Trial of
Recycled Glass as Pipe Embedment Material

Department of **Environment & Climate Change** NSW

The Department of Environment and Climate Change NSW appreciates the assistance provided by Sydney Water and Benedict Sand and Gravel in undertaking the trials and preparation of this report.

Published by:
Department of Environment and Climate Change NSW
59–61 Goulburn Street
PO Box A290
Sydney South 1232
Ph: (02) 9995 5000 (switchboard)
Ph: 131 555 (environment information and publications requests)
Ph: 1300 361 967 (national parks information and publications requests)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

ISBN 978 1 74122 416 0
DECC 2007/160
Published December 2007

Printed on 100% recycled paper. Elemental chlorine free (ECF).

Contents

1. **Introduction** 2
2. **Chemical testing** 3
   Testing procedure
   Results and analysis
   Aluminium investigation
3. **Specifications** 5
   Table 1: Conductivity and resistivity of glass samples
4. **Field trials** 6
5. **Safety issues** 8
   Glass dust
   Glass particle handling
6. **Other issues** 9

Appendices

1. **Summary of chemical testing** 10
2. **Sydney Water Engineering Product Specification** 14
3. **Sample Quality Control procedure** 16
4. **Sample Material Safety Data Sheet** 17

1. Introduction

Large quantities of glass containers are currently recovered for recycling from the municipal and commercial waste streams in NSW. However, the process of collection and sorting glass results in the high generation of mixed, coloured and small glass pieces, or 'fines', which are unsuitable in the manufacture of new glass containers. To utilise this resource, a recycled product sector is emerging to reprocess the glass fines into suitable materials for use in civil construction projects.

These secondary resources, if demonstrated to be fit-for-purpose and environmentally appropriate, are potentially suitable for a range of alternative uses including concrete aggregate, cement mix, abrasive media, pipe bedding material (replacing natural sand), leachate drainage layer material in landfills (replacing gravel), landscaping and water filtration. The use of recycled glass as a substitute for quarried material not only conserves natural resources but also reduces waste sent to landfill.

In NSW approximately 195,000 tonnes of container glass waste is collected for recycling each year. Approximately 100,000 tonnes is sorted by beneficiation plants in NSW and Victoria and utilised in the manufacture of new glass containers. 20,000 tonnes of recycled container glass is also being processed and sold into drainage aggregate, abrasives, paver manufacture, fibreglass and asphalt markets. The remaining material is currently considered unsuitable for remanufacture into glass containers and represents an opportunity to develop new products.

The Sustainability Programs Division (SPD) of the Department of Environment and Climate Change NSW (DECC) is facilitating efforts by recyclers to produce glass products with new uses. Tests, trials and the development of generic specifications for recycled glass in a range of new applications will assist the increased use of recycled glass as a replacement for non-renewable, quarried materials. The current market price for the glass sand blends used in both trials is comparable to the cost of natural, quarried sand used for this purpose.

Sydney Water wanted to trial glass fines as pipe bedding, and the DECC agreed to facilitate the assessment of four samples of crushed glass prepared by Sydney recycler Benedict, on behalf of Sydney Water.

The material tested and trialled was produced from glass fines which are the residual glass left after the main recycling process occurs. The kerbside waste material is collected, sorted and all of the glass material above 30mm in size is recycled; the residual from this process is delivered to Benedict Sand and Gravel for further processing.

The glass fines are vigorously screened, vacuumed, crushed and then finally graded through screen decks to produce a minus 4mm unwashed glass sand. To improve the grading and therefore enhance the compaction and drainage characteristics, the material is then washed through a series of cyclones. The final glass product is then mixed with sand in required proportions; in the trials, combinations of 25% glass/75% sand, 50% glass/50% sand and 100% glass were used. Each batch was graded to ensure that the blend conformed to the current Sydney Water specification for pipe embedment. The product was delivered with a moisture content of at least 6%, therefore minimising potential hazards associated with airborne dust. Quality Control procedures were developed to ensure that Sydney Water's standards were met by each batch delivered (see Appendix 3).

2. Chemical testing

Where glass fines are used in pipe bedding applications there is a possibility that they will be applied to land in ecologically sensitive environments. To address this issue Sydney Water specified that the testing requirements should address the parameters identified in the following published guidelines:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)*, Volume 1 — The Guidelines ('ANZECC 2000'); and
- *National Environment Protection (Assessment of Site Contamination) Measure 1999*, Table 5-A — Soil Investigation Levels.
- *Environmental Guidelines: Assessment, Classification and Management Of Liquid and Non-Liquid Wastes* (DECC, 2004) (the 'Waste Assessment Guidelines').

