadam (VDBBC) is recommended for the Structural Course with the HRABC being compacted to a method specification and the VDBBC being compacted to the end point specification given in Report PA/SCR243.

8.3.2 Re-usable materials

After two years in service, several unbound re-usable granular and granular-bituminous materials are giving good performance in comparison to the crushed rock Type 1 sub-base controls. The crushed quarry aggregates, china clay stent, crushed kerbstones, bituminous planings and granulated bituminous materials were all classed as Category A materials.

On a Type 2 category road, the slate is not performing as well as Type 1 sub-base on the basis of visual and deflection surveys and on a Type 4 road, the deflections are higher on the slate section than on the Type 1 sub-base control section. Consequently, it is recommended that slate is used for the Structural Course only on Type 4 roads until further performance data is available. It is appreciated that slate has been used successfully on several schemes, complying with the requirements of Type 1 sub-base, but in the relatively narrow haunch situation its early life performance has not been as good as expected.

Furnace bottom ash (FBA) has a low Ten-per-cent Fines Value and a variable plate bearing modulus. Although after 2 years in service on a Type 4 road, the visual condition is similar to adjacent sections containing other unbound materials, the deflections are considerably greater. In view of this, it is recommended that FBA be used only on Type 4 roads for the Structural Course until further performance information is available.

The recommended thicknesses for unbound re-usable materials in the Structural Course of Type 3 and 4 roads are given in Figure 6 and Table 6.

8.3.3 Cold recycled materials

The design recommendations for cold recycled materials are based on the performance to date of the materials used in the haunch trials and on practical considerations of recycling.

8.3.3.1 In-plant recycled bituminous materials

After two years in service in the haunch trials, planings with 14mm maximum aggregate size recycled with foamed bitumen in a specialist plant performed similarly to 28mm DBM when used in the Structural Course. The design recommendations for this material are based therefore on a performance equivalency factor of unity with hot-mix bituminous materials. In the trials, planings rejuvenated in a cold screw-mixing plant using a proprietary rejuvenator and used in the Structural Course, performed slightly better than untreated planings on the basis of deflectograph and

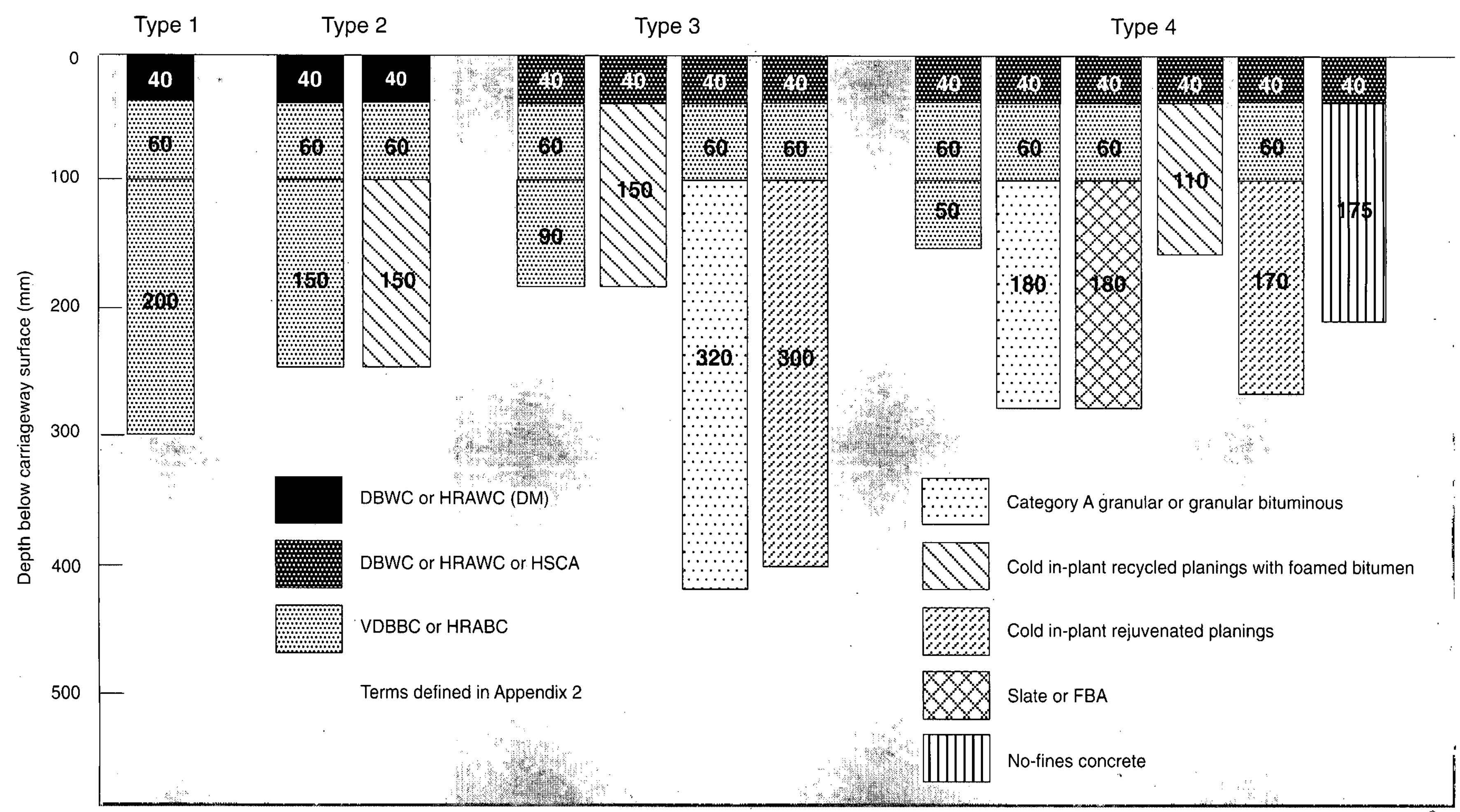

Fig.6 Thickness of the structural course and surfacing layers, road type categories as table 2

TABLE 6

Thickness of Structural Course for re-usable granular and granular-bituminous materials

Re-usable material	Recommended thickness of lower Structural Course (mm) Type 3 road	Type 4 road
Category A granular or granular-bituminous material materials in trials: crushed quarry aggregates china clay stent crushed kerbstones granulated bituminous materials bituminous planings	320	180
Slate	not recommended at present	180
Furnace bottom ash	not recommended at present	180

visual surveys and this is reflected in the recommended thickness for the Structural Course.

