SO YOU HAVE NO SOIL FOR QUARRY RESTORATION?

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Abstract

After 1948, and unlike opencast coal mining, much of the quarrying sector failed to make adequate provision for restoration soils until well into the 1960s. In consequence many hard rock quarries, and especially the older operations, now have insufficient stockpiled soil for restoration purposes especially when allowance is made for stockpiles that are unavailable due to badgers and other wildlife.

This paper examines the shortfall of restoration soils and avenues that are currently being explored to rectify the problem by forming artificial soils from quarried materials not required for sale or other onsite use. The soil forming techniques employed are akin to those initially set out in government funded research in the 1990s covering the restoration of brown-field sites, but not specifically addressing quarry restoration. The current study includes a review of the use of quarry discards (non-mineral bi-products) and the addition of specially manufactured compost that is beginning to arise from green waste recycling. The previously used amendments such as de-inked paper fibre, manures and slurries and many other types of compost now require a permit or a permit exemption for use from the Environment Agency. This new compost is a product and its use is not restricted by regulator involvement or fees.

The preliminary findings are presented of soil forming trials undertaken for Natural England at a range of quarry operations where geological conditions and restoration objectives vary considerably from low to high pH soils and both agricultural use and bio-diverse planting is required. Further investigations are also underway on behalf of WRAP (Waste and Recycling Action Programme) in Wales in respect of the use of this new green waste compost and the liquid digestate from the processing of food and farm waste to promote rapid growth and avoid gullying and other forms of erosion in steep, high level restoration sites often associated with high rainfall areas in Wales. Investigations have included the use of these materials with artificial soils formed from slate, opencast coal, metalliferous mining and aggregate discards.

These techniques could assist in the restoration of aggregate sites, developed like many opencast coal mines, in industrially contaminated areas as well as assisting with restoration where little natural soil remains.

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Introduction

In 1999 the Department of the Environment Transport and the Regions (DETR) sponsored research on a study entitled Soil-forming materials and their use in Land Reclamation (Bending et al 1999). Whilst this was a comprehensive review of techniques and methods used in the 1990s it concentrated to a high degree on derelict land and was written at a time when there were only limited restrictions on the importation and use of soil amendments.

It has long been recognised that many older hard rock quarries have little soil for restoration since workings commenced before planning permission was required and the scrutiny of planning conditions was limited up until the 1970s. As a consequence less soil was available for restoration than required. There may also be other factors inhibiting the use of stockpiled soils including badgers and other wildlife.

This paper deals with overcoming the shortfall in restoration soil in a manner consistent with the current regulatory regime where the use of soil amendments such as farmyard manure and many of the other composts recommended in the previous study can no longer be used without a waste permit or a licence/permit exemption from the Environment Agency. It covers previous and ongoing work undertaken for Natural England and for WRAP in Wales.

Background to artificial soils

Soil comprises a mixture of minerals and organic matter. Where soils have to be manufactured – artificial soils – both mineral materials and organic matter has to be mixed.

Texture in soils is basically defined by sand, silt and clay components, but obviously also includes gravel and cobble size materials that frequently occur on most quarry sites. The grading of soil is important since particle size has a considerable impact on permeability and drainage. Restoration soils must be ventilated to ensure plant growth. The properties and mineralogy of clay-sized materials also affects the availability of cations for plant growth.

The key chemical parameter is that of pH which influences the restoration objectives and depends to a considerable degree on local geology, especially the composition of the rock or gravel materials being excavated. Other parameters of interest include electrical conductivity and cation exchange capacity, both of which relate to the availability of plant nutrients and the need for organic amendments. Beneficial nutrients include nitrogen, potassium, calcium and magnesium. Sodium and some heavy metals can be deleterious to plant growth.

Soil mineral materials are available on many former mineral workings as various accumulations of what the Environment Agency now calls non-waste bi-products. Typically these may comprise:-

- Spoil heaps
- Backfill in excavations
- Stockpiles of marginal mineral
- Amenity or screening banks
- Fine discards in lagoons or silt ponds
- Planings from haul roads or trafficked areas

Provided appropriate investigations are undertaken beforehand such materials can be readily recovered by secondary excavation or primary processing that may include scalping and screening. On some older aggregate quarry sites it may be feasible to re-work previous accumulations of spoil to recover mineral gradings and concurrently materials for soil formation. Figure. 1 shows this in progress at Penlee Quarry in Cornwall.