DECC agreed to facilitate the testing of several glass fines samples and to assess the results inclusive of the parameters contained in the above published guidelines. For this purpose, Sydney Water supplied four crushed glass samples of different grading (particle size distribution) prepared by Benedict.

Four samples were supplied to Sydney Water as follows:

- -4mm (i.e. less than 4mm particle size)
- -4mm+2mm (i.e. a graded product containing particles less than 4mm but greater than 2mm in size)
- –2mm+1mm (i.e. a graded product containing particles less than 2mm in size but greater than 1mm)
- -1mm+0.4mm (i.e. a graded product containing particles less than 1mm in size but greater than 0.4mm)

Testing procedure

Crushed recycled glass used in the trials

The glass samples were tested for numerous chemical and physical contaminants including a range of metals and other inorganics, pesticides (including fungicides and herbicides), PAHs, PCBs, VOCs, TPHs, other general organics, nutrients, BOD, total suspended solids, and COD. The samples were also examined for asbestos, and the pH and electrical resistivity of the glass samples were determined in accordance with Sydney Water specifications (see Appendix 1). The samples were analysed for both total and leachable concentrations.

The extracts were prepared in accordance with the following standard methods:

- USEPA Method 1311 *Toxicity Characteristic Leaching Procedure* Revision 0, 1992, Test Methods for Evaluating Solid Waste, USEPA Publication SW-846, Third Edition.
- USEPA Method 1312 *Synthetic Precipitation Leaching Procedure*, 1994, USEPA Publication SW-846 update II, September 1994.
- ASTM Method D3987-85 (2004): Solid Test Method for Shake Extraction of Solid Waste with Water (American Society for Testing and Materials Standards).

Results and analysis

For each of the four samples, all of the identified chemical and physical contaminants were either not detected or were present at background or trace levels. No asbestos was detected and the samples were found to consist of a mixture of glass fragments, dust particles, sand, organic fibres, brick, bitumen, plaster, paint flakes and debris.

Based on the results of the chemical testing, the crushed glass products had levels of metals, persistent organics and a range of other organic pollutants that were well below the limits for inert waste classification in Table A4 of the DEC's Waste Assessment Guidelines, and well below soil investigation levels in the NEPM (Assessment of Site Contamination) 1999.

The main pollutants present were non-metallic inorganics in the form of ammonia, phosphorus and nitrates, as well as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and C_{15}-C_{28} hydrocarbons. Following additional investigation and testing this was attributed to paper and food residues in the glass fines samples. Based on these findings, the material should not be odorous or otherwise objectionable from an amenity perspective.

The critical Quality Assurance/Quality Control aspect is to ensure that during manufacture of the crushed fines product there has been appropriate cleaning and washing of residual impurities from the glass. This should be reflected in any product specifications developed by industry.

Aluminium investigation

Sydney Water was also particularly interested in any aluminium content of the glass but it was not an issue as far as contamination in the glass fines is concerned. Aluminium occurs naturally as a compound in many Australian soils, especially clay.

Presently wastes containing aluminium or aluminium compounds as constituents need not be assessed and classified in respect of aluminium under the Waste Guidelines. Jurisdictions overseas, including USEPA and UK Environment Agency and EU Directives, do not regulate aluminium as a contaminant in waste. Aluminium wastes that do not exhibit dangerous properties are also not regulated as hazardous waste under international treaties, e.g. Basel Convention, OECD Directives, etc.

The site inspection of Benedict's glass recovery process on 22 August 2006 revealed that any aluminium substance present in the glass fines would be in the form of aluminium metals or aluminium oxide residues which probably originated from the aluminium objects such as cans, pull-rings, non-ferrous objects and dirt present in the glass waste. Although Benedict's plant is equipped to remove the bulk of these non-ferrous substances, some particulates and fragments generated from these aluminium objects could end up in the reprocessed glass fines.

The other possible source of aluminium compounds would be from the glass itself but such would be in a non-dispersible form, i.e. locked up within the glass matrix as a mineral complex.

The chemical testing included tests for aluminium, see results in Appendix 1. The presence of any aluminium metal and/or metal compounds in the glass fines is not expected to present an unacceptable human health and/or environmental impact when used as a sand substitute.

3. Specifications

The specifications for pipe embedment used by Sydney Water are those published by the Water Services Association of Australia (WSAA). Sydney Water identified six pipe bedding specifications that may accommodate the supply of crushed glass as an alternative to natural materials (see WSAA specifications: www.wsaa.asn.au/pdf/2006/PurchaseSpecs_05.pdf)

These specifications contain a number of performance properties that will have to be demonstrated by suppliers including hardness, strength, grading, wet/dry strength variation, particle density, plasticity index and resistivity.

