Historic England

Preserving Archaeological Remains

Appendix 5 – Materials for Use in the Reburial of Sites

Summary

This document is part of a suite of documents about the preservation of archaeological sites. It is a technical appendix to the main text (Preserving archaeological remains: Decision-taking for sites under development) and should be read in conjunction with that document, and where appropriate, the range of planning policy guidance detailed therein.

This appendix describes backfill and geotextile considerations for the reburial of archaeological sites.

It describes appropriate backfill materials (sand, gravel and other types of ballast) and sets out some general principles to which all materials used for reburial should adhere. These include the need for them to be permanent, cause no mechanical damage to archaeological remains, release no new material into the site, have no significant effect on soil water chemistry, and be visible to future archaeologists.

Specific calculations for the selection of appropriate sand for reburial are summarised from previous research, to enable readers to correctly identify local products for use in mitigation schemes.

Different types and uses for geotextile are reviewed and advice is provided on the need for appropriate record keeping to ensure archaeologists are able to access details of past reburial schemes if sites are revisited in the future

Additional methodological detail and technical advice is provided in the following appendices:

Appendix 1 – Case studies
Appendix 2 – Preservation assessment techniques
Appendix 3 - Water environment assessment techniques
Appendix 4 – Water monitoring for archaeological sites

Contents

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Front cover: name
Reburial of Roman Bath house at Shadwell, East London.

Introduction

Archaeological sites often need to be reburied as part of a development plan or following on from other interventions which leave unexcavated stratigraphy exposed. This may sometimes take the form of temporary reburial in order to retain the intact portions for the short or medium term, awaiting further excavation. However, the aim of most reburial programmes is the long-term preservation of the artefacts, ecofacts and other forms of evidence that the site contains.

The materials used to effect site reburial will need to meet a number of requirements from a geotechnical standpoint (see Shilston and Fletcher 2006) and will also be constrained by aesthetic and economic considerations. However, primarily, they must maximise the potential for preservation. It is the aim of this document to discuss the properties of those materials along with some of the reasons for using them, and to help readers make informed decisions about their selection. The principles are discussed first, and followed by a number of examples illustrating their use in practice.

Selection Principles for reburial materials

There is no single way of reburying archaeological sites any more than there is a single way of digging them. The approaches are dictated partly by the variation in technical requirements arising from the development at different sites (see Davis *et al* 2004). Even within a single site, there can be a range of impacts to the archaeology dictated by different end-uses. Tilly (2006), Hughes *et al* (2004a,b), Hughes and Butler (2004), and Hughes and Seaman (2004), for example, describe systems of multiple ground beams, piling and tensioned concrete slabs to cover various types of remains and allow construction to proceed on top. These schemes are the province of engineers who should be involved from the outset in any preservation plan. However, the site itself, especially the state of preservation of archaeological materials and the environmental conditions of the deposits, will also dictate some aspects of the reburial materials. Delicate artefacts need protection from both mechanical damage by downward pressure (see McGowan and Prangnell 2015) and chemical damage from reburial material constituents, so the medium in contact with any archaeological remains must not only minimise chemical degradation, but must also be soft enough to avoid abrasion. If new materials are introduced, they must not release any constituent part of themselves into the stratigraphy (see Simpson 2006). Also, they must not cause any significant changes to the pore water chemistry at the site. A change in pH, could, for example occur if a sand containing even small amounts of calcium carbonate was used as protection for deposits that were hitherto non-calcareous.

As well as the ballast to backfill the site, some situations will require the use of a mesh or fabric. This must not be an organic material because of the danger of providing nourishment for microbial activity. The recommended materials are geosynthetics. These are long-lasting polymers commonly introduced to provide a definitive layer by which future archaeologists can identify undisturbed stratigraphy (see discussion below).

In summary, the reburial materials used should:

- Be permanent, not changing over time.
- Cause no mechanical damage to the stratigraphy or artefacts.
- Release no new material into the stratigraphy.
- Have no significant effect on soil water chemistry of the stratigraphy.
- Be visible to future archaeologists.

1 The Materials and their Properties

1.1 Existing spoil from the site

In most circumstances, the existing spoil from an excavated site must be the first choice for reburial of that site, at least from a chemical viewpoint. Nothing else can be specified which will so effectively minimises new taphonomic impacts on the surviving archaeological remains. However, the existing spoil may not always be so desirable from a mechanical point of view, especially if it contains large or sharp stones. Furthermore, it will often be mixed, with upper organic humus-rich material and subsoil material not necessarily separated; there may not be enough of it to fill in the volume necessary to achieve the desired ground surface. In addition, the existing spoil may not have suitable geotechnical characteristics as a load bearing stratum for subsequent construction work.