Soil amendments are added to the basic mineral components of soil to speed up the soil forming process and to promote plant growth. These amendments can be both organic and inorganic. Inorganic amendments include waste lime, fertilizers and other materials that might act to improve drainage and soil texture including Pulverised Fuel Ash (PFA), slag or gypsum etc. Organic soil amendments have in the past included:-

- Sewage including solid and liquid sludges and cakes etc
- Manures and slurries from farming
- Wood residues
- Paper sludge
- De-inked paper fibre
- Mushroom compost
- Wool waste
- Green waste

The use of any organic soil amendment comprising a waste product, including composts and manures is an activity that is likely to require a permit from the Environment Agency. The use of even small quantities of these materials for mixing and forming artificial soils in a quarry may require a permit or an exemption by the Environment Agency. Small quantities can be used as

Figure 1. *Re-processing quarry backfill at Penlee Quarry, Cornwall.*

soil amendments, but an exemption is required with a fee and annual payments. Given the industry experience elsewhere this is not an attractive route likely to promote restoration.

However, DEFRA, the controlling government department, has supported WRAP in the development of two new products. The first is Quality Protocol Compliant British Standards Institute Publicly Available Standard (PAS100), a compost produced from green waste recycling and the second is BSI PAS110, an output from food waste and farm waste using bio-digestion techniques with a digestate product rich in nitrogen, potassium and phosphorous. This second product is in the final process of approval by the Environment Agency, and is intended for use with growing crops and other vegetation. It has been trialled with farm crops and part of this study has included an investigation of its use in small trials of plant growth on artificial soils that have incorporated PAS100.

This project is important since it can potentially provide very necessary improvements in the restoration of existing and former mineral workings, some of which are genuine blots on the landscape, notably the slate tips in north Wales and old metalliferous mining tips. Some of these have been devoid of vegetation since they were formed more than 100 years ago. The project may also assist in the management of waste processing products formed by the treatment of green waste and food and agricultural waste which together comprise a significant proportion of waste generation in Britain. It is important that alternative uses are made of these materials in an environmentally satisfactory manner.

The Study

For Natural England, through DEFRA's Aggregates Levy Sustainability Fund, the study of artificial soils has included the selection and development of trial plots on five aggregate quarry sites:-

- Penlee Quarry, Cornwall – metadolerite
- Cromwell Quarry, Yorkshire – gritstone
- Oathill Quarry, Gloucestershire – limestone
- Shellingford Quarry, Oxfordshire - limestone gravel
- Sandy Heath Quarry, Bedfordshire – sand

The intention was to develop a series of trial plots using mixes of available soil forming mineral material and BSI PAS100 and different combinations of seed and small scale planting appropriate to the setting and the local rock chemistry.

Hence at each of these quarries an investigation was undertaken of the actual restoration requirements and the potential for other arrangements in the context of existing conditions and available soil forming materials. In places this required the instigation of screening trials or the investigation of existing stockpiles from screening or scalping. The detailed chemistry of soil forming mixes, with and without PAS100, was determined in advance of sowing and planting.

Trial plots – Aggregate sites using PAS100

Trial plots were set up in selected locations that would not be disturbed during the period of the trial and where fencing could be installed to restrict the access of wildlife, sheep and mobile plant. Six or nine plots each 3m x 3m with 1m spacing between plots were formed at each site using a combination of front end loaders, backhoes and hand tools.

Quality Protocol Compliant PAS100 was brought on to the site from the nearest available source, usually within 20km of the site. Where possible a -20mm product was used although on a larger scale -40mm material is suitable when agricultural equipment is available. The PAS100 was mixed by hand having been first spread to the appropriate thickness to ensure the relevant percentage mixing which was typically 10% - 25% to a depth of 200mm.

Once completed, in early spring 2010, the plots were fenced and then sown. Subsequently the growth has been monitored quarterly with an in-depth review of the success of the trial plots in terms of baseline data on survival rates for trees, shrubs and initial establishment of sown grassland or wildflower plant communities.

