

UPGRADING THE USE OF RECYCLED MATERIAL - UK DEMONSTRATION PROJECT

**Dr R J Collins
Building Research Establishment
Watford WD2 7JR
UK**

ABSTRACT

This paper describes full-scale demonstration projects on recycling and the use of reclaimed materials in construction work at BRE. Included are both demolition and construction phases and, in particular, the first-ever use in the UK of recycled aggregates in ready-mixed concrete. Reclaimed bricks and reclaimed flooring materials were also used. The projects, a new office and seminar building at Watford and a 500m³ strong floor facility at Cardington near Bedford, also enabled the practicalities of reuse and recycling to be studied in terms of commercial, operational and contractual issues. At Watford, 96% of waste from the demolition of old buildings was recycled, including the resale of roofing sheets and timber boarding, and the salvage of other materials for internal use or donation to charities. Difficulties in the supply of suitable reclaimed and recycled materials for new construction highlighted the need for improved coordination and quality control. Overall, this increased costs, but savings were made in the demolition contract and in the use of reclaimed flooring. Future savings of costs may be made by pre-planning for the use of waste streams for input to the design process plus a sensible approach to risk management.

INTRODUCTION

In recent years there has been considerable interest and research into reuse and recycling of materials during the demolition and construction of buildings. In the UK, however, little progress has been made in the practical implementation of research and government recommendations. The construction of the Energy Efficient Office of the Future on the BRE Watford site was an ideal opportunity to carry out a demonstration project to identify and study the practicalities of reuse and recycling and to show the commitment of the UK Department of the Environment and of BRE to sustainable construction. As part of this research programme, concrete containing recycled aggregate was used both in the new building at Watford, and in a new strong floor facility at the BRE Cardington Laboratory at Bedford.

THE ENERGY-EFFICIENT OFFICE OF THE FUTURE AT BRE

A new office and seminar facility at the heart of the BRE Garston site - the energy-efficient office of the future - will act as a model for low energy and environmentally aware office buildings of the next century. J Sisk & Son Ltd have constructed the building to the designs of a team led by architects Feilden Clegg in consultation with BRE staff. Recycled aggregates have been used under the supervision of structural engineers Buro Happold and staff of BRE Inorganic Materials Division as well as reclaimed bricks and other reclaimed materials.

READY MIXED CONCRETE WITH CRUSHED CONCRETE AGGREGATE

This building incorporates the first-ever use in the UK of recycled aggregates in ready-mixed concrete. Crushed concrete from Suffolk house, a 12-storey office block being demolished in central London, has been used as coarse aggregate in over 1500m³ of concrete supplied for foundations, floor slabs and structural columns and waffle floors. The new building has been used as a full-scale demonstration project to show how new and higher-grade uses of waste and recycled materials can be introduced in support of UK commitment to the principles of sustainable development and to assist the attainment of Government targets for the contribution of these secondary materials to aggregate supply.

SITE CLEARANCE

Old buildings on the site required demolition before new construction could start. The majority of the materials were either reclaimed for reuse or recycled. Concrete and masonry from the old building were crushed on site by the demolition contractors, G J Gaywood Ltd, using portable plant. This material has been used for hardcore during construction of the new building. Gaywoods also reclaimed all metals for recycling and timber roof boards for reuse in the manufacture of pine furniture. Before final demolition of the old buildings on the site, many of the abandoned fittings were removed and donated to Hertfordshire schools through a recycling scheme run by Rotary and SATRO (Science and Technology Regional Organisation). Materials included light fittings, sockets, fire alarm equipment, office blinds, racking, filing cabinets, wood offcuts etc. An inventory of all materials is given in table 1 and indicates that 96% by volume were recycled and only 4% went to landfill.

Table 1 Summary of demolition waste management

Materials	Estimated Quantity	Disposal option
Bricks	500m ³	hardcore on site
Roofing sheets	300m ²	sold for reuse
Roofing timber	300m ²	sold for furniture
Slate cladding	40m ²	removed for reuse
Iron and steel	90 tonnes	sold to metals dealer
Lead and copper	1.3 tonnes	sold to metals dealer
Concrete	600m ³	hardcore on site
Fixtures, fittings, furniture	6m ³	reused
Cast iron drainpipes	10	reused
Remainder of building	50m ³	landfill

CONCRETE IN THE ENERGY-EFFICIENT OFFICE OF THE FUTURE

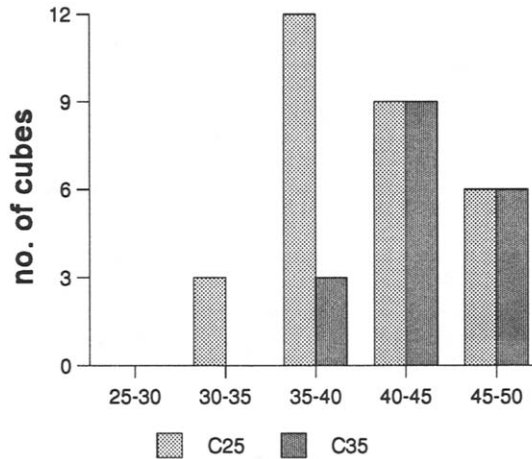
For the foundations, a C25 mix (75mm slump) for Class 2 ground conditions was specified. According to BRE Digest 363, a minimum OPC-based cement content of 330kg/m³ and a maximum free water/cement ratio of 0.50 are required. For floor slabs etc, a C35 mix, also with 75mm slump was specified. RMC trial mixes (all with water-reducing admixture Fosroc Conplast P250) gave the alternatives in table 2 below.