These specifications also have the following requirements:

- The material is free from dangerous chemicals as proclaimed by the relevant regulators.
- The material is free from noxious weeds as proclaimed by the relevant regulators.

No tests were carried out for noxious weeds, but the method of collecting and processing the glass creates very little likelihood of weeds being present, and the inert nature of the crushed glass means that the material would be unlikely to sustain growth of any weeds that were present.

The WSAA Specifications also include requirements for pH and resistivity to provide optimum corrosion protection of ductile cast iron pipe and fittings. It was decided to include these in the testing program even though they are strictly fitness-for-purpose properties. Initially, these properties were determined on a leachate extract using APHA *Standard Methods for the Examination of Water and Wastewater*. The laboratory determined conductivity using the APHA test method and then resistivity using the simple relationship Resistivity = 1/Conductivity.

Secondly, these same properties were determined using the solid glass samples themselves by GHD Geotechnics using the soil testing methods in AS1289 *Methods of testing soils for engineering purposes* AS1289.4.3.1 (pH) and AS 1289.4.4.1 (resistivity). The results are shown in Table 1.

Table 1: Conductivity and resistivity of glass samples

Crushed glass samples	**Conductivity (TCLP extract)** (uS/cm) as per APHA method	**Resistivity (TCLP extract)** (Ohm cm)	**Resistivity (glass)** (Ohm cm) as per AS 1289.4.4.1 method
-4mm unwashed	140	7100	3800
-4mm+2mm	79	13 000	>10 000
-2mm+1mm	130	7700	4600
-1mm+0.4mm	220	4500	2200

These results are well within the requirements of WSA PS — 350 Compaction Sand For Pipe Embedment which requires a resistivity greater than 1500 Ohm.cm2 (sic) when determined in accordance with AS 1289.4.4.1.

The results for pH were also within the requirements of WSA PS — 350 which requires that the material has a pH in the range 5–9 when determined in accordance with test method AS 1289.4.3.1. The pH of the samples was in the range 7.1–8.7 — see Appendix 1.

4. Field Trials

Two locations were identified by Sydney Water as suitable to trial the crushed glass in their operations as a replacement for sand. The aim of the trials was to assess the performance of the material during placement in terms of its suitability for the purpose of pipe-embedment, ease of handling, occupational health and safety requirements and compaction. In both locations, three different glass+sand mixtures were used; 25% glass and 75% sand, 50% of each, and 100% glass.

The first trial location was a 1 metre deep trench, approximately 20 metres in length, of a water mains renewal at Kingsgrove, in southern Sydney. The pipe used was DN 100 PVC-M blue water pipe with 16 BAR pressure and included a water hydrant in the section renewed.

Placement, compaction and testing of the embedment material was undertaken in accordance with the Water Supply Code of Australia, WSA-03 (Sydney Water Edition). Compaction testing per AS1289.5.6.1 (as specified by WSA-03) returned results in the range 73.0–76.0% which exceeded the minimum requirement of 70%.

The Sydney Water staff carrying out the work considered that the trial material was easier to handle and spread than natural sand and that it compacted naturally. A mechanical compactor was used for the trial because that is the usual work practice for sand fill.

Left: Kingsgrove water mains pipe bedded and backfilled with 100% glass

Below: Compaction of glass sand backfill in the Kingsgrove trial.

The second trial was conducted with sewerage pipes on a Daracon development at Greystaynes, in western Sydney. During this trial PVC sewerage mains pipe was laid in three connected trenches totalling 60 metres with depths between 1 and 3 metres.

Although sand embedment is not normally used for embedding PVC sewer pipes, the purpose of the trial was to obtain further feedback from contractors regarding the workability and ease of placement of the material. (Note: Sand embedment may be used for reinforced concrete or vitrified clay pipes; these are generally large diameter pipelines for which no current projects were available for trial).

The construction workers using the material commented that it handled as easily as natural sand and that they experienced no greater problems with odour, skin contact or dust.

Above: 50% glass/sand blend covering the sewer pipe

Below: 100% glass fines bedding the sewer pipe

Below: 25% glass/75% sand blend sewer pipe bedding placement

5. Safety issues

Risk can be defined as the significance of an occurrence in terms of its likelihood and the severity of possible injury or harm. From an occupational health and safety perspective there are a number of perceived risks that arise from using crushed recycled glass onsite. These perceived risks are predominately associated with the inhalation of dust from the glass and the potential for cuts from handling the glass particles.

