Treatment and Recycling of Soil and Aggregates of Trench Excavations

Andrew R. Dawson  
BA., MSc., DIC., CEng., MICE., FGS  
Associate Professor  
University of Nottingham  
Nottingham Transportation Engineering Centre  
University Park, Nottingham, NG7 2RD, UK  
Tel: +44 115 / 951-3902, Fax: +44 115 / 951-3898  
E-Mail: andrew.dawson@nottingham.ac.uk

Dipl.-Ing. Susanne Schulz  
Universität Karlsruhe (TH)  
Institut für Straßen- und Eisenbahnwesen  
Kaiserstraße 12, D - 76131 Karlsruhe  
Tel: +49 721 / 608-3652, Fax: +49 721 / 607610  
E-Mail: schulz@ise.uni-karlsruhe.de

Dr.-Ing. Rainer Hess  
Durth Roos Consulting GmbH  
Gartenstraße 26, D - 76133 Karlsruhe  
Tel: +49 721 / 38473-16, Fax: +49 721 / 38473-77  
E-Mail: rainer.hess@durth-roos.de

Phillip Windsor  
Project Manager  
BEng (Hons), Mphil, LLM  
University of Nottingham  
School of Chemical & Environmental Engineering  
University Park, Nottingham, NG7 2RD, UK  
Tel: +44 115 / 846-6369, Fax: +44 115 / 951-4115  
E-Mail: phil.windsor@nottingham.ac.uk

Andrew Batchelor, BEng.  
Research Associate  
University of Nottingham  
School of Chemical & Environmental Engineering  
University Park, Nottingham, NG7 2RD, UK  
Tel: +44 115 / 846-6390, Fax: +44 115 / 951-4115  
E-Mail: andrew.batchelor@nottingham.ac.uk

Besonderer Dank gilt dem „Department for Innovation, Universities and Skills“ des Vereinigten Königreiches (früheres Department for Trade and Industry) für die Förderung des Forschungsvorhabens, sowie Yorkshire Water als Projektleiter und Parker Plant als Hersteller für die Zusammenarbeit mit der University of Nottingham.

Patching, as a consequence of service trench rehabilitation, influences the assessment of road infrastructure, especially in urban areas. Whether the excavated material is reused or replaced, there are differences in material properties and in the performance of the existing structure and the backfilled trench. Thus, from a technical viewpoint, restored trenches tend to be weak areas of the road surface. The aim of a current research project is to reduce waste material by recycling the excavated material into the trench backfill. Especially the sometimes high moisture content is a challenge to the treatment. On the basis of first tests a procedure is proposed to create a “new recycled material” for stable backfilled trenches with low rates of material replacement.

Special thanks go to the Department for Innovation, Universities and Skills in the UK (former Department for Trade and Industry) for funding this work, as well as to Yorkshire Water as the project manager and Parker Plant as manufacturing partner for the collaboration with the University of Nottingham.
Road and Utility Infrastructure

Municipal roads have to serve for many more purposes than just traffic. Public or private service companies provide water supply and disposal as well as gas, district heating, electricity and communication infrastructures (Figure 1). As these infrastructures are an important component of public infrastructures providing basic services to the general population, the executing companies are usually granted a preferential access to the municipal right of way (ROW). The terms for occupancy of the municipal ROW not always include a financial compensation for the direct and indirect incurring costs. But some sources are convinced, that the annual concession levies the system operators pay to cities and communities in Germany are more than sufficient to cover the maintenance of the road network [4].

![Figure 1: Infrastructures of service providers](image)

The occupation of the municipal ROW by utility companies is causing direct and indirect costs to the municipalities. These costs can be divided into two groups [3]:

- **Administrative Costs:**
  They are required for keeping and managing records of the utility locations, for issuing permits and plans coordinating the location of infrastructure. The road administration also has to inspect the construction site to ensure, that all applying regulations are being observed. There are management costs for coordinating public advertising and signage for detours and road closures. Last but not least the general administrative costs include the processing of damage claims and an overhead.