1.2 Sand

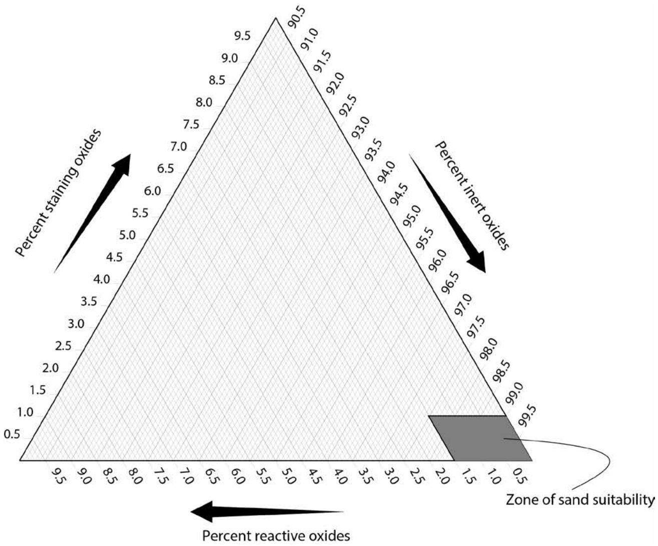
The mechanical properties of sand make it highly suitable for reburial work, and it is frequently the cheapest readily available material in most localities.

Good quality building sands (subject to careful selection, see below) are free of most soluble salts and are chemically inert over human timescales. The solute properties of the pore water will tend, therefore, to remain unmodified and reflect simply the incoming water. This issue needs to be considered where hydrological inputs other than rainfall are likely. Sand cannot provide any buffer against unfavourable qualities such as agricultural chemicals in surface runoff. In most cases, however, the character of the input water will be the mild (and chemically weak) acidity of pure rainfall, or the same groundwater to which the site has hitherto been subjected.

Not all sands are suitable for reburial projects. Generally, it is high silica, low iron sands that need to be used. A full discussion of sand characteristics and sourcing can be found in Canti and Davis (1999). A summary selection procedure adapted from that paper is as follows:

- Source as locally as possible; transport costs are a large part of the final bill.
- Sands need to be pale-coloured (best range of Munsell hues: 7.5 YR, 10 YR and 2.5 Y; and of values: 6, 7 or 8) and non-calcareous. These are largely characteristics of the geological deposits from which the sands are derived, details of which the quarry should be able to supply.
- Sands need to be relatively clay-free. This can be a function of geology, but is also artificially achieved by many quarries through washing.

Once possible sands are established as passing these general suitability tests, more detailed examination of their characteristics needs to be carried out. Most quarries will provide accredited chemical data from X-ray fluorescence (XRF) tests, loss-on-ignition and particle size (often called ‘mechanical’) analyses. Alternatively, samples can be requested and these three tests then commissioned.



Sample	R1	R2	R8	R9
Munsell	2.5Y	10YR	2.5Y	10YR
Colour (value)	7/4	6/2	7/4	6/4
XRF—SiO_2	98.42	98.82	86.62	93.47
XRF—$Al2O_3$	0.45	0.28	3.42	1.15
XRF—TiO_2	0.1	<0.05	0.19	0.08
XRF—ZrO_2	<0.05	<0.05	0.05	<0.05
XRF—V_2O_3	<0.05	<0.05	<0.05	<0.05
Total inert oxides	**98.97**	**99.10**	**90.28**	**94.7**
XRF—CaO	<0.05	<0.05	2.49	0.11
XRF—Na_2O	<0.05	<0.05	0.14	<0.05
XRF—MgO	<0.05	<0.05	0.49	0.14
XRF—K_2O	<0.05	0.05	2.22	0.61
XRF—P_2O_5	<0.05	<0.05	0.05	0.1
XRF—BaO	<0.05	<0.05	0.55	<0.05
XRF—SrO	<0.05	<0.05	<0.05	<0.05
XRF—ZnO	<0.05	<0.05	<0.05	<0.05
Total reactive oxides	**<0.5**	**<0.5**	**5.9**	**0.96**
XRF—Fe_2O_3	0.18	0.23	0.75	3.1
XRF—Mn_3O_4	<0.05	<0.05	<0.05	<0.05
XRF—Cr_2O_3	<0.05	<0.05	<0.05	<0.05
Total staining oxides	**0.20**	**0.25**	**0.80**	**3.15**
LOI (loss on ignition)	0.03	0.14	2.84	1.13

Figure 1
Ternary diagram showing suitability envelope for use of sand in reburial projects, based on totals of inert, reactive and staining oxides.

