USE OF ALTERNATIVES TO PRIMARY AGGREGATES IN CONCRETE

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Abstract

Construction and Demolition (C&D) waste constitutes a major portion of total solid waste production in the world, and for the present most of it is used in land fills. This paper discusses different aspects of the problem of recycled materials, which can be used extensively in concrete as recycled and secondary aggregates (RSA) as replacement of natural aggregates in concretes. This includes first recycled aggregate (RA) and recycled concrete aggregate (RCA). This paper deals with the problem of the building and demolishing waste recycling and it also shows material potential of recycling. Recycled concrete aggregate is derived from existing concrete, whilst recycled aggregate is aggregate resulting from the processing of inorganic material previously used in construction, e.g. crushed concrete, masonry, brick.

Keywords: Recycled aggregate, Recycled concrete aggregate, Construction and Demolition waste

1 Introduction

Preservation of the environment and conservation of the rapidly diminishing natural resources should be the essence of sustainable development. Whereas on the one hand, there is shortage of natural aggregates (NA) for production of new concrete, on the other the enormous amounts of demolished waste produced from deteriorated and obsolete structures creates severe ecological and environmental problem. One of the ways to solve this problem is to use this 'waste' as aggregates. Such 'recycled' aggregate could also be a reliable alternative to using natural aggregates in concrete construction.

It is estimated that the production of C&D waste (without earth) in the EU could be as much as 180 million tons per year. Though clear figures about recycling are not available for individual countries, but is estimated, that very little demolished waste is currently recycled or reused anywhere in the world. Recycled materials are generally less expensive then natural materials, and recycling for example in Germany, Holland and Denmark show that is less costly than disposal.

Recycling of C&D waste was first carried out after the Second World War in Germany though the first knows attempts to make this waste to back to the age of ancient Greeks and Romans. Since then, research work carried out in several countries has demonstrated sufficient promise for developing use of C&D waste as a constituent in new concrete.

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2 Terminology in recycling

The following terminology will be used in publications about recycled materials:

Construction and demolition waste (C&DW): Waste materials which arise from the construction or demolition of buildings and/or civil engineering infrastructure, including hard C&D waste and excavation waste, whether segregated or mixed. Could be broken concrete, bricks, masonry, soil, asphalt, tiles, wood, plastic, metal a.o. from demolished buildings.

Waste concrete (WC): Concrete debris from demolished structures as well as fresh and hardened concrete which has been rejected by ready-mixed or site-mixed concrete producers or by concrete product manufactures

Recycled concrete (RC): Hardened (old) concrete that has been processed for reuse, usually as aggregates. It has been demolished and removed from pavements, bridges, foundations, or buildings and crushed into various sizes for reuse.

Recycled concrete aggregates (RCA): Aggregates produced by the crushing of original concrete (inorganic material previously used in construction and principally comprising crushed concrete). Such aggregates can be fine or coarse recycled aggregates. Also may be referred to as recycled aggregates. Recycled concrete aggregate is increasingly available and is often an economical alternative to new aggregate. Project managers can ensure that their contractors are aware of opportunities to recycle this material and can require the use of recycled material in construction. Users of recycled concrete aggregate should take customary precautions to ensure that the material is suitable for the intended application.

Crushed demolition debris: Mixed crushed concrete and brick that has been screened and hand-sorted to remove excessive contamination

Recycled aggregate concrete (RAC): Concrete produced from recycled aggregates or a combination of recycled and conventional aggregates such as sand, gravel, or crushed stone. Sometimes is referred to as new concrete. RCA is obtained from crushing demolished concrete structures, discarded precast elements and unused hardened concrete. By definition it must be predominately composed of concrete (at least 84% by mass) with no more than 5% masonry. RCA can be obtained from reinforced and plain concrete in the same way that natural aggregates are obtained from natural rock using primary and secondary crushers. RCA may have a rougher surface texture than crushed natural aggregates, but will have similar shape. The performance characteristics of RCA are better than those of recycled aggregate and consequently there are fewer restrictions on their use in concrete. RCA is not the same as "recovered" concrete aggregates, which are obtained by washing the cement paste out of fresh concrete and returning the aggregate to the aggregate stockpile. However, it does include aggregates obtained from surplus concrete that has been allowed to harden before crushing.

