Development Of Guide Specifications For Recycled Aggregates In Concrete Construction

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Summary: Recycling of construction materials is growing along with the demand for recycled materials. However, this growth is often constrained by specifiers' insufficient knowledge of material performance, low awareness of benefits, and perceived risks. Until recently, in Australia, the use of crushed concrete derived from building demolition has been restricted to granular sub-base layers in road pavement construction and drainage, or excavation fill applications. However, improved crusher technologies, rubble screening and aggregate washing, and tighter regulation of the recycling industry, have contributed to significant improvements in the quality of recycled concrete products. Consumer acceptability of recycled materials, however, largely depends on products being technically suitable, cost competitive and meeting environmental impact requirements.

This paper discusses the proposed Guide specification document which will cover existing technical information and potential uses of recycled concrete and masonry waste into a structured format, required for specification guidelines. This includes information on recycled material properties and performance, and examines technical and market considerations of construction and demolition (C&D) waste recycling, based on field trials of premix recycled concrete. Different sources of aggregate batches are assessed in relation to existing Australian Standards for natural aggregates, in particular AS 1141, to establish conformance of recycled products. The proposed Guide specification document will provide engineers with product specification information and the tools required for conventional design with graded recycled C&D waste material.

Keywords: Concrete, guidelines, recycled aggregate, specifications.

1 INTRODUCTION

The development a national Guide specification document on recycled concrete and masonry aims at providing engineers with product specification information and the tools required for conventional design with graded recycled construction and demolition (C&D) waste material. The document broadly outlines general specification requirements for recycled concrete and masonry materials, based on laboratory investigations and detailed local field performance evaluations of civil and municipal construction works involving recycled concrete aggregates.

Current national experience and knowledge regarding the use of these materials not only vary from material to material, but also in the way in which they are used. Furthermore, the availability of specification guidelines specifically for secondary and recycled materials is limited. However, in recent years, the gradual shift towards performance-based specifications has given rise to amendments of existing codes that also permit the use of all materials irrespective of their source, provided they comply to required specified performance rather than the conventional prescriptive requirements. Given that the recycling of construction materials is growing along with the demand for recycled material, it is important for specifiers to gain knowledge of material performance and an awareness of the benefits and perceived of risk of recycled construction materials.

2 PROJECT OBJECTIVES

The document provides general guidance to those who have an interest in using or increasing their understanding of recycled concrete aggregate (RCA) and masonry materials in construction applications.

These guidelines cover recycled material performance, limitations, and product testing and evaluation compliance requirements when considering the use of these materials. It is intended to assist suppliers, specifiers, regulators and end-users of recycled aggregate materials to gain some understanding of key material properties, by providing relevant information for

determining the suitability of recovered material for use in selected civil, recreational and municipal construction applications. It is envisaged that manufacturers of recycled concrete and masonry products can produce material of suitable specifications for its intended use, based on standard crushing and grading processes for target applications.

The extensive survey of local applications of recycled concrete highlights case studies where recycled aggregate products either meet or fail to satisfy service performance requirements.

3 CONCRETE RECYCLING

Recycled concrete is basically old concrete that has been demolished and removed from foundations, pavements, bridges or buildings, and crushed into various size fractions for reuse. The feedstock material often includes small quantities of natural rock and construction masonry. Generally, recycled products can be produced from all but the poorest quality clean feedstock through a series of processing stages involving crushers, screens and devices for removing foreign material.

Material recycling in construction has been practised for many years now. However, there are several emerging issues relating to material specifications, testing and compliance protocols, characterisation procedures, design practice and material durability that need to be established. Whereas industry standard quality assurance procedures and product performance protocols are rapidly evolving, the need exists for tighter regulation given the diversity of feedstock sources and variations in the mode of aggregate production.

A high proportion of conventional demolition waste, particularly the fraction derived from concrete, brick and tile, is well suited to being crushed and recycled as a substitute for newly quarried (primary) aggregates. These materials are currently widely used in lower grade applications, most notably engineering fill and road sub-base applications. The use of such recycled concrete aggregates in new concrete is much less common, and technically much more demanding.

For these selected construction applications, recycled materials have the potential to partially displace equivalent volumes of primary aggregates. Preservation of non-renewable virgin aggregate resources, in turn, reduces the pressure on increasingly scarce landfill space.

