HONG KONG EXPERIENCE OF USING RECYCLED AGGREGATES FROM CONSTRUCTION AND DEMOLITION MATERIALS IN READY MIX CONCRETE

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Abstract

The construction activities in Hong Kong generate about 14 million tons of construction and demolition (C&D) materials each year. Recycling the C&D materials is one of the measures to reduce the burden on public fill capacities. This paper discusses the latest application experience of using recycled aggregate in construction projects in Hong Kong and recommends a broader scope of use of recycled aggregates in areas other than ready mixed concrete.

1. Introduction

The rapid development of Hong Kong in the last two decades led to the generation of huge volumes of construction and demolition (C&D) materials. In the past, the inert portions of these C&D materials, such as rock, concrete and soil, had been

beneficially reused as fill materials in forming land for Hong Kong's development. However, the increasing opposition to sea reclamation by the general public has rendered most reclamation projects either delayed or much reduced in scale. If these materials have to be disposed of at landfills, it will accelerate the depletion of the already limited precious landfill spaces. Hong Kong is now facing a crisis on how to accommodate these surplus materials. Apart from putting more efforts in minimizing its generation and the setting up of temporary fill banks, recycling is one of the most effective means to alleviate the growing problem [1].

2. Recycling

In mid-July 2002, the Hong Kong SAR government established a pilot C&D materials recycling facility in Tuen Mun to produce recycled aggregates for use in government projects and for research and development works [2]. The plant has a designed handling capacity of 2,400 tonnes per day. The processing procedure for recycled aggregate comprises the following processes: (1) a vibrating feeder/grizzly for sorting the hard portions from the inert C&D materials which are suitable for subsequent recycling; (2) a jaw crusher (primary crusher) for reducing the sorted materials to sizes of 200 mm or smaller which can be handled by the secondary crushers; (3) a magnetic separator, manual picking gallery and air separator for removal of impurities before the materials are fed into the secondary crusher; (4) cone crushers (secondary crusher) for processing the clean materials into sizes smaller than 40 mm; (5) vibratory screens for separating the crushed recycled aggregates into different sizes; and (6) storage compartment for temporary storage for recycled aggregates. The facility is able to produce Grade 200 rockfill and recycled aggregates of various sizes, ranging from 40-, 20-, and 10-mm coarse aggregates to fine aggregates (<5 mm) for different applications.

Due to the varying sources of the incoming materials, a prudent quality control approach has been adopted by the recycling plant. Only suitable materials (e.g., crushed rocks, concrete) are processed at the plant. Brick and tiles are generally not allowed. The produced recycled aggregates are sampled and tested daily. Since production commenced in July 2003, the facility has already produced approximately 240,000 tons of recycled aggregates with consistent high quality that meets the specification requirements.

3. Specifications and Applications

Internationally, the RILEM specification is the most commonly accepted standard for recycled aggregates [3]. But in Hong Kong, due to our limited experience in using recycled aggregates and Hong Kong's different nature of building construction, a more prudent approach has been adopted. After detailed laboratory investigations and plant trials [4], the government has formulated two sets of specifications governing the use of recycled aggregates for concrete production [5].

For lower grade applications, concrete with 100% recycled coarse aggregate is allowed. Recycled fines are not allowed to be used in concrete. The target strength is specified at 20 MPa and the concrete can be used in benches, stools, planter walls, concrete mass walls and other minor concrete structures. The specification requirements for recycled aggregate are listed in Table 1.

Table 1: Specification requirements for recycled aggregate for concrete production in Hong Kong

Requirements	Limit	Test method
Min. dry particle density (kg/m^3)	2000	BS 812: Part 2
Max. water absorption	10%	BS 812: Part 2
Max. content of wood and other material less dense than water	0.5%	Manual sorting in accordance with BRE Digest 43
Max. content of other foreign materials (e.g., metals, plastics, clay lumps, asphalt, glass, tar)	1%	
Max. fines	4%	BS 812: Section 103.1
Max. content of sand (< 4 mm)	5%	BS 812: Section 103.1
Max. sulphate content	1%	BS 812: Part 118
Flakiness index	40%	BS 812: Section 105.1
10% fines value	100 kN	BS 812: Part 111
Grading	Table 3 of BS 882: 1992	
Max. chloride content	Table 7 of BS 882 – 0.05% by mass of chloride ion of combined aggregate	

For higher grade applications (up to C35 concrete), the current specifications allows a maximum of 20% replacement of virgin coarse aggregates by recycled aggregates and the concrete can be used for general concrete applications except in water retaining structures.

As of the end of October 2003, there have been over 10 projects registered to consume over 22,700 m^3 of concrete from Grades 10 to 35 using recycled aggregates. The usage varies from reinforced pile caps, ground slabs, beams and parameter walls, external building and retaining walls, to mass concrete.