The performance of planings rejuvenated in-place using diesel was considered to be unsatisfactory because ruts developed after light trafficking and its loadspreading ability was no better than that of untreated bituminous planings. In view of its poor resistance to deformation on a lightly trafficked Type 4 road, the process is not recommended for haunch repairs.

The recommended thicknesses for in-plant recycled materials for use in the Structural Course are given in Figure 6 and Table 7.

8.3.3.2 In-situ recycled materials

The structural design for in-situ recycling for haunch repairs depends on several factors. The process produces the Structural Course and Foundation Platform in one operation which makes the ability to compact the recycled layer a controlling factor for design. The width of the haunch repair determines the size of the compaction equipment that can be used and consequently the maximum thickness that can be compacted satisfactorily in one layer. Recycling equipment generally operates at a minimum width of 1 metre and at this width, the maximum finished thickness of a compacted layer is 200mm to ensure satisfactory compaction. This will therefore limit the depth of recycling if the existing materials are to be used. For greater widths, larger compaction plant can be used and it is therefore possible to compact thicker layers. At the haunch trial in which in-situ recycling was employed the haunch width was 1.4 metres and the compacted thickness of the recycled materials was 280mm.

Another factor is the suitability and thickness of the materials present in the haunch. It is strongly recommended to

TABLE 7

Thickness of Structural Course for cold recycled materials

Re-usable material	Recommended thickness of Structural Course (mm) Type 1 road	Type 2 road	Type 3 road	Type 4 road
Cold in-plant recycled bituminous planings with foamed bitumen	not permitted	150 *	150 #	110 #
Cold in-plant rejuvenated bituminous planings	not permitted	not suitable	300 *	170 *
Cold in-situ rejuvenated bituminous planings using diesel	not permitted	not suitable	not suitable	not suitable

* 100mm of dense bituminous surfacing layers required

\# 40mm of dense bituminous surfacing required avoid mixing subgrade material into the recycled mix. A detailed site assessment is necessary to determine the type and thickness of the materials present and to provide samples for mix design.

If the thickness of existing materials is insufficient for in-situ recycling it is possible to replace part of the subgrade with a re-usable granular or granular-bituminous material to provide the required depth of construction. This might be a viable option if short lengths within an otherwise suitable site have insufficient thickness of material available.

For materials recycled with cement binder, a 40mm wearing course is often sufficient to provide the required structural capacity. However, other designs give the option of using thicker surfacing layers in order to reduce the depth of recycling if there is insufficient material suitable for recycling. Generally, materials recycled in-situ with foamed bitumen require thicker surfacing layers than in-situ recycling with cement. If the complete road is not going to be resurfaced as part of the remedial works then allowance must be made to ensure that there is sufficient depth of material for in-situ recycling after taking into account the material to be removed to incorporate the new wearing course.

Cold in-situ recycling with cement should be designed to produce a material with a mean minimum 7 day compressive strength of $4.5N/mm^2$. In the trial, the test section recycled with cement binder is performing as well as the hot-mix bituminous materials on the basis of deflection and therefore the design thicknesses given in Table 8 are based on an equivalence factor of unity. The test section of in-situ recycling with foamed bitumen binder is giving a performance equivalence factor of 0.7 in comparison to dense bitumen macadam on the basis of deflection measurements. Consequently, in Table 8 the recommended thickness of cold in-situ recycling with foamed bitumen binder has been increased relative to hot-mix bituminous materials.

Table 8 gives an option of offsetting the thickness of the surfacing layers against the depth of recycling. The designs will be updated as monitoring of the haunch trials proceeds. It should be noted that further research is being carried out to develop a robust structural design method for in-situ cold recycling.

It is recommended that in-situ cold recycling with foamed bitumen should be used with caution on sites with a high water table. Also it is suggested that in-situ recycling should not be used on subgrades with a bearing capacity of less than 2 per cent CBR unless it is feasible to stabilise the subgrade before recycling.

TABLE 8

Thickness of combined Structural Course and Foundation Platform for cold in-situ recycled materials

Cold in-situ recycling	Depth of recycling (mm)					
	Type 2 road		Type 3 road		Type 4 road	
Thickness of surfacing layers	100mm	140mm	100mm	140mm	40mm	100mm
With foamed bitumen						
Subgrade CBR <2	n/r	n/r	n/r	n/r	n/r	n/r
2-4	n/r	280	250	200	280	195
5-7	n/r	260	230	170	260	185
8-14	300	240	215	160	245	160
>15	270	215	185	130	215	130
Thickness of surfacing layers	40mm	100mm	40mm	100mm	40mm	100mm
With cement						
Subgrade CBR <2	n/r	n/r	n/r	n/r	n/r	n/r
2-4	300	240	240	180	200	150
5-7	280	220	220	160	180	150
8-14	270	200	200	150	160	150
>15	250	200	200	150	150	150

n/r - not recommended unless the subgrade is stabilised before recycling

9. CONSTRUCTION PRACTICE

A high standard of workmanship is required for the construction works at the edge of the carriageway as this is the area that is most highly stressed by vehicles, particularly if the carriageway width is limited.

The performance of the road pavement forming the haunch repair depends on the bearing capacity of the sub-grade to sustain the loads transmitted through the pavement layers. It is important therefore to ensure that the condition of the subgrade is not allowed to deteriorate during the construction process. Any ingress of water from the verge or through the construction must be limited as far as possible and it may be necessary to pump out water from the excavation.

It is strongly recommended that the drainage system is examined thoroughly and any defects rectified to ensure adequate provision of drainage to remove surface and groundwater during construction and in service. Care should be taken to avoid a haunch construction which will form a sump or a water-trapping barrier between the subgrade of the existing carriageway and the verge.

Where a soft subgrade is encountered, the use of a geosynthetic separator is recommended to ensure that the Foundation Platform is not contaminated by clay migration from the subgrade.

When constructing the Foundation Platform, particular care should be taken with materials susceptible to moisture. All materials should be protected from the weather when stored on site and from the ingress of water when exposed in the haunch. If moisture susceptible materials become saturated after placement it is possible to stabilise them in-situ with cement.

The material at wearing course level should match the existing surfacing as far as practicable to ensure a uniform surface texture and skid resistance.

Particular care should be taken to ensure that the stepped carriageway detail is constructed as specified and that an adequate tack coat and edge sealant is applied to the adjacent carriageway to prevent water ingress.