Table 1
XRF chemical data for 4 sand samples studied by Canti and Davis (1999).

Once the data are available, the following selection procedures should be carried out:

- Particle size data should show 98% or more finer than 2 mm and 5% or less finer than 63 µm.
- Loss-on-ignition (LOI) should be 2% or less.
- The LOI percentage and any other tiny values (labelled 'trace' or 'less than 1%') can now be ignored and the other percentages recalculated.
- These modified oxide percentage values should be put into three groups
  - Inert oxides: SiO_2, $Al2O_3$, TiO_2, ZrO_2, V_2O_5
  - Reactive oxides: CaO, Na_2O, MgO, K_2O, P_2O_5, BaO, SrO, ZnO
  - Staining oxides: Fe_2O_3, Mn_3O_4, Cr_2O_3

The totals of these groups should be: staining oxides 1% or less, and reactive oxides 1.5% or less, leading to an inert oxides total of 97.5% or more. This can be visualised as a ternary diagram on which the suggested oxide group limits are represented as an area of acceptability (Figure 1).

Four sand samples from the original study are shown in Table 1. Sample R1 and R2 would pass the tests described above, as they contain more than 97.5% inert oxides, and very low percentages of reactive or staining oxides. Sand R8 contains higher levels of calcium oxide (CaO) and potassium oxide (K_2O) than is appropriate in a sand used for reburial (and also a higher LOI result than is acceptable too). Sand R9 has a high level of iron oxide (Fe_2O_3) which is also higher than the levels for staining oxides suggested above.

1.3 Gravel

Siliceous gravels can provide an excellent backfill for volume filling where protection is not needed or has already been provided by sand. A particular advantage of widely available rounded flint gravels (such as pea shingle) is that they are free-running and therefore do not need compression. However, it is very important to ensure that these gravels are composed of silica rather than crushed stone from other geological sources (such as limestone), otherwise similar problems as discussed above for sand could occur. It is also critical that gravels are washed and clean, and do not contain other adhering particles.

1.4 Other forms of ballast

There may be circumstances where other filling materials are needed for some reason, or are cheaply available. It is quite possible, for example, to use some types of stone chippings as part of a reburial program, after careful consideration of the mechanical and hydrological effects (see for example Ardito 1994). In such circumstances, a chemical analysis of the proposed material may be needed to compare with the site's environmental conditions, for example deposit pH. Local geological advice should then be sought, and the suitability weighed up on a case-by-case basis. An unusual form of ballast is described below in Example 3.

1.5 Geosynthetics

There is a wide range of sheet and fabric materials available for reburial schemes. The most commonly used are geotextiles; these are usually permeable meshes or fabrics made from polypropylene or polyester and thus last for centuries in the ground. They are designed to separate, protect and reinforce layers, filter materials or assist drainage in many geotechnical and construction situations (see Kavazanjian 2004). The numerous types available have a range of strengths and permeabilities.

Most geotextiles are either woven or needle-punched, the latter having better water-flow characteristics. When the mesh becomes very large and the grade is heavy enough to develop some rigidity, they are called geogrids. These geogrids are welded rather than woven together and have specific structural properties. Geotextiles and geogrids together are commonly referred to as geosynthetics.

Figure 2
Example of a geotextile used as a barrier layer.

Geosynthetics have a number of uses for reburial schemes. They can be one or more of the following:

- A barrier layer - Geosynthetic materials (commonly geotextiles) are often used to prevent archaeological layers becoming mixed by bioturbation, for example weed and tree roots, earthworm burrows or larger animal holes.

- A marker layer – Some reburial schemes may have quite a fixed timescale over which the site is being reburied and there may be an expectation that further excavation or another phase of monitoring will take place in the future. A geotextile can be included to provide a precise demarcation to assist in relocation from archive descriptions. Coloured geotextiles designed specifically as marker / indicator layers are available.

- A load-spreading layer - All geosynthetics will have a slight load-spreading effect. The more rigid ones, especially geogrids (*see* Figure 3) can help prevent future damage from feet and vehicle wheels. This may be planned traffic or, in the case of public spaces, allowing for unplanned risks such as unauthorised driving or heavy contractor machinery.