4. Case Study: Hong Kong Wetland Park

Hong Kong Wetland Park is located at the north-western part of Hong Kong and is close to the border between Hong Kong and Shenzhen of the Mainland. After completion in 2005, the park will have a 10,000 m^2 visitor center comprising exhibition galleries, AV theatres, souvenir shops, cafes, children play areas, classrooms and a resources center. In the project, recycled aggregate is employed to replace part of the virgin aggregate in the majority of the structural concrete. The highest concrete grade used is C35. The designed slump is 100 mm but in some cases, 75-mm slump concrete is also used. The concreting work of the Phase II project started in April 2003 and up to September 2003, a total volume of about 5,000 m^3 of ready mixed concrete using recycled aggregates has been placed.

Based on the specifications, the replacement levels of recycled coarse aggregate were 100% and 20% for concrete grades C20 (or below) and C25 to C35, respectively. Because of the limited experience in using recycled aggregates in concrete in Hong Kong, at the beginning of the project, the cement contents for the concrete mixes were deliberately increased by around 4% to compensate for the higher initial free water content required by the recycled aggregates so as to maintain a similar water/cement ratio.

The statistical results listed in Table 2 show that the average 28-day cube strength and the standard deviation of recycled aggregate concrete used in the project were about the same as those of ordinary concrete. The similar standard deviations show that the quality of concrete using recycled aggregates can also be controlled to a similar stability as that of ordinary concrete.

Table 2: Statistical results of recycled and natural aggregate concretes

Concrete grade	Slump (mm)	RA (%)	Cement (kg/m^3)	w/c	28-day cube strength (MPa)	S.D. for running 40 samples
C35	100	20	395	0.466	47.3	2.8
C35	100	0	380	0.473	48.2	4.1
C35	75	20	380	0.468	47.1	4.8
C35	75	0	365	0.479	45.8	4.5
C30	75	20	360	0.486	44.7	4.4
C30	75	0	345	0.507	42.1	4.7
C20	75	100	300	0.607	31.4	5.0
C20	75	0	290	0.603	32.8	4.4

In Hong Kong, most concrete batching plants were originally designed and built for concrete production with virgin aggregates only. In order to accommodate the recycled coarse aggregate, additional storage compartments had to be installed with all the necessary feeding and batching accessories. Also, as the water absorption rate of recycled aggregates was much higher than that of virgin aggregates, and to avoid excessive slump loss, the recycled aggregates were required to be pre-wetted both at the stockpiles of the recycling plant and by sprinkling water mist on the recycled aggregates during unloading at the receiving hopper at the batching plant before feeding to the overhead bin. The moisture content in the recycled aggregate was then compensated during the mix design. Chemical admixtures that would facilitate good workability retention were also added. But soft materials such as old cement mortar that were originally adhered to the old aggregates were quite easily broken off during mixing of the concrete which further contributed to the slump loss. The slump of the concrete produced therefore tended to be rather unstable, although the performance could still be controlled within the limits of acceptance. Also, the rate of slump loss was high which meant the workable time of the concrete was also reduced. As such, when recycled aggregates are used in ready mixed concrete production, it is advisable to adopt a higher initial design workability to compensate for the higher anticipated slump loss.

5. Ongoing Research

More research and development work is required to promote the use of recycled aggregates. Continuing research is being conducted by Government, universities and the industry to extend the scope of applications of recycled aggregates in Hong Kong. This includes studies on the production of precast bricks and blocks [6], the influence of the initial moisture states of recycled aggregates on the properties of concrete produced [7], the use of pfa, and the production of C45 recycled aggregate concretes. A recent study at the Hong Kong Polytechnic University aims to study the properties of recycled aggregate concrete prepared under a steam curing regime. Preliminary results indicate that compared with concretes cured under normal water temperature, steam curing increased the early strengths but reduced the long-term strengths for all normal and recycled aggregate concretes. But the detrimental effect of using steam curing on the 28-day strength decreased with increase in recycled aggregate contents. Furthermore, the drying shrinkage and creep of the steam cured recycled aggregate concrete were less than that of the normal cured counterparts. This result suggests that one of the most practical ways to utilize a high percentage recycled aggregate in structural concrete is in precast concrete products produced with an initial steam curing regime after casting.

6. Conclusion

Hong Kong is running out of both reclamation sites and landfill space for the disposal of construction & demolition materials/waste. It is important for Hong Kong to adopt a strategy to reduce and recycle C&D materials/waste and handle it in a more environmentally responsible way. Recycled aggregates have been demonstrated to be able to produce quality concrete for structural applications. More research and

development is needed to further promote the recycling concept and widen the scope of applications of recycled aggregates.

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