Sustainability briefing

Recycled and secondary aggregates in concrete

In considering the use of recycled and secondary aggregates, the structural engineer should consider the issues set out in this briefing

Introduction

There are already mechanisms including aggregate levy and landfill tax to provide economic incentives to the construction industry to use recycled aggregates. The role of the structural engineer is to ensure the appropriate use of both recycled and secondary aggregates. A limited percentage replacement is usually permitted under BS 8500.

Recycled and secondary aggregates are generally formed of crushed construction waste or by-products of industrial processes, but can also include some post-consumer waste products such as crushed bottle glass. Construction waste can be divided into potentially good quality material, essentially crushed concrete (RCA), and lower quality material which can include high proportions of crushed masonry (RA). Industry by-products can similarly be divided in high and lower performing materials.

Terminology

Terminology relating to recycled and secondary aggregates varies between users with the term recycled aggregate often being used to describe all non-primary aggregates although the term recycled and secondary aggregate (RSA) is preferred in this briefing. Nevertheless, it is convenient to make various distinctions. BS 8500-1[1] provides definitions for two types of recycled aggregate suitable for use in some concreting applications:
– Recycled concrete aggregate (RCA) is aggregate principally comprising crushed concrete.
– Recycled aggregate (RA) is aggregate resulting from the reprocessing of inorganic material previously used in construction.

Strict composition limits for coarse recycled aggregates (RCA and RA) for use in concrete are provided in Table 2 of BS 8500-2: 2006[2]. Other recycled aggregates include spent rail ballast and recycled asphalt although the latter may not be suited to use in concrete.

Secondary aggregates (SA) are generally by-products of industrial processes which have not been previously used in construction. They can be divided into manufactured SA (including air-cooled blastfurnace slag, sintered fly ash (Lytag) and crushed glass), and natural SA (including china clay stent coarse aggregate, slate waste, and china clay sand).

Demand and use of aggregates

The demand for aggregates for use in concrete and other construction applications is enormous (currently estimated at over 250Mt in the UK/pa[3]). Whilst they are abundant materials, and the mineral planning process and the work of the Environment Agency seeks to ensure minimum impact socially and environmentally, exploitation of aggregate sources near population centres, even small ones, and in areas of scenic beauty, has always been unpopular. There are, however, potential sources of granular materials that go to waste with the consequential issues of land-fill and, in the cases of china clay waste and slate waste, above-ground dumping. Use of this RSA can reduce the rate of depletion of natural resources and reduce problematic waste.

The UK produces about 70Mt of RCA each year, and it is used in a wide variety of building and infrastructure applications. Recycled aggregates are already in use partly as a result of the landfill tax and aggregate levy influencing the supply industry to increase its use, but also due to client demand for so-called ‘sustainable construction’. The overall use of RSA in the UK is well above the European average[3].

Concrete containing recycled concrete aggregate is now becoming available in limited quantities from some suppliers. China clay sand and coarse aggregate (stent) are commercially available in the UK. Air-cooled blastfurnace slag is also available but from two of the three UK sources is generally only suitable for use in low strength concrete. Sintered fly ash lightweight aggregate is readily available in some markets but is currently imported. Spent railway ballast has recently become available from some suppliers.

Recycled aggregates are generally only suitable to replace a limited proportion of the natural coarse aggregate and little, if any, of the sand fraction. Research and experience may allow the currently accepted proportions to increase without compromising performance. Where the project allows, specific trials, testing and careful selection of materials may speed this trend (e.g. the use of crushed railway sleepers in the Wessex Water HQ allowed 40% replacement of coarse aggregate against the industry norm of 20%). Some secondary aggregates can be used to completely replace the natural coarse and/or sand fractions although existing mix designs appropriate for natural aggregates may need to be modified.

Standards for aggregates

The European Standard for aggregates for concrete[4] has been updated to include recycled aggregates. Although it does not yet cover ‘unfamiliar materials from secondary sources’ such as crushed glass, it does include specific requirements for air-cooled blastfurnace slag. Secondary natural aggregates, such as china clay stent or slate waste, should meet the requirements of the standard in the same way as any primary natural aggregate.

Many other countries may not yet have appropriate standards and, even where standards exist, there may be regulatory or client specification barriers to overcome. Materials outside the scope of standards should be used with caution – just because a material is hard and granular doesn’t mean it is suitable for use in concrete!

Use of RSA will generally require forward planning to:
– identify suitable materials, sources and suppliers (location, quantity, ability to supply);
– assess suitability, quality and variability (for established or previously used materials this may already be available);
– review the feasibility of any on site source and requirements of meeting legislated waste protocols if transporting materials to the site;
– obtain agreement of client, contractor and concrete supplier;
– explore the economics;
– allow the producer to perform concrete trials to establish mix designs and provide assurance of required properties;
– prepare the specification (‘Recycled aggregates shall be used’ is not sufficient).

These requirements can be significant and currently a potential barrier to use. As familiarity with the material and supply options increases, this issue should become less of a problem. In all projects the benefits of meeting technical performance requirements effectively and economically will probably be central. There is also a need for careful planning if material is to be retained and reused on site, and on constrained sites it may not be practicable.

Principles

Requirement of recycled and secondary aggregates should be considered for any project following the principles set out below.