For grassland and wildflower plant communities two types of measurement were made; the first involved sampling the percentage foliage cover of vegetation using 1.0m x 1.0m sample quadrats and recording separately the percentage of grasses, herbaceous plants, ruderal weeds and bare ground. This was undertaken twice for each plot and a mean taken. The second measurement involved two samples per plot using a 0.25m x 0.25m quadrat subdivided into 25 equal squares (50mm x 50mm). The frequency of occurrence of five selected species was measured and a mean of the two samples recorded for each plot.

For trees and shrubs a count of tree survival, the height of each tree and an assessment of condition was made.

As may be seen from Figures 2 to 4 below, the vegetation thrived where PAS100 had been added to the mineral soil mix and most, but not all, mineral soil mixes with no PAS100 had inferior growth.

Trial plots in Wales using PAS100 and applying PAS110 after growth

This work was undertaken for WRAP in Wales. Four plots were selected in Wales to represent major areas of remaining or problematic restoration issues. Particular attention was given to high level sites (above 300m AOD) with high rainfall (above 3,000mm per annum). Sites selected included:-

- Slate waste in north west Wales
- Metalliferous mining waste from central Wales
- Opencast coal waste from south east Wales
- Sand and gravel spoil from Quaternary deposits in north east Wales

At these sites mineral matter was selected and soil plots formed in a similar fashion to those for Natural England, but many of the plots were larger and formed

Figure 2. *The benefits of adding PAS100 at Oathill Quarry; on the left hand side no PAS100 has been added to the quarry discards. It has been added on the right hand side.*

Figure 3. *The benefits of adding PAS100 at Bryn Posteg; on the left hand side PAS100 has been added but not on the right hand side where seeding has failed in the lead-rich mineral waste.*

in triplicate to allow for more extensive analysis of the impact of plant growth with and without PAS100 and the subsequent effect of dosing with PAS110.

The trial soil plots were formed on three of the quarry sites; at two of them they were located on existing waste stockpiles. However the metalliferous mining waste was excavated and transported to a landfill site where trial plots were formed on a lined base to capture leachate that might have a high lead and zinc content. At its original location there was no visible plant growth and probably had been none for the 150 years since it had been tipped on the site. It is interesting to note that the metalliferous waste mixed with PAS100 produced significant growth when seeded, as shown in Figure 3.

An application had to be made through the Environment Agency for permission to trial PAS110 prior to its full approval as a product. As noted above, PAS110 has been extensively used in the agricultural community on trials located near to anaerobic digestion plants. In those trials the PAS110 was injected into the soil in which plants were growing. In the WRAP Wales trials the fertilizer was added by spraying on to growing vegetation

Figure 4. *The benefits of adding PAS100 at Penlee Quarry; the three trial plots on the left hand side comprising waste materials from different quarry operations had PAS100 added. The seeding and planting on the right hand side with no PAS100 has failed.*

with equipment used for hydroseeding (see Figure 5) and, on a small scale, using watering cans. At all the sites there were some untreated plots with which comparisons could be made. This treatment was only started in June and July, but some photographs have been taken of the relative growths in treated and untreated plots.

Figure 5. *Trials in progress at Ffos-y-Fran on open cast coal waste. The left hand photograph shows PAS110 being added to trial plots that had previously been treated with PAS110 prior to seeding. The right hand photograph shows PAS110 being added to an area of existing vegetation on open cast over- and inter-burden with growth from original hydroseeding. Note the fencing required to protect the trials.*

FINDINGS

PAS100 trials

2010 was not an easy year for plant trials. The winter was late and severe with heavy spring rains followed by an extended dry period during the summer that has had a severe impact on growth rates. However at most of the trial sites a significant difference was apparent between growth on soils containing PAS100 as compared with pure mineral soils. This is definitely the case with respect to Penlee and Cromwell Quarries and is also apparent at Oathill and Sandy Heath Quarries. Ground conditions were affected by high spring rainfall at Shellingford Quarry and in consequence there was a late start to growth and one set of plots that had incorporated re-worked silt showed very poor response relative to other soil mixes at that and other quarries. The generation of good tilth in the soil mix is a key factor in heavy clay and silt rich soils and the timing of the use of these soils, even when mixed with PAS100, appears to be critical to early growth.