Where haunch repairs effect a widening of the carriageway it may be necessary to re-align the centre line of the road and renew the white lines and reflecting road studs.

9.1 SUPERVISION AND TESTING

It is recognised that a high level of supervision is often difficult to achieve on small-scale repairs although efforts to do this should be made.

Materials should be tested in accordance with recommended guidelines against the recommendations given in Appendices 3 and 4.

The use of appropriate compaction plant is essential together with the use of an established testing regime where required. The performance of both unbound and bound materials depends substantially on the degree of compaction achieved. It is important to ensure that when compaction is by method specification, the work is supervised adequately to ensure that the requirements are being achieved.

A cross section of the haunch construction is given in Appendix 6 together with construction tolerances and information on edge sealants and tack coats etc. Supervisors should ensure that construction proceeds according to these recommendations.

9.2 COMPACTION

Haunching work differs from normal road construction in that access can be awkward and the working width is restricted which makes it difficult to fully compact the extremities. The choice of materials in the Structural Course and Foundation Platform and the selection of appropriate plant can assist the ease of compaction. A schedule of typical compaction plant is given in the earlier Reports PA/SCR243 and ENG/1/91.

Placement and compaction of all types of Foundation Platform materials should be by method specification in accordance with the compaction tables given in Appendix 2 of Report ENG/1/91.

Where a bituminous hot-mix material is selected for the Structural Course, hot rolled asphalt basecourse complying with BS594 (1992) is preferred because it is easier to compact than dense macadam. The compaction of asphalt materials can be carried out by method specification. However, dense macadam materials complying with BS4987 (1993) are generally more difficult to compact and it is most important to ensure that they are compacted thoroughly to ensure good performance. It is recommended therefore that dense macadam materials are compacted according to an end product specification; a recommended end product specification is given in Appendix C in Report PA/SCR243.

Compaction of the surfacing layers should be by method specification.

In plant recycled bituminous materials using foamed bitumen binder should be compacted in layers not exceeding 200mm.

9.3 BITUMINOUS PLANINGS

Bituminous planings exhibit considerable resistance to compaction when dry due to the plasticity of the bitumen coating. This can give a high voids content, of the order of

15 to 25 per cent and limits the thickness of the layer that can be compacted satisfactorily. It is recommended that bituminous planings should be compacted in layers not exceeding 150mm. Better compaction can be achieved when the planings are warm.

Laboratory compaction tests carried out according to BS5835 (1980) show that the addition of water has a significant effect on the state of compaction producing voids contents of less than 5 per cent at the optimum moisture content. It is recommended that bituminous planings are compacted at moisture contents close to the optimum. Method compaction should be used as recommended in PA/SCR243 except that the maximum compacted layer thickness should be 150mm.

If it is not possible to determine the optimum moisture contents in the laboratory then general guidance is given in Table A3.3. The optimum moisture content of the planings used in the trials were between 5 and 8.5 per cent and the bituminous planings were supplied at moisture contents of between 0.5 and 1.5 per cent. The quantity of water needed to provide the optimum moisture content should be added to the planings before placing and compacting in the haunch. Unless the subgrade is clay, it is better to have slightly more moisture than less. Care should be taken when constructing on moisture susceptible subgrades.

An upper limit of 10 per cent bitumen content is recommended for planings to be used for haunch repair.

The results of plate bearing tests on bituminous planings in hot weather should be interpreted with care because the long period of loading can cause plastic deformation. Site measurements of the installation strength of layers of bituminous planings can be determined indirectly by using a dynamic cone penetrometer (Section 7.3).

10. DESIGN EXAMPLE

An example is given for the repair of a defective haunch on a rural road of 6.5m average width and 1km long connecting a classified rural road with the outskirts of a small town. A new industrial estate has been built close to one end of the road and the traffic using this rural link road has increased during the last year. About 0.5km of the road is winding and bordered with trees on both sides. Over-riding has occurred in several places along this stretch of the road. Winter weather and subsequent thaw has weakened the edges and several potholes have appeared and much of one edge has suffered fairly severe deformation. The other 0.5km of the road is generally wider and straight. No over-running has occurred and deterioration is limited to two short lengths on one side of the road.

The condition was noted on a routine safety inspection and also as a result of complaints from motorists.

The gullies to the drainage ditch on the north (badly deteriorated) side of the road have silted up and there is considerable standing water at the edge from time to time. Various patch repairs have been carried out during recent years to maintain the road in a reasonable condition.

Due to the recent increase of traffic and frequent over-running it is decided to widen the road as part of the haunch repairs.

10.1 ASSESSMENT OF HAUNCH CONDITION

The steps outlined in Flowchart A are followed. In this example there are no deflectograph measurements and the defective haunch has been identified by a visual inspection. The precise location, lengths and widths of deterioration have been noted together with the type and severity of the deterioration. There is sufficient room to widen the road on the north side where it bends through the trees and this will be done. The drainage will be repositioned and renewed as part of the works. The land required is already owned by the authority.

There are four areas on the north side that are dangerous. These potholes/areas of extensive deformation have been filled in with temporary patches.

The Statutory Undertakers were consulted and no apparatus was present on the northern haunch or verge. Telephone and electricity supplies are present in the southern verge and in places into the edge of the road. These have been identified and marked by the relevant Statutory Undertakers.

A trial pit in the form of a slit trench 1.5m x 0.75m was excavated from the edge of the road through the outer wheelpath on the north side of the carriageway at chainage 300m where the haunch was in poor condition and cores, 100mm diameter were taken at 100m intervals in the nearside wheelpath along the length to be repaired. A core was also taken in the outer wheelpath on the southern side of the road. The type and thickness of the bound layers extracted in the cores and from the pit were recorded and the granular foundation was excavated from the trial pit. Samples of soil were taken from the pit and the CBR and moisture content were determined in the laboratory. A cone penetrometer was also used in the bottom of the trial pit to assess the in-situ variability of the CBR. It should be borne in mind that during a dry summer unrepresentative values of CBR might be obtained from in-situ measurements.

The existing construction comprised:

1. two applications of surface dressing
2. dense macadam on average 40mm thick (35-50mm)
3. open macadam on average 80mm thick (60-110mm)
4. unbound granular material (type 2 sub-base) on average 400mm thick (350-450mm)
5. sandy subgrade (5 per cent CBR)

At the edge of the road and to within approximately 300mm from the edge, the construction thicknesses were substantially less, having on average 80mm of bituminous material on a variable thickness (200-350mm) of unbound granular material.

