ALLOCATION SOLUTIONS FOR RECYCLED MUNICIPALWASTE AGGREGATES

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Abstract

Municipal waste presents major environmental and public health concerns. The disposal of municipalwaste has become a major worldwide environmental problem. Landfill sites are considered as environmentally questionable option and their capacity are decreasing rapidly. Nowadays, various processes have emerged to recycle the waste as synthetic fuel gas, heat source, polymers, fertilizers, and particulate solid residues. In this study, the possibility of recycling these particulate solids as aggregate in concrete was considered. The physical properties and size distribution of recycled aggregates were measured along with the effect of using these recycled aggregate on the compressivestrength of concrete. The resulting outcomes of these tests were compared with concrete sample prepared with conventional crushed stone as coarse aggregate and natural sand as fine aggregate materials. No doubt, recycled aggregates can be used as a replacement of natural course and fine aggregates, but there is need for further investigations about its effect on the concrete properties.

Keywords: Waste Management, Aggregates, Compressive Strength

Introduction

Municipal waste has been produced since the beginning of civilization and was conveniently and unobtrusively disposed of in large open land spaces, as the density of the population was low. Today, with increasing population, the disposal problems become more difficult, due to greater production of waste per unit area and decreased proportion of land availability for its disposal. Although regulations have evolved over the years at different levels of the government to solve solid waste management issues, recycling efforts have being encouraged.

Proper sorting of municipal waste is essential in promoting effective recycling. Still different types of waste are mixed, thus, the recyclability of the waste becomes tough, and affects the recyclability of end-of-use. The recycling plant considered in this study was able to recycle the municipal waste as synthetic fuel gas, heat source, polymers, fertilizers, metals, and particulate solid residues. The plant was facing an issue with the disposal of the solid residues and preserves the value of recyclable materials, as it was able to salvage the others. This paper presents research that focuses on the reusability of the particulate solid residues as combined coarse and fine aggregates in concrete production.

Moreover, quarries used to extract crushed stone and natural sand for concrete production are serious environmental issues. As coarse and fine aggregates used in concrete mix are normally occupying 60% to 70% of the total volume of the concrete (Portland Cement Association). Hence, replacement of natural aggregates by recycled aggregates is an important and valuable environmental asset; it reduces the overall waste flows of the municipal recycling plant and prevents the destruction of green forest.

Materials

The cements used in this study for the concrete mixture is PA-L 42.5, which conforms with EN 197 European norms CEM II /A-L and to Lebanese standards LIBNOR. Two types of aggregates were selected in this study: the first was natural coarse and fine aggregates, and the second type was recycled aggregates obtained from a municipal waste recycling plant.

Experimental Investigation

Different materials differ significantly in their physical properties. Information about these properties is desirable in deciding which material is most suitable for a particular use in order to be able to predict the compressive strength behavior of the material. The key factors affecting compressive strength are the recycled aggregates used (López-Gayarre 2009, González-Fonteboa 2005), the aggregate water absorption capacity (López-Gayarre 2009, Yang 2008, Etxeberria 2007, Tabsh 2009), and the aggregate specific gravity (De Brito 2009).

The Specific Gravity and Absorption Test

The specific gravity of an aggregate is defined as the mass of the aggregate in air divided by the mass of an equal volume of water. The specific gravity for recycled aggregate was measured by using a simple density bottle test technique (Pyknometer), using procedures set out in ASTM Standards (ASTM C127 2002). The concept of this test is to calculate the volume of a known mass of substance immersed in a known density liquid (water). The resulting data of this test are presented in the table 1.

Absorption is when a solid absorbs a mass of liquid. This mass transfer takes place at the interface between the solid and the liquid, at a rate depending on both the solid and the liquid. Water absorption can be measured by a number of methods. In this study, procedures set out in ASTM Standards (ASTM C127 2002, ASTM C128 2002) were used for measuring the water absorption of the recycled aggregates. The absorption values resulted from the test are presented in table 1.

Table 1. Properties of coarse natural and recycled aggregates considered

Aggregate	Source	Specific Gravity	Absorption %
Fine	Natural sand	2.61	0.9
Coarse	Crushed stone	2.6	1.6
Recycled	Municipal waste	2.2	6.36

Referring to table 1, from the specific gravity (SG) results, it is well clear that the recycling aggregate is15% lighter than natural aggregate. American Concrete Institute (ACI E1-07) classifies aggregate with Specific Gravity (SG) equal to 2.3 as normal weight aggregate and less than1.85 as lightweight aggregate. Following this, mixing concrete with the recycled municipal waste aggregate used in the investigation (SG=2.2), will produce moderate structural light weight concrete. This is a good indicator, especially when the studied recycled aggregate is applied to concrete structures, as it will result in 15% less in structure total weight, which also considered as moderate-strength lightweight concrete, and certainly it would result in large saving cost in the structural elements sizes and reinforcement.

As for absorption tests, table 1 shows that the absorption of the tested recycled aggregates is 6.36%, which is greater than that of normal aggregate (0.5% to 4%), but it stills within the range of light weight aggregate (5% to 20%) as recommended in ACI code (ACI E1-07). In particular, the lightweight aggregates can absorb more water than normal weight aggregates due to their cellular structure. This means that lightweight aggregates usually absorb more water when placed in a concrete mixture, and this must be taken into consideration in proportioning lightweight concrete.