In recent years, well-processed recycled products produced from good quality feedstock material have been demonstrated to comply with most test requirements for conventional materials for a range of applications. Several of these quality recycled aggregate products, which meet the same or equivalent performance specifications, are in current use in place of primary aggregates. The use of recycled products is therefore expected to increase with time and meet lesser discrimination in the market place.

Test procedures for virgin materials are currently used to characterise generic fundamental properties of recycled aggregates, as listed below. Data generated from such tests are useful in assessing overall performance of recycled aggregates compared to conventional materials, particularly for road base and new concrete applications:

- grading, particle shape and surface texture;
- specific gravity;
- moisture absorption;
- aggregate crushing value; and
- degree of contamination.

The bulk density of loose recycled aggregate was determined in accordance with AS 1141.6. As shown in Fig. 1, the density of oven-dried recycled aggregates is generally lower than that of the reference basalt aggregate. The lower density values of recycled aggregates compared to conventional aggregates arise mainly from relatively porous and less dense residual mortar lumps or particles adhering to the surfaces of original natural aggregate particles.

The specific gravity of coarse recycled aggregate ranges from 2.2 to 2.5, which is slightly lower than that of conventional virgin aggregates. The fines fraction of recycled aggregates has a lower density compared to the coarse material.

The absorption capacity of recycled aggregates is variable and generally higher than the standard threshold for primary aggregates. Water absorption values measured in accordance with the procedure described in AS 1141.6 are shown in Fig. 2. The absorption values for coarse recycled aggregate products generally range from 4 to 7% compared with less than 2% for primary aggregates. Higher values up to 8% can be expected for blends of recycled concrete and other materials.

An assessment of the contaminant levels of aggregate batches indicates a limit of no more than 2% inclusive of brick and stony material. Alternatively, the general impurity content comprising friable materials and materials with density less than 1950 kg/m^3, is of the order of 1.2% of total material weight, as shown in Fig. 3. Average batch compositions were assessed by visual examination of the +4.75 mm fraction sieved in accordance with AS 1152. Hand sorting of all foreign material was first carried out on the dried material, followed by wetting, to ensure complete identification and classification of all types of contaminants.