The width of the new haunch on the northern side will be 1.75m which extends approximately 1m into the road to include the nearside wheelpath. The road is being widened by approximately 0.75m.

The drainage ditch will be repositioned 1m to the north and the verge will be lowered flush with the carriageway; at present it is uneven and varying in height between -50mm to +150mm.

10.2 ASSESSMENT OF RE-USABLE MATERIAL

Flowchart B was used as a guide to assess a supply of demolition waste comprising about 50 per cent of crushed concrete and 50 per cent of crushed brick. This material is available from a local demolition contractor who has facilities for crushing and screening. When available, it has been used locally for foundations for housing estate roads and no leachate problems have been reported. The presence of lime or cement mortar is unlikely to cause a contamination problem although gypsum plaster might give some cause for concern if present in large proportions. Crushed demolition waste is used extensively in Holland and their specifications do not permit more than 1 per cent of non-stony matter, (plaster, plastic etc.).

Samples of material were obtained from the supplier and the particle size distribution was measured. The grading was continuous, similar to Type 1 but with a slightly higher fines content (12 per cent). The site was not located in an area susceptible to freezing and therefore the frost susceptibility was not measured. The supplier had no records of frost susceptibility measurements.

Material was being laid elsewhere and the opportunity was taken to do some plate bearing tests on a housing estate site where a mean plate bearing value of 75MPa was achieved. It was thought that, with better construction control, a higher value might have been possible. The compactibility and the Ten-per-cent Fines Value (TFV) were measured in the laboratory and these produced a peak density of 1850kg/m^3 at an optimum moisture content of 9.8 per cent and a TFV of 80kN.

The assessments indicate that the material is suitable for the Foundation Platform and might be suitable for the Structural Course.

10.3 STRUCTURAL DESIGN OF THE HAUNCH

Flowchart C was used to investigate the viability of various designs for this site depending on the materials used. In this local community, recycling is an important environmental goal and therefore re-usable materials are used in the haunch reconstruction wherever possible. It is also important from an engineering viewpoint that the overall thickness of construction of the haunch is similar to that of the existing road in order not to create a sump at the edge of the road into which water could collect.

The first requirement is to design the Foundation Platform. The equilibrium CBR of the subgrade is known to be 5 per cent and Table 5 shows that the demolition waste will require a Foundation Platform of 315mm unless further plate bearing measurements are carried out and an equivalent modulus in excess of 100MPa is achieved. If this can be achieved on site then the thickness of the Foundation Platform can be reduced to 250mm.

The next stage is to calculate the thickness of the Structural Course for various design options. First, the future traffic loading must be assessed to determine the road type category.

Fortunately, a traffic count had been carried out 3 months ago as part of the routine assessment by the authority. For this link road it was considered that the growth rate was 3 per cent in view of the recent opening of the industrial area and the plans for increased trade.

A full traffic assessment was made according to Table A 5.1 in Appendix 5. The results are given in Table 9. If a traffic count had not been available it would have been necessary to follow the procedure given in Section 8.2.

The calculation of cumulative traffic showed that the road was category type 3.

For comparison, the broad brush calculation described in Section 8.2 was carried out. An adjustment was necessary to account for the differences between the assumed and estimated traffic growth rate. The calculation was carried out according to the following equation:

$$\text{msa} = ((9000 \times 1.4)/1.25) \times \text{AADF} = 1.41$$

This calculation confirms that the road is category type 3. The difference in calculated cumulative traffic between the two methods occurred because of the difference between the assumed traffic class distribution and the observed distribution.

If the crushed demolition waste is also to be used as the Structural Course, a plate bearing modulus of 100MPa must be demonstrated. A thickness of 320mm will then be

TABLE 9

Calculation of design traffic

Vehicle class	AADF factor (A)	Growth factor (B)	Wear traffic (C)	Cumulative (T)
Buses & Coaches (PSV)			1.3	
OGV1				
2 axle rigid	71	1.4	0.34	0.247
3 axle rigid	24	1.4	1.7	0.417
3 axle articulated	15	1.4	0.65	0.100
OGV2				
4 axle rigid	15	1.4	3.0	0.460
4 axle articulated	9	1.4	2.6	0.239
5 axle articulated	6	1.4	3.5	0.215
Total cv/day 140	Design Traffic (msa)	1.678		

required under 100mm of bituminous surfacing layers. This design will give a total construction thickness of 670mm assuming the required equivalent modulus of 100MPa can be achieved It was noted that this construction thickness is greater than the average construction thickness of 520mm of the existing road, although taking into account the observed tolerance in the measured thickness the maximum thickness of the existing road could be 610mm.

An alternative design for the Structural Course, according to Figure 6, is 90mm of dense bituminous base course material.

In order not to carry out further plate bearing tests and to avoid constructing a sump at the edge of the road it was decided to use the following design for the haunch reconstruction:

Foundation Platform	250mm crushed demolition waste
Structural Course	90mm very dense bitumen macadam basecourse
Surfacing layer	60mm very dense bitumen macadam basecourse
Surfacing layer	40mm dense bitumen macadam wearing course

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* These TRL unpublished Project Reports are available on direct personal application only from the Transport Research Laboratory.

APPENDIX 1: GLOSSARY OF TERMS

HAUNCH - The outer edges of the carriageway either side of the centre of the road.

HAUNCHING - Maintenance of the outer edges of the carriageway. This involves partial or total reconstruction of a defective edge structure or the construction of a new section to widen the carriageway.

SUBGRADE - Natural soil or rock.

EQUILIBRIUM CBR - A measure of the in-service bearing capacity of a material especially that of the subgrade.

FOUNDATION PLATFORM - A layer which reflects the subgrade condition and provides a stable platform upon which the Structural Course can be adequately compacted.

STRUCTURAL COURSE - The main stress distribution layer within the pavement whose thickness is dependent on traffic loading.

WEARING COURSE - The surface layer of the road designed to provide an even surface with a high resistance to skidding and deformation.

RECYCLING - The process by which materials can be re-used for their original purpose.

IN-SITU RECYCLING - A process using specialised plant to mix materials in-place in the road with the addition of hydraulic or bituminous binders. The in-situ recycled materials are recompacted to form foundation or structural layers.