The occupational health and safety concerns outlined above were investigated in detail in the report prepared for DECC; Feasibility Assessment of Generating Crushed Glass Fines for Markets, Part 1. Technology Review, dated 31 May 2004, prepared by the University of New South Wales. This report references the work done in this area by the Clean Washington Centre, USA, and the University of Dundee, Scotland, and is summarised below.

Glass dust

Glass dust is an inert nuisance dust and has no significant biological effect although it may interfere with comfort and welfare. There is no evidence that glass dust causes permanent damage to the respiratory system. Some concerns arise from the use of crystalline silica, which is the cause of silicosis and a known carcinogen in the manufacture of glass containers. While silica sand is a raw material used in the production of glass, the manufacturing process converts the crystalline structure to an amorphous state bonded in the final product, resulting in recycled container glass containing less than 1% crystalline silica. The report concluded that the dust generated by glass cullet is not considered hazardous and does not contribute to silicosis or cancer.

Glass cullet has a specific gravity lower than natural aggregates and it can cause dust clouds as it is handled by equipment on construction sites, particularly when dry. Comments from the sub-contractors handling the material at the Greystaynes site indicated that it generated less dust than other materials and was therefore less offensive than the fill material otherwise used onsite when tipped into trenches.

Dust suppression by hosing down stockpiles of glass material is the most effective measure to control dust. Glass cullet is free-draining and has compaction characteristics that are not moisture sensitive so the application of water should not negatively impact on its performance. It was also noted during the Greystaynes trial that the materials had been exposed to hot, summer weather in the field for almost two weeks and still had very good moisture content.

The general conclusion is that dust generated by this material is no more harmful than the dust generated by naturally occurring sand. However, with respect to occupational health and safety, consideration may need to be given to requiring the crushed glass material to be supplied moist or with some other precaution to minimise dust exposure.

Glass particle handling

The University of NSW report above cites the Clean Washington Centre experience which showed that particles less than 19mm represented no greater hazard of causing skin cuts than conventional crushed construction aggregates. It also reported that glass particles smaller than 6mm were completely benign.

However, because of its abrasive qualities, crushed glass can be a greater skin irritant than conventional aggregates and soils and could even cause eye damage. The hazards associated with handling crushed glass can be avoided by the same protective measures that apply to natural crushed aggregates and which would normally be specified in the Material Safety Data Sheets for all materials.

During the field trials, concerns were raised regarding the potential for glass to splinter and form sharp shards during handling and placement. To investigate this, Sydney Water commissioned GHD Geotechnics to undertake additional laboratory tests whereby samples of 50% glass/ 50% sand blend and 100% glass were initially microscopically examined (for particle shape) and graded. Subsequently the material was subjected to compaction, followed by re-examination and grading. The test report stated that it was ‘difficult to discriminate’ between the un-compacted and compacted material.

6. Other issues

Any advice provided in this report is specific to the sample glass material provided and the circumstances of the two trials. Future users of recycled glass for pipe embedment should satisfy themselves that any particular use of the glass fines material is appropriate, having regard to the nature and quality of the material that is supplied and the characteristics of the application site and receiving environments.

No tests were performed to examine whether or not the glass fines would perforate protective polyethylene sleeves around ductile iron pipes or score plastic pipes, however pipe manufacturers contacted were confident that the fines would not damage the sleeves.

In assessing applications for approval to use various engineering products and materials for the construction and maintenance of water and sewerage infrastructure, Sydney Water makes informed judgement of their conformance to relevant water industry engineering and/or material standards and to Sydney Water's requirements for economic and safe asset creation and performance.

With many specialised products and materials, such as glass fines, there are often no specific industry standards available. Additionally customers do not necessarily have the ability to make objective assessments of health and environmental risks associated with their use. Those who accept the use of specialised products and materials may also expect the manufacturers and suppliers to ensure the products offered to the market are 'safe', and expect any declarations to be supported by documented evidence, with liability remaining with the manufacturer and supplier.

For example, a prerequisite for Sydney Water in approving a 'non-standard' product for use by contractors or Sydney Water personnel is that the manufacturer/supplier shall declare that the product is safe to use and not harmful to the environment when it is used in accordance with the published Material Safety Data Sheet, and/or other controls recommended by the manufacturer/supplier. Any declaration of this kind should be supported by documented, specialist evidence. When Sydney Water approves a product for use, it does not reassign any liability arising from using that product from the manufacturer/supplier to Sydney Water.

These requirements, while appearing onerous, are standard features of material quality assurance and control and assist the resource recovery industry in building a positive reputation based on success.