Table 2 Trial Mixes

(e) - estimated by interpolation

Description	OPC + ggbfs	OPC / ggbfs	28-day strength
C25 Class 2 Mix 1	375 kg/m ³	100/0	47N/mm ²
C25 Class 2 Mix 2	375 kg/m ³	50/50	45N/mm ²
C25 Class 2 Mix 3	375 kg/m ³	30/70	36N/mm ² (e)
C35 Mix 1	385 kg/m ³	50/50	46N/mm ²
C35 Mix 2	400 kg/m ³	30/70	46N/mm ² (e)

C25 Mix 3 and C35 Mix 1 were chosen for use. A high content of ground granulated blastfurnace slag was chosen for the C25 mix to maximise chemical resistance, but a slightly lower level was chosen for the C35 mix for protection against carbonation. All mixes contained 985 kg/m³ of crushed concrete coarse aggregate apart from mixes for pumping in which this was reduced by 50 kg/m³ and the cement content increased by 10 kg/m³. With the aid of a portable laboratory, RMC made frequent tests on the concrete delivered to site and showed that the maintenance of quality was adequate (figure 1).

Figure 1 Concrete mix quality control data (compressive strength in N/mm²)

STRONG FLOOR AT BRE CARDINGTON LABORATORY

A new strong floor at the BRE Cardington Laboratory was chosen to demonstrate the use of mixed concrete/masonry recycled aggregate derived from general demolition waste. The strong floor is a heavily reinforced slab 0.5m thick on which to place full-scale buildings up to eight storeys high for testing to destruction. Although the tender documents suggested that preference would be given to tenders incorporating the use of recycled aggregates, none was offered as supplies of suitable material were not readily available. Since a rapid start to the work was required, one of the tenders which was the most suitable in all other aspects (but of course quoting the use of natural aggregates) was accepted, leaving about 3 weeks to arrange and certify a suitable source.

500m³ of concrete was to be placed in one day, 23 February 1996, and about 100 tonnes of RCA (containing up to 50% brick) would be required to replace 20% of the natural coarse aggregate. The nearest source that could be found in the short time available was King's Cross, but the tonnage required in the 20-5mm size range could not be produced until a few days before casting. Another source of material was located on the other side of London near Dartford. Samples of both materials were taken for trial mixes at RMC. Both contained in the region of 40% brick masonry. From 7 day strength data it was assessed that there would be no problem in achieving a strength of at least 35N/mm² at 56 days (as required in the project specification) in any of the test concretes with 20% replacement of natural coarse aggregate by RCA. The mix chosen for use contained RCA from King's Cross and 385 kg/m³ cementitious material (70% ggbfs / 30% ordinary Portland cement). No problems were encountered with production and placement, and strength data indicated that strength requirements were exceeded by a wide margin.

SPECIFICATION AND RISK

Despite a large body of laboratory research data showing that recycled aggregates can give excellent performance in concrete, practical use in the concrete industry has been restricted by questions of specification, risk, availability and cost. These issues have been highlighted in the demonstration project at BRE. In a recent study¹ on the relationship between specifications and the use of recycled materials and other wastes as aggregates, it was concluded that British Standards in themselves (and in particular, BS5328 for concrete) did not prevent the use of recycled aggregates in concrete. The main reason for exclusion of such material is the wording of contract specifications which in addition demand compliance with BS882 (*Natural* aggregates for concrete). Only BS1047 (Blastfurnace slag aggregate) or sometimes BS3797 (Lightweight aggregate) are allowed as alternatives. To use any other type of aggregate, evidence of suitability for purpose (as required in BS5328) is not in itself sufficient for specifiers. Whether or not the substitution of recycled aggregates for natural aggregates in concrete increases the risk of failure, modifying the specification to allow little-used non-BS materials will tend to place all of risks pertaining to its use on the specifier. This will result in unacceptable extra costs which will probably be difficult (and costly) to quantify.

The only practical course, until such use of recycled aggregates becomes more common is for the client to take on this part of the risk. The client may be prepared to do this either to save costs or, more likely, to gain “green” credentials. It is possible, however, that the client may be prevented by fundholders in their own specifications from taking extra risks or using recycled aggregates. BRE as client has gone down this path both to make a closer assessment of such practical matters, and to demonstrate its confidence in the use of recycled aggregates in higher grade applications. The Department of the Environment might be regarded as “fundholder”, not in this instance applying additional specifications, but having objectives similar to BRE, and in the promotion of an increase in the use of recycled materials in construction.