OFF-SITE PLANT RECYCLING - The process of mixing materials excavated from roads with bituminous or hydraulic binders in a mixing plant which can be located centrally or at the road site. The mixed materials are then laid and compacted conventionally.

RE-USABLE MATERIALS - Granular materials that have already been used in the construction industry that can be re-used or recycled after suitable processing.

GRANULAR-BITUMINOUS MATERIALS - Granular materials that have been coated with a bituminous binder. The bituminous materials can comprise a mixture of materials from road construction sites (e.g. planings, cooled or rejected hot-mix materials) or waste production mixes of bituminous materials.

ALTERNATIVE MATERIALS - Granular materials that have the potential to be used as aggregate in road construction but which are usually produced as a by-product from an industrial process.

MARGINAL MATERIALS - Natural rock that even after processing does not comply fully with the requirements of Type 1 or Type 2 granular foundation materials.

HYDRAULICALLY-BOUND MATERIALS - Granular or granular-bituminous materials that are held together with a binder that requires the presence of water to cure. (The binder is usually cement, lime or other pozzalanic materials or a mixture of such binders).

PLANINGS - Bituminous materials planed out from the road.

GRANULATED BITUMINOUS MATERIALS - Surplus or waste bituminous materials that have been crushed/screened to produce a consistent sized product. The bituminous materials can comprise a mixture of materials from road construction sites (e.g. planings, cooled or rejected hot-mix materials) or waste production mixes of bituminous materials.

FOAMED BITUMEN - A bituminous binder produced by injecting cold water under controlled conditions and with certain additives into hot penetration grade bitumen before application through specially designed nozzles and spray bar. The foamed bitumen expands to 10 - 15 times its original volume. The foamed bitumen process is a Mobil Oil Ltd. patent.

APPENDIX 2: MATERIALS FOR HAUNCH REPAIR RECOMMENDED IN PA/SCR243 AND ENG1/91

GSB 1	Granular sub-base Type 1 as described in the Specification for Highway Works (MCHW 1) clause 803, but with moisture content controlled to within +1% to -2% of OMC.
GSB 1X	A granular material displaying a higher permeability than GSB 1.
GRAN	Any granular material which is physically and chemically stable, of adequate intrinsic strength and provides an equivalent modulus (bearing capacity) of at least 70MPa after compaction. The moisture content requirement for GSB 1 may also be applicable to GRAN materials dependent upon the grain size distribution.
DBBC	20mm dense basecourse macadam BS4987: Part 1: 1993 Clause 6.5, 100 Pen grade binder.
VDBBC	As DBBC material but coupled with end point compaction specification given in Appendix C4 of TRL Report SCR243.
HRABC	Rolled Asphalt Basecourse BS594: Part 1: 1992, Table 2 Column 2/3, 50 Pen binder.
HSCA	High Stone Content Asphalt incorporating 100 Pen binder BS594: Parts 1 and 2: 1992, Table 3 Col 3/4, 3/5 Table 4 Col 4/4, 4/5 or refer to PA/SCR243 Appendix C5 (1994).
DBWC(10)	10mm close graded wearing course macadam BS4987: Part 1: 1993 Clause 7.4, 100 Pen grade binder. Crushed rock or slag aggregate of PSV not less than 50.
DBWC(6)	6mm dense wearing course macadam BS4987: Part 1: 1993 Clause 7.5, 100 Pen grade binder. Crushed rock or slag aggregate of PSV not less than 50.
HRAWC(DM)	Rolled Asphalt wearing course BS594: Part 1: 1992, Table 3 Column 3/2, 50 Pen binder Table B1 Stability 5kN +/- 3kN. Crushed rock or slag coarse aggregate of PSV not less than 45 with coated chippings of appropriate PSV.
HRAWC	Rolled Asphalt wearing course BS594: Part 1: 1992, Table 6 Column 6/4, 50 Pen binder crushed rock or slag coarse aggregate of PSV not less than 45 with coated chippings of appropriate PSV.

APPENDIX 3: REQUIREMENTS FOR GRANULAR AND GRANULAR-BITUMINOUS MATERIALS

TABLE A3.1

Recommendations for the assessment of the suitability of granular and granular bituminous materials for the Structural Course

Property	Material behaviour controlled	Requirement	Measurement method
Particle size distribution	Stiffness, strength, permeability and frost susceptibility	Continuously graded Maximum particle size 75mm with not more than 15% larger than 37mm. Maximum fines content 10% passing 0.075mm.	BS812: Part 103 Methods for determination of particle size distribution. (BSI,1985)
Particle flakiness	Ease of compaction	Flakiness index shall not exceed 35	BS812: Part 105 Methods for determination of particle shape. Section 105.1 Flakiness Index. (BSI,1989)
Compactibility,	Degree of compaction	Material shall be placed and compacted near the optimum moisture content (OMC-2% to OMC+1%)	BS5835: Compactibility test for graded aggregates. (BSI,1980) or BS1377: Part 4: Compaction related tests. Clause 3.7 Method using vibrating hammer (BSI 1990) or for Type 3 & 4 roads, Appendix C1 of PA/SCR243
Optimum Moisture Content	Stiffness & ease of compaction		BS812: Part 109 Methods for the determination of moisture content.
Particle Strength	Resistance to crushing	Material shall have a TFV >50kN * TFV test is not applicable to material derived from bituminous road planings or concrete	BS812: Part 111 Methods for the determination of ten per cent fines value. (BSI,1990). The test sample shall be in a soaked condition at the time of test.
Plasticity	Moisture susceptibility, strength	The material passing 425 microns shall be non-plastic The plasticity index test is not applicable to material derived from bituminous road planings or concrete	BS1377: Part 2 Soils for engineering purposes. Classification tests. (BSI,1990)

Notes:

1. Materials derived from bituminous planings and concrete can be assumed to contain aggregates that comply with the TFV and plasticity index required for granular and granular-bituminous structural layers for haunch repair. Aggregates for bituminous materials are required to possess greater internal strength and lower plasticity than required for haunch repair.

2. * Local experience should be taken into account because some materials are capable of achieving the plate bearing values recommended for structural layers without complying with these TFV's. Concern about degradation during compaction should be addressed by determining the particle size distribution before and after compaction. Low TFV does not necessarily preclude use as grading, particle size and self-cementation, which occurs with some materials, may counteract the weakness.