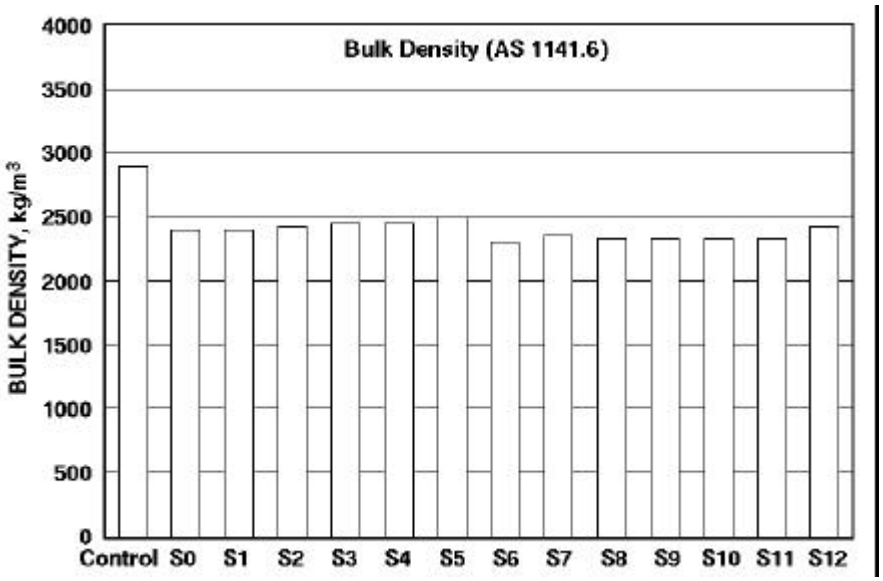

Figure 1. Plot of bulk density values of aggregates

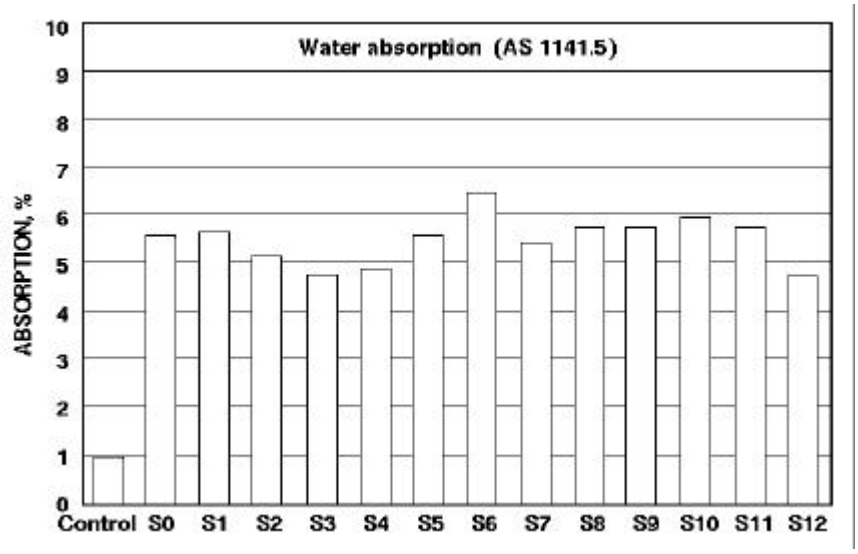

Figure 2. Water absorption of aggregates

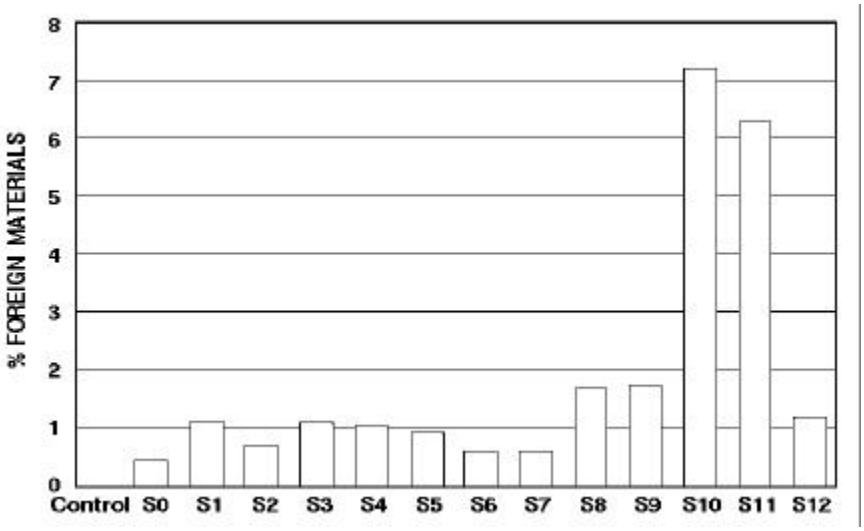

Figure 3. Total contaminant level expressed as per cent by weight of sample.

4 AGGREGATE FOR CONCRETE PRODUCTION

For concrete production, graded recycled concrete aggregates must be dimensionally stable with regard to variations in moisture content, and sufficiently strong for the desired grade of concrete. The material typically has to comply with grading limits specified in AS 2758.1, and have suitable particle shape and surface texture. Additionally, RCA must neither contain reactive contaminants nor react with cement or reinforcing steel. Table 1 summarises some typical limits in recycled concrete aggregates.

Table 1. Typical limits recycled concrete aggregates (RCA)

RCA property	*Class 1A RCA limit*	*Class 1B RCA limit*	*Test method*
Brick content (maximum)	0.5%	30%	—
Stony material <1950kg/ m^3	1%	5%	—
Friable material (maximum)	0.1%	0.1%	—
Particle shape, 2:1 ratio	35%	35%	AS 1141.14
Particle density: saturated surface dry (minimum)	2100 kg/m^3	1800 kg/m^3	AS 1141.6
Bulk density (minimum)	1200 kg/m^3	1000 kg/m^3	AS 1141.4
Water absorption (maximum)	6%	8%	AS 1141.6
Aggregate crushing value (maximum)	30%	30%	AS 1141.21
Total Impurity level (maximum)	1%	2%	
LOI (max)	5%	5%	
Lost substances in washing (maximum)	1%	1%	
Soundness loss (maximum)	9%	—	AS 1141.24
Particle size distribution by dry sieving	—	—	AS 1141.11

It is recommended that the initial evaluation of RCA for premix concrete production involves direct comparison of the aggregate's physical and mechanical properties, plus the durability characteristics of the concrete, using conventional natural aggregate concrete as the reference material.