– RA can be a highly variable and is generally suitable only for use in low-grade concrete; it is not recommended for use in structural concrete.

– RCA should only be used if it is locally available (within roughly 30 miles) or would otherwise go to landfill. Long distance road transport of RCA is to be discouraged.

– The deployment of RCA to replace primary aggregates in situations where both fine and coarse portions can be used (e.g. as fill) should be given preference to deployment in structural concrete.

– Secondary aggregates can be transported a significant distance by rail or water if they would otherwise be treated as a waste. In the UK there are secondary aggregates available to some locations, but not all, which would otherwise be stockpiled or treated as waste.

The primary aggregate replacement level should be chosen to ensure that the Portland Cement content is not significantly raised.

Project examples

The prestigious office development at One Coleman Street in the City of London is recognised as the first major use of china clay stent coarse aggregate in concrete outside the South West of the UK[5]. The stent was used to completely replace the normal primary coarse aggregate in pile-caps, floor slabs and the structural frame. China clay sand was not used because of its increased cement demand.

China clay stent is also being used, alongside a small proportion of ground glass sand, to meet the stringent recycled/secondary content requirement for concrete in the 2012 London Olympics construction. The proportion of stent aggregate in this case varies with the strength class of the concrete.

Air-cooled blastfurnace slag from Port Talbot is routinely being supplied into structural quality concrete by at least three ready-mixed concrete plants in the Cardiff and Swansea area and has recently become available in the London area. At least one concrete supplier is meeting customer demand for RSA content through the use of spent railway ballast.

Drawbacks

Natural aggregates are still cheap and plentiful in most areas with a well developed commercial supply infrastructure. There are few commercial sources of recycled or secondary aggregates although that situation is slowly changing as demand grows.

Sources of secondary materials are, in some cases, far from centres of construction activity (e.g. china clay waste in Cornwall and slate waste in Wales). Use of RSA may carry a cost penalty until their use becomes more widespread or greater incentives are provided by governments or the waste producers. Some RSA may carry a need for increased rates of testing and, possibly, increased cement content which can potentially offset any sustainable advantage of the RSA.

The British Standard for Concrete[2] excludes the use of coarse RCA in concrete for exposure conditions that include chlorides, significant freeze-thaw or aggressive ground conditions unless suitability in such uses has been demonstrated. No guidance at all is provided on the use of RA or fine RCA.

Potentially longer supply distances can increase the transport impacts of moving materials. Although aggregates contribute a small proportion of overall concrete eCO_2, RSA can increase mix eCO_2 through increased transport distances and if the cement demands are increased to ensure performance.

Academic research tends to be optimistic about the properties of concrete made with secondary aggregates from some unlikely sources (e.g. sewage sludge ash and periwinkle shells). It is therefore essential to be sure materials are appropriate for general application within the established supply chains.

In summary, RSA should be considered by following the principles set out above in order to ensure that the best practical environmental option is achieved.

References

1 BS 8500-1: *Concrete – Complementary British Standard to BS EN 206-1 – Part 1: Method of specifying and guidance for the specifier,* BSI, 2006

2 BS 8500-2: *Concrete – Complementary British Standard to BS EN 206-1 – Part 2: Specification for constituent materials and concrete,* BSI, 2006

3 *Sustainable Development Report*, http://www.qpa.org/sus_report01.htm Quarry Products Association, 2007

4 EN 12620:2002 + A1:2008: *Aggregates for concrete,* European Committee for Standardisation, CEN, 2008

5 Marsh, B. K.: 'One Coleman Street – a case study in the use of secondary materials in concrete', *The Structural Engineer*, **85**/9, 1 May 2007, p 35-37

Further Information

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Sustainability briefing on Recycled and Secondary Aggregates in Concrete (appearing in *The Structural Engineer* 88 (15/16) 3 August 2010)

Comment from reader:

I recall that as a member of the Hawkins committee dealing with *Minimisation of Alkali-silica reaction* we included the following in the 3rd Edition of the Concrete Society report.

"The classification of recycled aggregates (including crushed concrete and other demolition waste) as high reactivity is a precautionary measure pending further knowledge about their long-term behaviour. Reclaimed aggregates, which are natural aggregates from fresh concrete, should be treated on the basis of the reactivity class of the original aggregate."

This was in 1999. I would be grateful if this could be brought to the attention of those dealing with the briefing. It would be interesting to know if the situation has changed since the issue of Concrete Society report.

Response from Panel:

The current and most up to date guidance is in BRE Digest 330, 2004 Edition. In particular see page 5 of BRE Digest 330 Part 2.

Recycled Concrete Aggregate (RCA) is defined as crushed concrete with not more than 5% masonry, and if the original concrete did not contain a highly or extremely reactive aggregate then the RCA is not classed as highly or extremely reactive. A nominal contribution to the alkali content of the concrete from the RCA should be included.

All other Recycled Aggregate should be assessed on a case by case basis as the potential composition can be so wide, and the recommendation is that it should be classified as high reactivity.

The position with respect to reclaimed aggregates appears to be the same, they should be classified in terms of reactivity of the original aggregate type or combination. The mixing of low reactivity aggregate with high reactivity aggregate means that it would all be classified as high reactivity.