Particle Size Distribution

Size distributions or grading of concrete aggregates affect seriously the workability, shrinkage, and durability of the resulted concrete (ACI 211.1-03 1991). Therefore, the particle size distribution of the investigated aggregates must be determined, and be compared with the standards grading limits of concrete aggregates.

Size distributions of the recycled aggregates samples were determined by sieving the samples in ascending order of aperture size, using procedures set out in ASTM Standards (ASTM C33 2002, ASTM C136 2002). The stack was vibrated for a time of 10 minutes using a machine with a gyratory and jolting action. The results of the sieve analysis are presented in table 2.

Table 2: Size distributions of the recycled aggregates samples

Sieve Number	**3/8**	**N4**	**N8**	**N16**	**N30**	**N50**	**N100**	**Pan**
Sieve size (mm)	**9.5**	**4.75**	**2.36**	**1.18**	**0.6**	**0.3**	**0.15**	
Weight retained (g)	79.6	306.2	430.6	145.7	33.7	7.2	1	0.5
% retained	8	38	81	96	99	100	100	100
% passing	92.08	61.59	18.73	4.22	0.87	0.15	0.05	0

The resulting sieve analysis data of recycled aggregates presented in table2, show clearly that 80% of the recycled aggregates can be classified in the range of coarse aggregate, refer to the size number 89 from the ASTM (ASTM C33 2002) for grading requirements of coarse aggregate. Also, 20% of the recycled aggregates in the sieves range of fine aggregates. Therefore, all the volume of normal coarse aggregate will be replaced by recycled ones, where part of the fine aggregates volume will be replaced by fine aggregates (about 35% of the fine aggregates absolute volume). Accordingly, two mix proportions were prepared to investigate the effect of using recycled aggregates in concrete mix on its compressive strength. In addition, the fineness modulus of the combined fine aggregates increased from 2.44 for normal fine aggregate to 2.95 for the combined ones; in fact, the combined fine aggregate will improve the performance of concrete in its fresh and hard stages.

Compression Test

Several studies (González-Fonteboa 2005, Yang 2008, Etxeberria 2007) have shown that up to 30% replacement of recycled aggregates ratios do not significantly affect compressive strength of a concrete mix, as long as the cement amount and the effective water/cement ratio (w/c) are kept the same. On the contrary, such an effect is important when the replacement ratio accounts for 50% or more of the total (Etxeberria 2007).

A comparative study on the effect of using recycled aggregates on the compressive strength of concrete mix was investigated. The compressive strength test was performed according to ASTM (ASTM C39 2002). The absolute volume method was used in the concrete mix design to calculate the weights of mixture proportions (ACI 211.1-03 1991). The compressive strength tests were conducted on both concrete mix and concrete bricks.

Two mix designs were prepared for the compressive strength tests of concrete mix as shown in Table 3. The w/c used in kept the same for both concrete samples; also 74% of the conventional aggregate absolute volume has been replaced by recycled aggregate.

Table 3: Mix compositions of both concrete samples used in this study

	Cement (g)	Water (g)	W/C	Natural sand (g)	Natural crushed stone (g)	Recycled aggregate (g)
Concrete mix with conventional aggregate	300	150	0.5	783	1150	0
Concrete mix with recycled aggregate	300	150	0.5	494	0	1215

Table 4 presents the resulting data of the comparative study on the effect of usage recycle aggregates in concrete mix on the compressive strength. Tests of compressive strength after 28 days yielded the results. Each average value is calculated with the results from three specimens. The compression test shows that replacing 74% of aggregate in the concrete with recycled ones resulted approximately the same concrete compressive strength even that its weight is lighter about 5%.

Table 4: Values of the compressive strength at 28 days

Size (cm^3)	Average Weight (g)	Average Strength (MPa)
Concrete mixed with natural aggregates		
10x10x10	2294	226.33
Concrete mixed with recycled aggregates		
10x10x10	2177.6	224.4

Two other mix designs were prepared for the compressive strength tests of concrete brick as shown in Table 5. The w/c used in kept the same for both concrete samples; also 100% of the conventional aggregate absolute volume has been replaced by recycled aggregate.

Table 5: Mix compositions of both concrete samples used in this study

	Cement (kg)	Water (kg)	W/C	Natural crushed stone (kg)	Natural Coarse aggregate (kg)	Recycled aggregate (kg)
Concrete brick with conventional aggregate	50	20	0.4	133	267	0
Concrete brick with recycled aggregate	50	20	0.4	0	0	350

Table 6 presents the resulting data of the comparative study on the effect of usage recycle aggregates in concrete brick on the compressive strength. Tests of compressive strength after 28 days yielded the results. Each average value is calculated with the results from three specimens. The compression test shows that replacing 100% of aggregate in the concrete with recycled ones resulted approximately the same concrete compressive strength and almost the same weight.

Table 6: Values of the compressive strength at 28 days

Size (cm^3)	Average Weight (g)	Average Strength (MPa)
Concrete bricks with natural aggregates		
15x15x15	6560	150
Concrete bricks with recycled aggregates		
15x15x15	6410	143

Conclusion

Environmental issues such as limited availability of landfills and destroying natural habitats (by land filling and excavating quarries), have emerged as major challenges that need to be addressed in terms of national policy. The work presented here represents the first of its kind in published literature in relating the municipal recycled materials to the concrete industries.

The need for this study is an obvious one from the environment and industrial perspective. The present paper is a probing attempt to illustrate that it is possible to replace natural aggregates by municipal recycled materials, that result in little apparent change in compressive strength of concrete mix, and been important and valuable environmental asset.

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