- Load protection during construction - A geotextile may be put in place for the sole purpose of preventing damage during the emplacement of reburial overburden, for example in the initial phases of the construction of an embankment or backfill of a site.

Figure 3
Example of a rigid geotextile used to spread load.

The strength of the geosynthetic specified for a particular plan will be dependent on structural needs and / or the degree of wear and tear it is expected to withstand. The permeability is another important issue, particularly because of the danger of producing locally waterlogged conditions. There appear to have been some cases where geotextile barriers have affected the drainage and gaseous exchange in such a way as to increase the risk of microbial attack (Hopkins and Shillam 2005; Nixon 1998). Generally, assuming that the other functions listed above are being successfully addressed, then the geosynthetic should be as permeable as possible.

1.6 Record keeping

Most reburial and mitigation schemes are designed to last for a long time. However, the requirements at preserved sites in the future are unpredictable. Part or all of any site may need to be re-excavated for unforeseen reasons, or to accommodate a completely new development. If this is the case, the importance of clear records is going to be paramount. A complete account of what was done, what materials were used, and what the aims were should be deposited in the Local Authority Historic Environment Record (HER) to inform any future works. The understanding of site preservation and reburial is constantly evolving and few dedicated experiments have ever been set up. Consequently, a well kept record may help future archaeologists plan similar schemes better and improve knowledge of their effectiveness.

2 Base Court, Hampton Court Palace

Base Court, Hampton Court Palace is a large courtyard surrounded by 16th century buildings. The pre-excavation courtyard surface consisted of a large grassed area bisected by a stone roadway and surrounded by paths and grass borders. The planned new stone surface for the courtyard was designed to fill in all the areas of grass, have a large new service conduit through the middle, and be capable of taking traffic up to a weight of 7.5 tons. The formation levels for the new surface were engineered so as to leave as much of the significant archaeological remains *in situ* as possible. Drainage for the surface and the surrounding roofs reused the Wren period brick culverts which had to be re-exposed, repaired, protected and sealed (Ford 2009).

Scheduled Monument Consent did not specify the reburial techniques, but consultation with English Heritage during the works led to stipulations that ground compaction was to be carried out only with non-vibratory rollers; that machinery should not cause ground disturbance or damage to the monument other than that which was expressly authorised; and that archaeological remains needed to be preserved and protected from compaction or compression due to plant movements or any other potentially damaging activity associated with the construction works. This meant that the base / sub-base had to be laid using plant positioned from the central carriageway at the edge of the excavation areas (shown with orange barriers in Figure 4). Infilling could progress across the exposed area from already laid base/sub-base until the process of infill was completed. No plant could track / move across any area revealed by the archaeological works unless it was on a laid base / sub-base that would offer protection from compaction or compression.

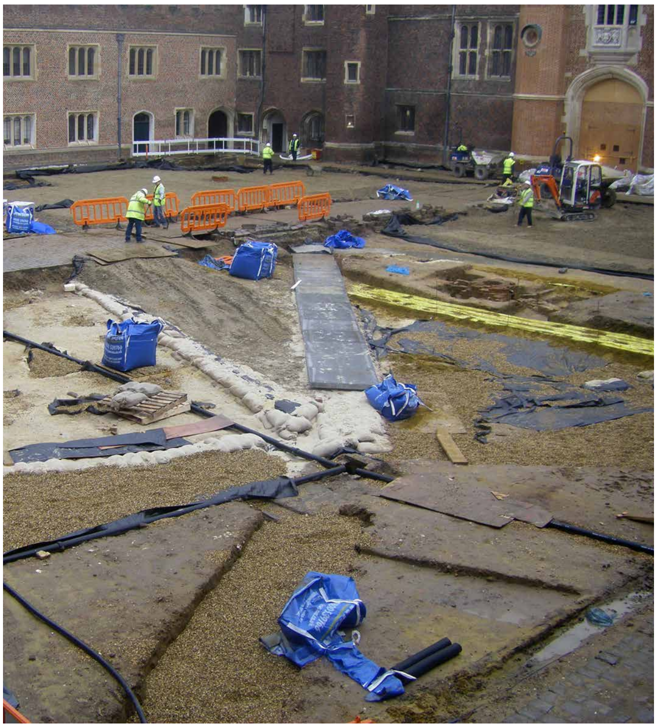


Figure 4
General shot of infill stages in progress at Hampton Court.