5 MASONRY RECYCLING

The recycling of building rubble comprising primarily of masonry material presents a much greater challenge for recycling, and severely lags progress in recovery and reuse of recycled concrete. Crushed masonry rubble is a useful material for several different applications in construction, and is mostly used as capping material or as blends with natural aggregates or recycled concrete as drainage or bulk fill material if sufficiently durable. They comprise mainly of burnt clay products, such as bricks, roofing tiles and lightweight blocks. Table 2 shows a summary of quality systems for recycled masonry materials.

Masonry waste often has much higher contamination levels compared to concrete feedstock. The key contaminants are Portland cement mortar, hardboard and plaster. Normal demolition masonry may comprise of components of building materials such as structural lightweight brick; concrete masonry units (block); natural stone; Portland cement mortar, plaster, and terrazzo; gypsum, plaster; ceramic materials; roofing tiles; glass; wood; paper; plastic; asphalt; and metals. The largest source of this class of feedstock arises from residential demolition and renovations. The nature of these contaminants severely restricts possible uses of recycled concrete products, demanding particular effort to separate them at source prior to demolition.

Table 2. Summary of quality systems for recycled materials

Processing requirements	*Quality requirement*
Feedstock sources	Demolition waste and industrial by-products
Feedstock acceptance	Avoidance of contamination by selective demolition and sorting and gate inspection
Material storage	Pre- and post-treatment storage, according to product quality and class
Material classification	Recycled materials should be classified according to intended use(s)
Engineering tests	Engineering tests and frequency of testing should be conducted according to specified standards

Foreign material content	Organic or inorganic contaminants
Environmental	Leachability

The processing of masonry rubble is similar to recycled concrete, but typically generates much lower value-added products. However, there are few premium applications that may be considered for good quality crushed brick rubble such as aggregate for lightweight concrete. Crushed masonry aggregate from various types of demolition debris may also be used in the premix or precast concrete industry.

Contaminants usually are of comparatively less concern in base aggregate applications compared to recycled aggregates which are to be used in new concrete. However, in permeable base applications where the material is not stabilised, dust and fine material wash-offs as well as leachate residues may settle on filter fabric or drainpipes before reaching drainage outlets, clogging pipes, binding filter fabric and ultimately causing system failure. Washing of recycled aggregates can, however, correct this problem.

Typical contaminants in demolition waste feedstock often include lightweight brick and concrete, asphalt, chlorides, cladding, soil and clay balls, steel reinforcement, tiles, vinyl, wood, glass, gypsumboard, hardboard, iron, admixtures and joint sealants, paper, plaster, plastics, rubber and roofing materials of various kinds.

As summarised in Table 3, some of the engineering properties of RCA that are of particular interest when RCA is used as a fill material include grading requirements, strength, specific gravity, durability, and drainage.

Table 3. Summary of engineering properties

Grading	The crushed and screened material should satisfy specified maximum size and grading requirements for a given application
Specific gravity	The specific gravity of RCA aggregates is slightly lower than that of virgin aggregates and ranges from 2.0 for fines to 2.5 for coarse particles
Strength characteristics	Processed RCA, being 100% crushed material, is highly angular in shape, and exhibits California Bearing Ratio (CBR) values comparable to crushed limestone aggregates
Durability	RCA aggregates generally exhibit good durability with resistance to weathering and erosion
Drainage characteristics	RCA is non-plastic; the coarse fraction is free draining and is more permeable than conventional granular material due to lower fines content

6 CONCLUSIONS

The Guide distils existing technical information and potential uses of recycled concrete and masonry waste into a structured format, incorporating specification requirements. It will provide information on material properties and performance. Access to reliable information on all technical material characteristics in a single document will facilitate decisions on product specification, use and marketing.

Through case studies and supplementary field testing, the project will also provide data on the longer term performance of materials derived from recycled concrete and masonry. This durability information will be the first effort in Australia to quantify and report long-term performance. Lack of this data in the marketplace continues to be an impediment to the wider application of recycled resources.