- **Physical Costs:**
  They cover any other direct and indirect expenses incurred by municipalities as a result of a service facility’s existence in the municipal ROW. These include construction delay costs for locating lines, shoring and tunnelling or in worst case repair costs when unmarked lines are damaged. Additionally cities and communities suffer pavement degradation costs as well as inconvenience costs for planning and constructing around these facilities.

As German road infrastructures has to be assessed in future on a yearly basis, the loss of value regarding each carriageway caused by surface damages and changes as well as by a reduction of life time the road structure is facing results in balancing costs. One way to reduce this type of costs is to coordinate construction measures. In best case the trench digging by a service provider is followed by a road construction measure to reduce the risk of surface damages and minimise road traffic intervention. This coordination is established in many countries for example based on a three month period [1].
Challenge of Adequate Patching

European, Canadian and American studies show as expected, that artificially introduced breaks or intrusions in a pavement surface significantly reduce the overall integrity of the structure and thereby pavement lifetime. The actual monitoring of pavement damage on a case by case basis and attributing specific reductions of pavement life to specific pavement cuts is technically impossible given the number of variables involved. A number of generalisations must be made to arrive at a reasonable estimation of accelerated depreciation and associated costs. In many countries including Germany, cities and communities have implemented pavement restoration specifications for utility cuts. Some Canadian municipalities invented types of mechanisms to repair and restore pavement surfaces to ‘better than existing’ condition [3]. It is believed, that in this case there may not be a need to recover pavement degradation costs. Future studies have to show, if the difference in properties of the pavement structure is not causing other surface damages.

To minimise the impact on the road surface an American company developed the keyhole coring and reinstatement procedure for utility cuts [5]. A core is drilled carefully out of the bound layers of the pavement structure. Excavating, repairing and refilling are carried out through this keyhole. After work is finished the undamaged core is placed back into the keyhole and securely bond to the surrounding pavement structure by filling the annular space with special sticking material. The specifications of this material claim to reach three times of the equivalent of usual traffic loading. For the installation of new supply and disposal lines this procedure is not suitable. Apart from this restriction the challenge of an adequate compaction is still present for the unbound layers of the pavement structure.

Many urban roads, where service trenches are most common, are quite old and it is hard to determine the subgrade on which they are built. To gain at least the existing performance trenches are mostly refilled and reinstated by quarried material. Because of the uncertainty concerning the existing subgrade the required kind of treatment to successfully recycle the excavated material is difficult to determine. To recycle material for the purpose of refilling trenches, the reused material has to provide comparable performance as it had before. As not every material is suitable for backfill, some material has to be stabilised.

One method to stabilise excavated material is to add a chemical recipe leading to a cement bound layer. The excavated soil is temporarily fluidised and reused with added cement to refill trenches without any mechanical compaction [7]. The recipe can be adapted to previous chosen properties, which should be comparable to the surrounding material. Stability is reached after the hydration process. For the production mixing plants are needed. A British project is looking for another way of treatment [2], whose equipment should fit in an excavation site.

Recycling of Building Material

Around six to eight million tonnes of soil, aggregate, asphalt, broken pipes and so on is dug from service trenches in roads in the United Kingdom each year and mostly sent to landfill. Every ton has to be paid for (landfill site fares, transport, taxes etc.) often in excess of £20/tonne. However, costs will continue to increase in coming years. Current estimates
suggest, that only the taxation element of tipping charges will increase to 34 pounds per tonne.

The idea in general, to recycle trench arisings, is not new. But they are mostly recycled on central recycling depots with separation, cleaning and stockpiling. Here the side-effects of transportation like noise, fuel, vehicles and therefore often occurring traffic congestion are the same as when transporting excavated material to landfill sites. There are a lot of factors against the use of recycling and alternative materials. Most of them are based on the lack of knowledge of mankind and concerns about the pollution of the environment for example due to leaching. But also the lack of suitable specifications and guidelines for recycling methods and materials contributes to the non-use of recycling in general. But there are also a lot of reasons arguing for (new) recycling-methods as well. Like the landfill site taxes mentioned above or the quarrying and levy for aggregates.