Natural England (Walton and Jarvis, 2011) gives details of these trials.

PAS100 and PAS110 trials

Again, as at Shellingford Quarry, these trials started late in the year, but were not so adversely affected by the absence of rainfall and high temperatures. Good growth was achieved on all the trial plots where mineral soil had been mixed with PAS100 prior to the application of PAS110.

Initial results show that it is principally Italian and perennial rye grass which has grown on the lead-rich mining waste used in trials at Brynposteg. To achieve any growth where there has been none for almost 150 years is excellent, not just in changing the appearance of a site but in its ability to thereby reduce the erosion of heavy metals into local water courses. Further tests are in progress to establish the take-up of heavy metals from the soil into the vegetation and also to establish the longevity of such growth (i.e. the normal consumption of available nutrients and die back). The need for regular addition of amendments needs to be assessed.

Details of the findings of these trials are given in WRAP Wales (Jarvis and Walton, 2011).

Overall findings

For any quarry restoration the soil types to be employed must be matched to the approved restoration objectives. Trials such as these can be undertaken to assist the better understanding of the seed mixes and planting, likely success rates and the costs. These trials needed careful organisation. Even for the nine trials with their restricted areas, the logistics of transporting, storing, mixing and applying PAS100 and PAS110 required detailed planning; particularly with respect to identifying adequate storage areas at the quarry to receive the imported materials prior to distribution across the wider extraction areas. On large scale quarry restoration projects, the volume of imported materials needs to be calculated such that the lorry movements are in themselves not an environmental problem.

Rabbit, deer and stock-proof fencing is essential to maximise the plant establishment and growth.

PAS100 compost undoubtedly acts as a retainer of moisture in otherwise dry non-waste quarry bi-products. This is a benefit to establishing plant growth. The further addition of water on an ad hoc basis or by irrigation systems can only increase and speed up plant growth and thereby act to reduce erosion on steeper sloping sites.

For most quarry restoration, especially where slopes are variable, PAS110 liquor needs to be applied by hydroseeding techniques rather than application techniques commonly used in agriculture. Pre-planning of access routes for the machinery and locations for spraying is usually beneficial. It is important that the hydroseeding, in itself, does not contribute to erosion on newly-established slopes.

PAS100 and PAS110 clearly aid the use of non-waste quarry bi-products in many types of restoration. However, it must be recognised that some restoration objectives such as impoverished limestone grassland will not be helped by the addition of such nutrient-rich, water-retaining materials. Only if the need to overcome erosion outweighs the ecological objective, should composts and amendments be used.

Generally, there appears to be a difference between the upland hard-rock quarries (north west of a dividing line roughly from Bath to The Humber) and lowland sand and gravel sites (to the south east of this line) in the amount of shortfall of restoration soils. This is because hard rock quarries are often longer term operations, some were started before soils were valued and progressive restoration is limited due to working at depth in an ever-deepening progression in the same footprint.

Finally, there remains the possibility of issues arising from the use of existing quarry waste as a source of mineral matter for mixing with PAS100 on the grounds that this ostensibly breaches the conditions of the Avesta Polarit tests (CBI Minerals Group 2010). These tests require that 'no further processing, treatment or blending is necessary'. Clearly the recovery of suitable mineral material for artificial soils from existing quarry spoil would not pass the test and it could even be argued that the mixing of any mineral matter from the site, whether a product or bi-product, could result in the material so mixed being classified as waste. The authors are most reluctant to accept this as it might prevent the production of artificial soils where the need is pressing. This would run counter to the ultimate objective of quarry restoration and years of research work undertaken to develop PAS100 for just such an application. Whatever the decision in this matter, still awaited from the Environment Agency, the use of newly created mineral quarry products specifically processed for mixing with another product to form an onsite artificial soil for restoration, does not appear to run counter to the classification of the primary mineral material other than as a non-waste bi-product. It would be unfortunate if the interpretation of legislation frustrated restoration objectives, some of which have been outstanding for many decades. The interpretation of the Mining Waste Directive should not frustrate good planning and good practice.

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