2.1 Reburial procedures

Small depressions up to c 0.05m deep were filled with kiln dried sand and covered with Rhyno GW 8118 woven polypropylene geotextile. Larger depressions and holes, linears and sondages were part-filled with kiln dried sand, lined out with Rhyno GW 8118 woven polypropylene geotextile, then filled with free-running pea shingle in small layers and manually compacted as the work progressed.

Open areas of surfaces and deposits were covered with 0.05m layer of kiln dried sand and then covered with Rhyno GW 8118. Structural remains (mortared brick, chalk and tile walls) were encased in hessian sand bags filled with kiln dried sand and built up on each side of the structural remains (wide at the base and narrowing upwards). Gaps between each layer of sandbags were filled with kiln dried sand. Finally, one depth of sand bags was placed on top of the structural remains and small holes filled with kiln dried sand.

The Wren culverts were re-excavated (Figure 5) exposing the brick-arches down to the level of the side walls. The brick structure was repaired and the cut refilled with free-running pea shingle up to and covering the apex of the culvert to produce a level finish. Pre-formed reinforced concrete slab sections were placed on top of level shingle (Figure 6) and sandbags used to build up height for concrete slabs if necessary.

5

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Figure 5
Wren's culverts trench under excavation.

Figure 6
Culvert trench covered with preformed slabs.

Figure 7
General geotextile cover and final base layer.

Once the protection had been laid in / on the excavated negative features, open areas and structural remains, the culverts were filled and covered in concrete slabs; the area was generally backfilled using 6F2 crushed concrete built up in 150 mm layers compacted with rollers up to the level of the underside of the new surface specification, then covered with Rhyno GW 8143 woven polypropylene geotextile. The final surface fill was then added (see Figure 7).

3 The Rose Theatre, London

The remains of the Rose Theatre were discovered in 1989, and had to be reburied due to existing planning permissions, allowing a building to be erected over the top.

The reburial was intended to protect the site itself and any organic remains from biological, chemical, and physical damage whilst it was under cover.

Figure 8
The Rose Theatre just before reburial.

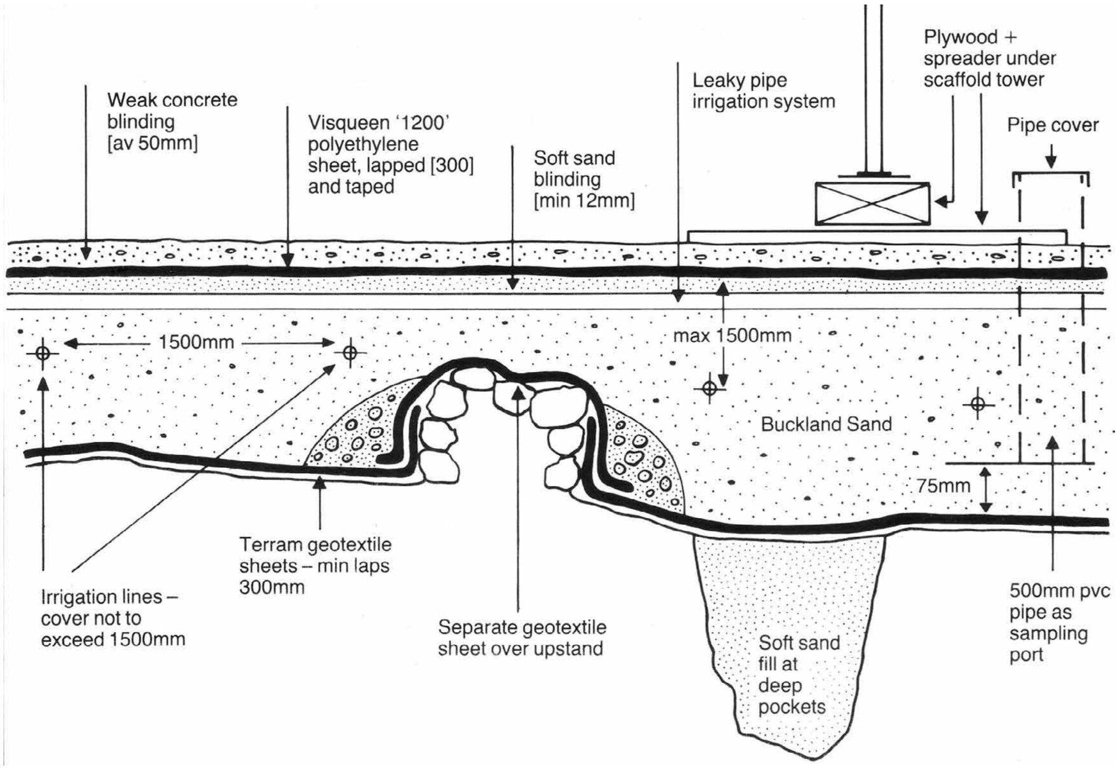

Figure 9
Schematic diagram of the Rose Theatre reburial.