2. CONSTRUCTION AND DEMOLITION WASTE AS RECYCLED AGGREGATES

2.1 Construction and demolition waste

The threat of contamination in the C&DW (Fig.1) is one of the biggest barriers to its use in construction products. The perception is that C&DW will be difficult to process, will contain some contamination that will affect the handling and properties of the end product and will always be considered inferior to virgin materials. The presence of other construction waste materials that may contaminate the hard C&DW fraction is common. These contaminants include both organic and inorganic materials, such as wood, bitumen, glass and metal. This contamination in C&DW needs to be removed during processing. Alternatively if a proportion of contamination is to be allowed in the manufacture of new concrete then the way it will affect the strength, bonding and lifetime of the product must be assessed. Once the C&DW has been crushed, sieved and if necessary decontaminated it can find applications as general bulk fill in drainage project, sub-base material in road construction or aggregate for new concrete.

The economic case for using C&DW to replace virgin aggregates will be affected by the technical findings of the on-going laboratory research. Other factors that will affect the economic viability of using C&DW in the manufacturing process include:

- the price of the finished concrete – the market suggests it needs to be cheaper than a conventional concrete manufactured with virgin aggregates. This is necessary to surmount "conservatism" by the marketplace
- positive financial factors such as Landfill tax and Aggregates that will be avoided by using C&DW to manufacture a product
- negative financial factors, such as transportation costs, the requirements of legislation, the need for demolition contractors to invest in new equipment and the additional processing costs which may arise from variations in the raw material that increase maintenance costs, downtime, processing cost due to more product line change, etc;

Other important factors that may be positive or negative include: Maintaining market confidence, maintaining market share and shareholder and client pressure.

Recycling waste	Year					
	2000	2001	2002	2003	2004	2005
Brick	589,4	990,0	1808,9	1391,6	1664,3	1711,3
Concrete	384,6	614,8	1013,9	1254,6	994,0	1233,4
Asphalt	317,9	323,9	475,2	516,4	514,2	597,6
Mixed Building Waste	79,0	3,9	0,6	59,0	130,6	122,2
Aggregates	704,0	513,3	464,2	913,4	718,5	596,2
Soil	261,0	275,7	339,4	452,1	432,3	298,2
Other	249,6	417,5	300,7	261,4	309,1	134,2
∑	2585,4	3139,0	4002,6	4848,5	4770,5	4865,4

Fig. 1 Construction and Demolition Waste Processed in Recycling Line in CR
(The amount in thousand of tones)

2.2 Recycled aggregates

Since there are many unsolved problems encountered in controlling the quality of recycled aggregates (RA), which include low compressive strength, wide variability of quality, high drying shrinkage, large creep and low elastic modulus, applications of are hampered. These problems are mainly resulted from the following two reasons:

- construction and demolition waste materials are always contaminated with foreign materials (glass, wood, soil, plaster, tile etc.)
- recycled aggregate particles are always attached with substantial amount of relatively soft cement mortar paste, making these aggregates more porous and less resistant to mechanical attacks.