3. The presence of excessive fines in granular materials can be detrimental to compaction in poor weather conditions. Fines should be limited to 10 per cent passing 0.075mm sieve to minimise compaction problems during wet weather.

TABLE A3.2

Recommendations for the assessment of the suitability of granular and granular bituminous materials for the Foundation Platform

Property	Material behaviour controlled	Requirement	Measurement method
Particle size distribution	Stiffness, strength, permeability and frost susceptibility	Continuously graded Maximum particle size 75mm with not more than 15% larger than 37mm. Maximum fines content 15% passing 0.075mm.	BS812: Part 103 Methods for determination of particle size distribution. (BSI,1985)
Compactibility	Degree of compaction	Material shall be placed and compacted near the optimum moisture content (OMC -2% to OMC+1%)	BS5835: Compactibility test for graded aggregates. (BSI,1980) or BS1377: Part 4 Compaction related tests Clause 3.7 Method using vibrating hammer (BSI 1990) or for Type 3 & 4 roads, Appendix C1 of PA/SCR243
Optimum Moisture Content	Stiffness & ease of compaction		BS812: Part 109 Methods for the determination of moisture content.
Particle Strength	Resistance to crushing	Material shall have a TFV >40kN * The TFV test is not applicable to material derived from bituminous road planings or concrete	BS812: Part 111Methods for the determination of ten per cent fines value. (BSI,1990). The test sample shall be in a soaked condition at the time of test

Notes:

1. Materials derived from bituminous planings and concrete can be assumed to contain aggregates that comply with the TFV required for granular and granular-bituminous foundation platform for haunch repair. Aggregates for bituminous materials are required to possess greater internal strength than required for haunch repair.

2. In determining the particle size distribution of granular-bituminous materials it is not possible to drive off free water by oven drying the material to 105°C prior to washing as this would result in the particles adhering together when the bitumen softened. Grading determinations on bituminous granular materials are therefore carried out as 'dry' (as delivered) tests.

   Because the particles tend to conglomerate due to the presence of bitumen the particle size distribution is dependent on the duration of shaking, the temperature at which the test is carried out as well as the grading of the mineral particles within the granular-bituminous material.

3. * Local experience should be taken into account because some materials are capable of achieving the plate bearing values recommended for structural layers without complying with these TFV's. Concern about degradation during compaction should be addressed by determining the particle size distribution before and after compaction. Low TFV does not necessarily preclude use as grading, particle size and self-cementation, which occurs with some materials, may counteract the weakness.

TABLE A3.3

Typical test values of materials used in the trials

Property	Material type								
	Type 1 Crushed rock Sub-base	Type 2 Gravel Sub-base	Slate	China clay Stent	Quarry aggregates	Crushed concrete kerbs	Bituminous road planings	Granulated bituminous materials	Furnace bottom ash
Particle size distribution Values of materials used in trials given in Table A3.4	Type 1	Type 2	Type 1	Type 1	Outside Type 1 or Type 2 (coarse)	Outside Type 1 or Type 2 (coarse)	Coarse of Type 2 from 5mm down	Type 1	Outside Type 2 as 8% oversize
Particle flakiness	Carboniferous Limestone 19 Granite 19	Flint gravels 11-20	93-100	n/m	n/m	n/m	n/m	n/m	n/m
Plasticity index	Non-plastic	<6	<6	<6	n/m	<6	n/a	n/a	n/a
Compactibility (kg/m³)	Carboniferous Limestone 2170-2230 Granite 2220-2300	Flint gravels 1950-2230	2215-2220	2370	n/m	2030	1910-1990	1815-1945	n/a
Optimum Moisture Content (%)	Carboniferous Limestone 2.6-3.5 Granite 5.5-7.0	Flint gravels 4.5-9.0	5.6-6.5	1.5	n/m	6.7-9.8	3.0-4.0 5.0-8.7 *	1.5-3.9 6.1 *	10-14
Moisture Content (%)	Carboniferous Limestone 1.1-4.7 Granite 0.5-7.0	Optimum Moisture Content	5.8-6.4	0.9-1.5	n/m	7.7-10.8	3.7-7.5	9.5-12.0	12-15
Particle Strength (Kn) (Ten percent fines - sample soaked)	Carboniferous Limestone 160 Granite 200-380	Flint gravels 240-320	n/m	n/m	n/m	90-105	n/a	n/a	Dry 25 Soaked 18

* Results based on BS1377 test procedure n/a - Test not applicable n/m - not measured

TABLE A3.4

Particle size distribution of materials used in the trials

BS sieve size	Percentage by mass passing													
	China Clay Stent	Slate Waste		Bituminous Planings			Type 1 GSB			Type 2 GSB	Granulated bituminous materials	Quarry aggregates	Crushed kerbs	Furnace bottom ash
75 mm	100	100	100	100	100	100	100	100	100	100	-	100	87	92
37.5 mm	94	96	99	99	96	100	100	100	100	100	96	100	58	90
20 mm	50	78	89	83		94	86		83	97	86	95	46	82
10 mm	41	54	63	47	52	70	66	55	55	80	55	79	34	69
5 mm	33	32	39	22	25	44	43	46	35	59	30	59	23	60
2.36 mm	28	20	26	11		27	30		26	44	17	45	17	52
1.18 mm	23	13	17	6.7		16	21		21	35	10	32	13	46
600 μm	19	9.2	11	4.2	2	9	16	20	18	27	6	24	11	39
300 μm	14	6.7	8	2.7		3.5	13		16	16	2	18	8	27
150 μm	11	5	5.7	1.7		1	10		14	11	0.5	15	5	15
75 μm	10	3.7	4.1	1.1	0.4	0.5	8	8	11	08	0.1	12	3	8

Tests carried out to BS812: Part 103 Methods for determination of particle size distribution. (BSI,1985) except for bituminous planings and granulated bituminous material for which a dry sieving method was used

TABLE A3.5

Plate bearing limiting values applied to trial materials

Plate bearing requirement	Re-usable material
Granular or granular-bituminous material that achieved an equivalent plate bearing modulus in excess of 100MPa	Type 1 fully crushed rock sub-base Crushed concrete kerbs China clay stent Quarry waste (crusher run) Bituminous planings Granulated bituminous material In-plant recycled bituminous material with foamed bitumen
Granular or granular-bituminous material that achieved an equivalent plate bearing modulus in excess of 70MPa	Slate
Granular or granular-bituminous material that achieved an equivalent plate bearing modulus less than 70MPa	Furnace bottom ash - variable results - mean 60 (30-100MPa)