For these reasons this project has been commenced to reduce waste going to landfill and to reduce the quarrying of replacements and thus non-essential vehicle movements and vehicle emissions around the trench by, as far as possible, recycling the excavated material for re-use as backfill. There are two other targets:

- To attempt to recycle the excavated material near the trench so as to further reduce the environmental impacts due to traffic and nuisance effects.
- To demonstrate adequate performance to national QA/QC reinstatement standards.

It is important for that the research will define a safe processing route, that has an efficient use of energy, time, space, personnel and consumables to transform the excavated material into a treatable form and also minimising the equipment needed for recycling as well as the operator input while providing protection from noise from the mechanical equipment.

Recollecting of Soil and Aggregates from Trench Excavations

To investigate the special challenges of recycling trench excavations, samples were taken from different excavation sites from two different areas in the northeast of England. The material coming from those trenches varied a lot. For example concrete, bricks, asphalt, broken pipes and limestone were found in many different kinds of trenches. Also the age of a pavement structure is important. Urban roads are sometimes quite old and it is not possible to get to know what kind of material will be excavated before digging up the road. Generally, great variations in trench arisings and their conditions can be expected as the reason for opening a service trench varies a lot. The area in which the road has been built and the materials used for sub bases either depend on the area and the age of the road. Clay was found in every trench (90% of roads in the United Kingdom are built on clay). Some of the material is very wet, for example due to leaking pipes or pipe bursts, (which were often the reason to open a trench). Figure 2 shows two different types of trenches where some of the difficulties mentioned above can be detected.

In general, trenches revealed asphalt, which is more easily separated during and by the excavation process, followed by aggregate, ash or unsorted coarse stones, followed by finer grained subgrade soil. The last layers are very difficult to separate by an excavation team as the unbound pavement and trench back fill materials are frequently contaminated with subgrade fines, which may also be very wet. The unbound and trench fill materials may be similar to conventional aggregate or may be very coarse and, in some cases, may contain significant proportions of subgrade soil.
Very wet clay, for example, is hard to separate from other material. On a vibrating screen, the clay started to agglomerate and blind the screens. It had to be forced through the screens by hand. This means, there has to be found an easy way to either treat the lumped material with other material or to dry the material out with the means of different drying processes. Figure 3 shows a big lump of clay with other material enclosed and the blinded holes of a vibrating screen.

It is difficult to make any fixed conclusion for trench arising treatment from the foregoing examinations. Trials had to be carried out in the laboratory to come to first conclusions. In any case, a way has to be found to dry out the rather wet material. For this purpose, the following (thermal or chemical) drying mechanisms can be considered:

- Industrial dryers transfer the heat to the surface of the wet solid and conduct through the material wall to its interior
- Dielectric, radio frequency and microwave heating generates heat by focussing energy within the body of the material and the heat flows to the exterior
- Absorbent dryers are used to ‘soak up’ unbound moisture with added material
Chemical dryers that react with water removing it from the soil into the reaction products.

**Treatment of Excavated Material from Service Trenches**

The following measures were undertaken to stabilise trench arisings and assess the behaviour of possible trench back fill material:

- Use of cement with other additives to enhance early strength for a high performance level as early as possible
- Application of lime to contaminated arisings in addition to binder proportions
- Use of ground granulated blast furnace slag (GGBS)
- Use of ashes as a bulking agent/grading amender where the arisings are low in fines
- Use of certain ashes to attempt to dry out the excavated material