Generally some modifications to the mix proportion are needed in the production of recycled aggregates, which can then be produced with the same production procedure as the conventional concrete does. However, such an approach will produce concrete with poorer quality, depending directly on the proportion of RA added. Hence, most studies recommend a limit of 30% of RA. Many researchers have successfully applied RA on pavement and roadwork or simple structures, underground structures, foundations, piles and mass concrete. However, its application to higher grade concrete is not common. These weaknesses of RA, including high porosity, high amount of cracks, high level of sulphate and chloride contents, high level of impurity and high cement mortar remains, will affect the mechanical performance of RA. The prerequisite in applying RA to high-grade concrete is to overcome these weaknesses. The amount RA which could be recycled will depend mainly on factors such as:

- location of the demolition site and of the manufacturing site
- level of contamination in the C&DW as a result of unsuitable materials used in the original construction or caused by poor segregation during the demolition process
- local demand for the material that varies depending on current development and infrastructure projects

Demolition contractors typically use jaw crushers or impact crusher which will process material more slowly to produce a crushed concrete and masonry of a particle size of 0-8, 8-32, 32-64, >64 mm. Screening after the material has been crushed is necessary to control the particle size of the finished product. The particle size of material required to manufacture new concrete will require demolition contractors to invest in new screens in order to produce the correctly graded material.

The quality of the recycled aggregate is dependent on the quality of the materials that are processed, the selection and separation processing used, and the degree of final processing that these materials undergo. There are two methods of producing recycled aggregates: in situ at the site of the arisings, or off situ in a central plant. Major cost savings can be achieved by in situ production of recycled aggregate, including transport costs and the accrual of the environmental benefits of reducing lorry movements.

2.3 Size distribution

It has been now generally accepted that, recycled aggregates, either fine or coarse, can be obtained by primary and secondary crushing and subsequent removal of impurities. Generally, a series of successive crushers are used, with oversize particles being returned to the respective crusher to achieve desirable grading. The best particle distribution shape is usually achieved by primary crushing and then secondary crushing, but from an economic point of view, a single crushing process is usually most effective. Primary crushing usually reduces the C&D concrete rubble to about 50mm pieces and on the way to the second crusher, electromagnets is used to remove any metal impurities in the material. The second crusher is then used to reduce the material further to a particle size of about 14–20 mm. Care should be taken when crushing brick material because more fines are produced during the crushing process than during the crushing of concrete or primary aggregates.

2.4 Removing contaminants:

Clean concrete cannot always be supplied by a demolition contractor. Concrete rubble often includes contaminants such as admixtures, asphalt, chlorides, cladding, soil and clay balls, glass, gypsum board, hardboard, iron, joint sealants, lightweight brick and concrete, paper, plaster, plastics, rubber, steel enforcements, tile, vinyl, wood, and roofing materials of various kinds. Contaminants are mostly a concern when recycled aggregates are to be used in new concrete. Dust and fines that cling to the large coarse aggregate particles are of little consequence in recycled aggregate concrete, and washing is not required. Bricks arising from demolition may be contaminated with mortar, rendering and plaster, and are often mixed with other materials such as timber and concrete. Separation of the potentially valuable facing bricks will be usually difficult and require hand sorting.

2.5 Properties of the recycled concrete aggregate

Usually replacement of only 10% to 30% virgin sand is used for new concrete. Is approved using 100% recycled coarse aggregate produces acceptable quality concrete. Use of recycled fines, however, in a new mix requires close examination. Recycled fine aggregate is angular, with a high porosity and low specific gravity. Using recycled fines further reduces strength compared with virgin sand, so its use in new concrete mixes should be carefully controlled. Concrete produced with recycled aggregate has lower of the strength of a comparable natural aggregate concrete.

The most marked difference in the physical properties of the recycled concrete aggregate is higher water absorption, lower bulk density, porous and rough surface texture and lower resistance to mechanical action on compare to natural aggregate. Workability of recycled aggregate concrete is lower that that of similar concrete mix with natural aggregate.

3 Conclusions

Use of recycled aggregates in concrete provides a promising solution to the problem of C&D waste management. Results of research show that recycled aggregates can be used in lower end applications of concrete or for making normal structural concrete with the addition of fly-ash, condensed silica fume and now with polypropylene fibres. Greater efforts are needed in the direction of creating awareness, and relevant specifications to clearly demarcate areas where RAC can be safely used. The recycling of this waste will reduce environmental damages caused by incorrect disposal, extend the useful life of landfills and preserve finite natural resources.

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