APPENDIX 4:
DESIGN REQUIREMENTS FOR COLD RECYCLED MATERIALS

TABLE A4.1

Recommendations for the assessment of the suitability of materials stabilised with foamed bitumen for the Foundation Platform and Structural Course

Property	Material behaviour controlled	Requirement	Measurement method
Particle size distribution of reclaimed materials used in the mix	Stiffness, strength, permeability and frost susceptibility	Continuously graded Maximum particle size 75mm with not than 37mm. Maximum fines content 10% passing 0.075mm.	BS812: Part 103 Methods for determination of particle size distribution. (BSI,1985)
Particle flakiness	Ease of compaction	Flakiness index shall not exceed 35	BS812: Part 105 Methods for determination of particle shape. Section 105.1 Flakiness Index. (BSI,1989)
Bitumen content	In-situ performance	Target +/- 0.8%	BS 598: Part 102 Analytical test methods (BSI 1989)
Compactibility	Degree of compaction	Material shall be placed and compacted at about the optimum moisture content (OMC -2% to OMC+1.5%) to achieve a relative in-situ density of 95%	BS5835: Compactibility test for graded aggregates. (BSI,1980) or BS1377: Part 4: Compaction related tests (BSI 1990) or for Type 3 & 4 roads, Appendix C1 of PA/SCR243
Optimum Moisture Content	Stiffness & ease of compaction		BS812: Part 109 Methods for the determination of moisture content.
Stiffness modulus	Loadspreading ability	Wet immersed stiffness modulus of 2400MPa.	BS DD 213: Method for the determination of the indirect tensile stiffness modulus of bituminous materials. Tests to be carried out on specimens cured for 72 hours at 60°C. (BSI 1993).

Note: It is recommended that stiffness modulus of materials stabilised with foamed bitumen is used as the basis for structural design. Cylinders, 150mm diameter 75-100mm thick shall be compacted to refusal in a PRD mould and cured for 72 hours at 60°C. The stiffness modulus shall be measured in the Nottingham Asphalt Tester at 20°C.

TABLE A4.2

Recommendations for the assessment of the suitability of materials stabilised with cementitious binders for the Foundation Platform and Structural Course

Property	Material behaviour controlled	Requirement	Measurement method
Grading	Stiffness & strength Mixability	Continuously graded Maximum particle size 75mm with not more than 5% larger than 50mm. Maximum fines content 10% passing 0.075mm.	BS812: Part 103 Methods for determination of particle size distribution. (BSI,1985)
Particle Strength	Degradation on compaction	Material shall have a TFV >50kN	BS812: Part 111 Methods for the determination of ten per cent fines value. (BSI,1990)
Compressive strength	Strength *	Material shall have a compressive strength after 7 days curing of >4.5N/mm²	BS1924: Part 2: Clause 4.2 Methods of test for cement-stabilised and lime stabilised materials (BSI 1990)

* Compressive strength of the in-situ recycled material is the basis for design. The minimum average strength of 5 cubes made from samples extracted from the full depth of mixed material at positions equidistant along the length of haunch repair completed in one day shall be 4.5N/mm² and the minimum strength of an individual cube shall be 2.5N/mm².

Subject to material suitability, compressive strength values in accordance with the strength requirements of CBM3 and CBM2 can be achieved.

APPENDIX 5: FULL TRAFFIC ASSESSMENT FOR HAUNCH DESIGN

INPUT DATA

A. Initial 24 hour AADF (Annual Average Daily Flow) of commercial vehicles in one direction (the direction associated with haunch repair) for each class of vehicle given in Table A5.1.

B. The growth factor for each class of vehicle over a 20 year period according to Table A5.2.

C. The wear factor for each class of vehicle given in Table A5.1.

PROCEDURE

1. Calculate the cumulative traffic in each vehicle class using the following equation:

$T = 365 \times 20 \times A \times B \times C \times 10^{6}$

2. Calculate the total design traffic by summing the cumulative traffic in each class.

TABLE A5.1

Calculation of full traffic assessment

Vehicle class	AADF (A)	Growth factor (B)	Wear factor (C)	Cumulative traffic (T)
Buses & Coaches (PSV)			1.3	
OGV1				
2 axle rigid			0.34	
3 axle rigid			1.7	
3 axle articulated			0.65	
OGV2				
4 axle rigid			3.0	
4 axle articulated			2.6	
5 axle articulated			3.5	
Total cv/day		Design Traffic (msa)		

TABLE A5.2

Vehicle growth factors for 20 year design period

Vehicle growth rate (%)	Vehicle growth factor
0.5	1.03
1.0	1.1
2.0	1.25
3.0	1.4
4.0	1.55
5.0	1.72
6.0	1.8
8.0	2.3
10.0	2.8