It was important to protect standing structures and surfaces from accidental damage during site works. A mitigation and reburial scheme was designed:

- to insulate the site against extremes of temperature
- to reduce oxygen at the excavated surface to prevent decay of the delicate exposed remains
- to rehydrate dry areas and allow the maintenance of a constant moisture content, whilst allowing the soil water chemistry to remain unchanged as far as was possible

The method adopted was therefore as follows: exposed timber features were securely wrapped in cling film and heavier grade polythene. All surfaces and features were then covered with a layer of permeable geotextile, the sheets of which were held in place by lime/sand mortar (1:6); all upstanding features were protected by mortar supports. Next, a high quality silica sand was mechanically sprayed onto the geotextile to a minimum depth of 300 mm above any archaeological remains. The dry sand was compacted by saturating it with water, thus also reducing the amount of air at the surface of the site.

Seven water monitoring points (using 68 mm diameter pipes) were built into the covering, and ten moisture sensitive electric cells were built in to record moisture content in the sand covering and within the archaeological levels. A 'leaky-pipe' irrigation system was laid in the upper levels of the sand, which was then covered with an impervious polyethylene sheet. This in its turn was covered with a weak mix concrete binding with a minimum thickness of 50mm (Ashurst, Balaam and Foley 1989).

4 Silbury Hill

After internal collapses in 2001, Silbury Hill underwent a large scale intervention to stabilise the existing 19th and 20th century tunnels as well as the 18th century vertical shaft (Harding *et al* 2013). After new recording and sampling of the tunnel walls in 2007, the site was refilled and closed off. Although the methodology was completely different to open-air preservation projects, it nevertheless illustrates just as clearly the principles outlined above of using appropriate reburial materials. Since Silbury Hill is constructed of chalk, then the principle of minimising the chemical impact meant that the ideal material for infilling needed to be chalk. A geologist was consulted to find chalk from the nearest possible source.

The extent and size of the voids encountered running up into the Hill meant that most of them could not safely be filled manually or mechanically with dry chalk. In the end a chalk paste was used, which could be pumped into the tunnels, finding the voids without dangerous handling. The mechanical effect of this pumped paste on the well preserved biological remains in the central organic mound was a concern, so the vertical faces in the whole area were backfilled with pure quarried chalk packed into polypropylene bags supplemented with loose quarried chalk. Polypropylene was chosen instead of hessian or another natural material in order to minimise the inclusion of new organic matter into the monument and thus reduce further fungal growth. Remaining minor voids were filled with hand or mechanically impacted chalk. Approximately 3,500 bags of chalk were used in the central chamber alone.

Once the delicate surfaces were lined, chalk paste could be pumped into the hill to fill the main tunnel and voids which rose up from it into the hill. Finally, a berm built of layers of compacted chalk was constructed across the entrance of the tunnel and the remaining section pumped full.

Figure 10
Bags of chalk in position.

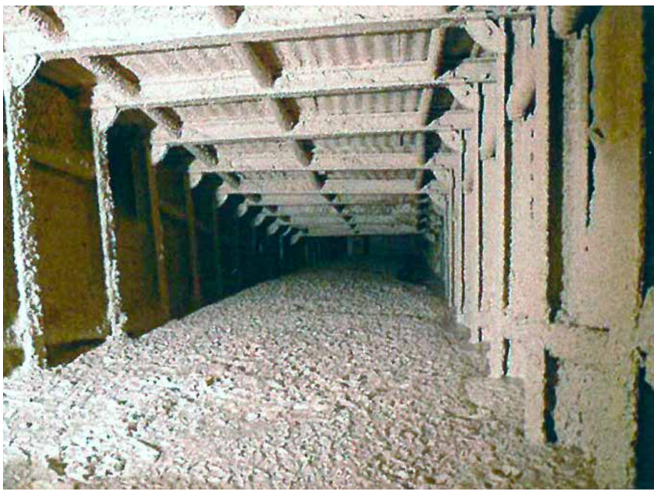

Figure 11
Chalk paste infilling the tunnel.

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6 Acknowledgements

Contributors

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