To get an idea of the strength of the material when mixed with stabilisers, unconfined compression strength (UCS) tests (Figure 4) were carried out. The curing time of the prepared specimen always was three and seven days, to see if the material would gain enough strength after a quite short period of time. The following table (Table 1) shows the amount of stabiliser added to the soil as a percentage of the weight of the soil, as this is the easier way to calculate the necessary amount of stabiliser on site. The results of the UCS testing are shown in Figure 5.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Stabiliser</th>
<th>Amount of stabiliser added (%)</th>
<th>Amount of water added (%)</th>
<th>Ratio soil/stabiliser/added water</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 (&lt; 5mm)</td>
<td>Cement+GGBS</td>
<td>0.5 + 7</td>
<td>1.9</td>
<td>91.4 : 6.9 : 1.7</td>
</tr>
<tr>
<td>A2 (&lt; 20mm)</td>
<td>Lime + Ash</td>
<td>1.5 + 6</td>
<td>4.0</td>
<td>89.7 : 6.7 : 3.6</td>
</tr>
<tr>
<td>B (&lt; 5mm)</td>
<td>Lime</td>
<td>4</td>
<td>none</td>
<td>96.2 : 3.8 : 0</td>
</tr>
<tr>
<td>C (&lt; 5mm)</td>
<td>Lime</td>
<td>5</td>
<td>none</td>
<td>95.2 : 4.8 : 0</td>
</tr>
<tr>
<td>D (&lt; 5mm)</td>
<td>Lime</td>
<td>5</td>
<td>none</td>
<td>95.2 : 4.8 : 0</td>
</tr>
<tr>
<td>E (&lt; 5mm)</td>
<td>Lime + Ash</td>
<td>1.5 + 6</td>
<td>none</td>
<td>93 : 7 : 0</td>
</tr>
<tr>
<td>F (&lt; 8mm)</td>
<td>Lime</td>
<td>4</td>
<td>none</td>
<td>96 : 4 : 0</td>
</tr>
<tr>
<td>G (balled material)</td>
<td>Lime</td>
<td>4</td>
<td>none</td>
<td>96 : 4 : 0</td>
</tr>
</tbody>
</table>

Table 1: Mixes used for stabilised soil testing (UCS)
Figure 4: Apparatus for UCS-testing and UCS test specimen

Figure 5: Results of compressive strength testing
Apart from the UCS testing indirect tensile strength and California bearing ratio (CBR) tests were performed. It is to mention for all tests, that the amount of provided and collected bulk specimen did not allow a statistically sufficient number of tests. So there is a need for more testing and examination. However it was possible to gain an idea of the behaviour of the stabilised and conditioned material. Therefore a more detailed basis for the forthcoming study was created.

One of the ashes used for UCS testing did not show any useful results. But because of its porosity and its initial moisture content (examination showed a moisture content around 68 %) it was tried to use it as an absorbent for very wet material. The ash was dried out and mixed with wet clayey and silty material. The moisture contents sank from 24 % down to 10.9 % (Figure 6). This made the resulting material very easy to handle, which will help the forthcoming procedure of screening, separating and crushing. The resulting mixture needs still more investigation as the environmental agency has to agree to use the new recycled material in road infrastructures.

![Figure 6: Drying effect of ash on very wet silty and clayey material](image)

**Summary and Conclusions**

The testing with different materials has demonstrated the following key features of relevance to the objectives of an on-site recycling of trench excavations:

- Ash in a dry condition shows great promise as a low-energy drying agent for wet soils, transforming them from highly plastic to more friable materials.

- It is possible to stabilise clays from trench excavations by the addition of lime, GGBS and ash materials. The strengths obtained are higher than experienced from almost all naturally occurring clay subgrades. These strengths are obtained relatively quickly though there may be some delay with the GGBS mix.

- Cement would seem to be the best binder for the coarser, albeit clay-contaminated, materials, which are very common in the United Kingdom. The ash and lime based mixes gained strength more slowly than hoped for.

Unbound materials made from material with a higher particle size than eight millimetres including some balled clay and materials made from coarse fragments, which had been crushed, gave CBR values likely to meet the requirements with just some light treatment. So
a selection of separated and crushed fractions could, with appropriate blending, produce high quality sub-base materials. That means even with high performance requirements concerning the structural properties of closed trenches the recycling of trench excavation material is possible and desirable. First it reduces the environmental impact from exchanging material (landfill and quarrying) and second it minimise transportation costs and, if performed near the trench site, will further reduce impacts.

References