APPENDIX 6: STRUCTURAL DESIGN DETAILS

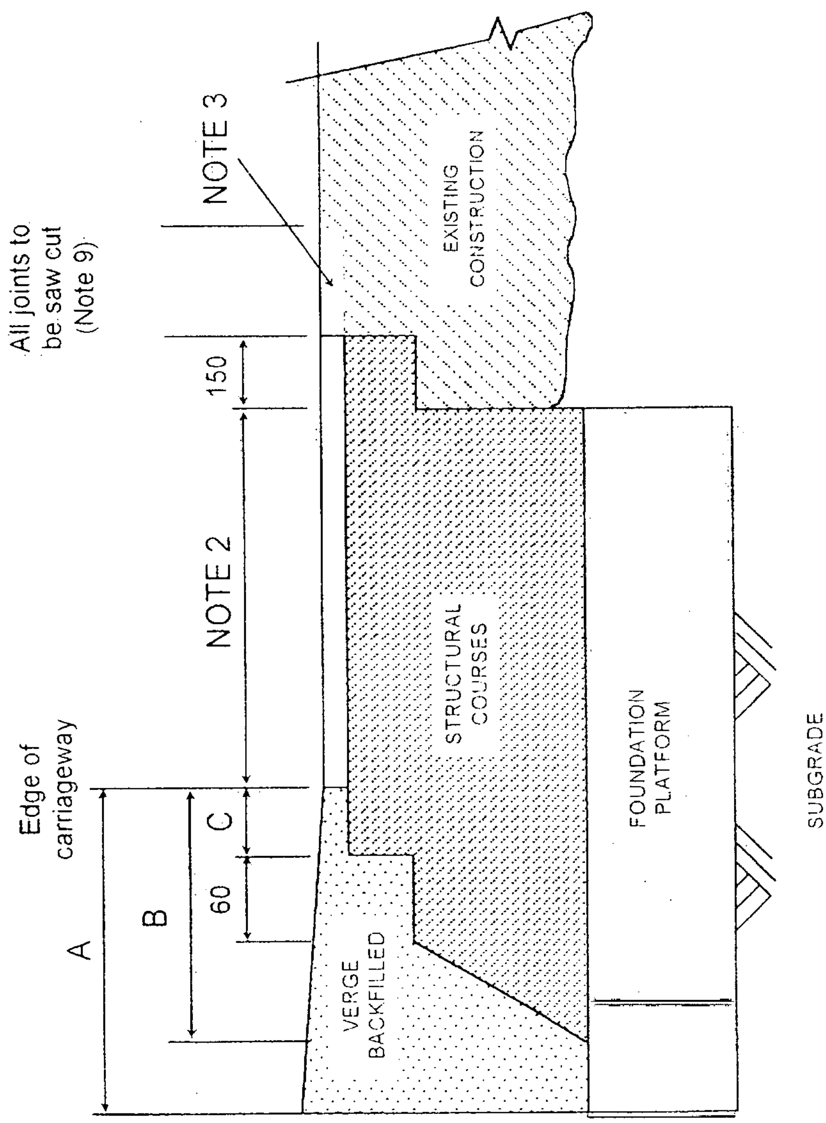
DETAILS OF STEPPED CARRIAGEWAY CONSTRUCTION	
DIMENSION FROM EDGE C/WAY	
A	
B	
C	

CONSTRUCTION THICKNESS	mm	MATERIAL
WEARING COURSE		
STRUCT (U) STRUCT (L)		
FOUNDATION PLATFORM		

DESIGN CBR (%)	

COMPACTION OF STRUCTURAL COURSES	END PRODUCT /METHOD

NOT TO SCALE



TYPICAL CONSTRUCTION DETAIL
CARRIAGEWAY EDGE STRENGHTHENING

NOTES

1. Dimensions A, B and C to be established after investigation.

2. Minimum width of construction should be appropriate for anticipated compaction plant but not normally less than 600mm.

3. Wearing course may be extended by 150mm if existing construction warrants this.

4. Wearing course surface texture and material properties (i.e. PSV etc) should 'match' the existing adjacent carriageway.

5. Structural Surfacing Courses may be combined.

6. Construction joint should be located outside the wheelpath zone where practicable.

7. Surface regularity on the new structure should be at least as good as on the adjoining carriageway.

8. Tack Coat

   Rapid curing cationic bitumen emulsion to BS434, typically 40% bitumen content.

   (The trial use of more modern variants is recommended as an alternative).

9. Edge Sealant

   Rapid curing cationic bitumen emulsion to BS434, typically 50 Pen or 70 Pen grade at 70% bitumen content or hot applied 50 Pen or 70 Pen grade bitumen to BS3690.

   (There is an increasing range of high build and elastomerised edge sealants becoming available and in general may be preferable to the above). The trial use of high build liquid sealants or solid sealing strips is recommended as an alternative.

10. Tolerances (on spec. nom. thickness):

    Subgrade Formation: +20mm, -30mm

    Found. Plat. (Granular): +20mm, - 30mm

    Found. Plat (Bit.): +10mm, -20mm

    Struct. Course (Granular): +20mm,

    Struct. Course (Bit.): +10mm, -10mm

    Wearing Course: +5mm, -0mm

11. The maximum reduction in overall nominal bituminous material thickness:-

    Road Type 1 and 2: 15mm

    Road Type 3 and 4: 10mm

12. Where a geosynthetic separator is specified at subgrade level then this should be Terram 1000 or equal approved.

13. Subgrade formation shall be trimmed and compacted prior to placement of Foundation Platform material (or geosynthetic separator if specified).

APPENDIX 7:
PROFORMA FOR RE-USE OF MATERIALS IN ROAD HAUNCHES

It would be appreciated if you would complete a copy of this proforma when you re-use or recycle materials for haunch repair. Although the proforma is fairly comprehensive, it is realised that in many situations it is not possible to make all the measurements etc. that you may wish during the course of design, assessment and construction. Nevertheless, it would be extremely valuable if you would complete as much of this form as possible and return it to:

Mr M Earland
Civil Engineering Resource Centre
Transport Research Laboratory
Old Wokingham Road
Crowthorne
Berkshire RG45 6AU.

HIGHWAY AUTHORITY:

CONTACT NAME/TELEPHONE/FAX NUMBER:

LOCATION OF WORKS

Road number: **Road Type category:**
Urban/rural: **Length of repair:**

DATE OF WORKS:

DESIGN OF HAUNCH REPAIR

Subgrade CBR:
Thickness of Foundation Platform:
Estimated traffic in direction of haunch repair:
Thickness of Structural Course:
Thickness of surfacing layer(s):
Thickness of in-situ recycling:

MATERIALS/ TECHNIQUES USED FOR HAUNCH REPAIR

Material used for Foundation Platform:
Source of material:
Distance transported:
Material used for Structural Course:
Source of material:
Distance transported:
Materials used for surfacing layers:

CONSTRUCTION OF HAUNCH REPAIR

	FOUNDATION PLATFORM	STRUCTURAL COURSE
Drainage:		
Methods of placement of materials:		
Compaction equipment used:		
Number of passes:		
Thickness of compacted layers:		
Density achieved:		
Plate bearing values:		

ASSESSMENT OF MATERIALS

Please provide on separate sheets any information regarding laboratory tests on the re-usable/alternative materials.

ANY PROBLEMS ENCOUNTERED

Please relate any difficulties with supply, consistency of materials / techniques and any problems encountered on site and how they were overcome.

REASONS FOR RE-USING MATERIALS, RECYCLING ETC.

ECONOMICS OF RE-USING MATERIALS

Thank you for your assistance.

MORE INFORMATION

The Transport Research Laboratory has published the following other reports on this area of research:

PA/SCR243 Road haunches: a guide to maintenance practice. 2nd edition. Report of a Working Group chaired by R A Luck, Divisional Surveyor, Gloucestershire County Council. 2nd edition. Price code C

TRL134 A study of footway maintenance, edited by Marilyn H Burtwell. Price code C

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