SPECIFICATION OF RECYCLED MATERIAL AND AVAILABILITY

With all building projects, a wide range of different materials and services are used and all must be on site at the correct time to avoid delays and causing an escalation of costs. Recycled aggregates prepared for use in concrete are not generally available in the UK and thus it is difficult at the present time to specify them for use in concrete construction. Apart from general statements to the effect that BRE expected the main contractor to assist in the incorporation of the latest of environmentally aware practices, no absolute commitment was made in the BRE project to the use of recycled aggregates in concrete. This aspect was “retrofitted” to the job specification, and accepted by the contractors as long as there was no extra cost to them and no hold-up in the supply of materials. Any difficulty in this respect would result in reversion to the use of natural materials. Further aspects of risk and specification are considered in references 2-4.

COSTS OF USING RECYCLED AGGREGATE

The need for trial mixes, quality control etc. has cost implications. Obviously, as a market develops, such costs will be reduced but are likely to remain higher than for natural materials. Costs will also be incurred for the higher cement contents often required by recycled aggregates. Such costs may eventually be offset by the increasing cost for landfill. An extra cost in the BRE

project was for increased transport requirements. This was accepted in order to obtain the most secure supply lines of material and ensure that this “one-off” demonstration project had the greatest possible chance of success.

BRICKS

Around 80,000 reclaimed facing bricks were used for the external cladding of the BRE Energy Efficient Office of the Future. Whole bricks could not be salvaged from the old buildings on site because of the strength of the mortar bonding them together. The material was thus crushed on site as hardcore for the new building. Insufficient time was available to test these materials for use as aggregate in concrete for the new building. It was proposed to purchase the bricks from the demolition of a hospital situated about 2km away. These bricks would have been considerably cheaper than new ones. Unfortunately, the demolition was delayed beyond the time that the bricks needed to be on site and bricks were obtained instead from a quality assured reclamation company. Greater costs were thus incurred in addition to extra charges from the both architect and main contractor resulting from the use of imperial size bricks in a building designed for metric bricks.

Buildings more than about 60 years old contain hydraulic lime mortars which assist considerably in the reclamation of whole bricks. Consideration was given to the use of hydraulic lime mortar for the new building but this would not give sufficient lateral strength to the modern thin-walled cavity construction. Lime mortars were generally used before cavity wall construction was introduced; sufficient lateral strength was given by the thickness of the walls. Lime mortars could have been used in the outer leaf of the new building if the thickness of the internal load-bearing blockwork were increased from 140 to 190 mm. This could not be justified in terms of the efficient use of material resources.

FLOORING

Hardwood parquet block flooring removed during refurbishment work at the former County Hall building in London has been relaid in the new BRE building at Watford. Only 300m² of the 18,000m² available were required. Despite the extra costs of cleaning and laying, an overall saving of 30% was made compared with the costs of equivalent new material.

DISCUSSION AND CONCLUSIONS

The construction of the new Energy Efficient Office of the Future at BRE has proved to be an excellent test bed both for demonstrating new recycling methods and for highlighting the difficulties encountered. The main problem was in sourcing suitable materials in sufficient time. This caused the main worry both for the graded recycled aggregate and also for a suitable source of reclaimed bricks to be used in the external cladding of the building. There is an argument that materials should be collected together in advance, but this needs a considerable amount of pre-planning, and clients and contractors alike do not wish to have large stockpiles lying idle for long periods. Such pre-planning, however, could allow clients and their architects to specify recycled material from the outset rather than substituting recycled materials afterwards as in this project. The “substitution” aspect of the BRE project, however, has been quite instructive. This aspect

of the project could well have been lost if a building had been designed with recycled and reclaimed materials in mind.

The construction of the new strong floor at Cardington has illustrated how recycled materials might be incorporated in concrete on a routine basis. No significant effect on concrete handling, maintenance of high production rates, placement properties, strength development etc. appears to be caused by replacing 20% of the natural coarse aggregate by RCA. Also the RCA in this case should potentially be more widely available, being produced from general demolition waste containing a mixture of concrete and brick. Because of the high production rates required for the Cardington project, a readymix plant was totally dedicated to the one project and a silo was available for the exclusive use of the RCA. Provision of extra storage capacity for RCA on a more general basis would require a fairly general use of RCA to be cost-effective at current price levels.

The next hurdles are (a) to pave the way for a greater availability of RCA of the correct grading and sufficient quality for use in concrete eg by a pilot quality control scheme, and (b) to establish acceptability of the product on the market. Some clients may be seeking "green" credentials, but at some stage in the future cost savings may also be obtainable. Job specifications for projects may cause some problems but these are not insuperable. BRE was able for its own construction projects, to use its wide range of expertise in discussing and overcoming specification problems where possible. The experience from this should in new projects assist the development of appropriate action in relation to standards and specifications and other barriers to utilisation.

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