Influence of Recycled Aggregates on Mechanical Properties of High Performance Concrete

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Student Paper Abstract

The use of reclaimed concrete as aggregate for new concrete and its influence on the mechanical properties has been investigated. The replacement of both fine and coarse aggregate was tested. Three different mixes were prepared, the first mix, or control mix, was prepared with natural aggregate, two additional mixes were prepared with different percentage of substitution of coarse aggregates. Weight evolution of the concrete as a function of age was measured on 2"x2"x2" concrete cubes subjected to different relative humidity conditions. Compressive strength was evaluated on concrete cylinders (4" x 8") at different ages: 3, 7, 14, 21 and 28 days. Porosity of different mixes with the same water to cement ratio is compared. The same procedure of testing was used with reclaimed concrete from existing structures (demolition products) and with concrete from laboratory testing. An analysis comparing physical and mechanical properties of the three mixes is presented.

Key Words

Student Paper, Technology, Construction Management and Engineering Technology

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1. Introduction

The Environment Protection Agency (EPA) has estimated that during 1996 the United States produced an estimated 136 millions tons of construction and demolition debris, not including debris from roads, bridges and land-cleaning materials [1]. Preservation of the environment and sustainability development have become of paramount importance in the construction industry. The use of recycled concrete obtained from demolition of existing structures in the manufacturing of new concrete contributes to this end by reducing the amount of natural resources extracted, reducing transportation, reducing the need to dispose of the debris and rubble product of demolitions and conserving space in existing landfills [2-5]. Other aspect to consider is the possible financial savings due to cost associated with dumping fees and transportation.

Recycled concrete has been primarily used in road construction; however it has been found also in the construction of noise barriers and embankments, general bulk fills, base/fill for drainage structures, soil-cement pavement bases, bituminous concrete, etc. According to the Federal Highway Administration (FHA), 38 states recycle concrete as a base material for road construction, while 11 states recycle concrete to be used in the production of new Portland cement concrete [6]. The recycling process of concrete involves crushing, removing and separation into various sizes and bulks. Reclaimed aggregate may be designated according to its origin and its quality; for example, Type 1 consists of primarily masonry rubble, Type 2 consists of concrete rubble and type 3 is usually a blend of materials.

The crushing process affects the characteristics of the resulting aggregates. It has been found that fine recycled aggregates obtained from recycling concrete are more angular and have higher absorption and specific gravity than natural fine aggregates. This angularity has been observed also in coarse aggregates and may result on either, an

increase of compressive strength and improved load carrying capacity, or on the weakening of the transition zone around the aggregate depending on the level and type of angularity. On the other hand, impurities present in the recycled material may cause expansion problems which can result in the formation of cracks. During recycling operations washing of the material may be required to remove or reduce the presence of 'tufa' (porous limestone-like material form from calcium carbonate).

It is thought that the characteristics of the reclaimed concrete aggregate should resemble those of the natural aggregates to ensure similar properties. However, it is known that the absorptive behavior of recycled concrete aggregate is higher than that of natural aggregates, affecting the mix design.

The investigation of the mechanical properties of recycled aggregate concrete is necessary to determine the feasibility of use as well as the impact on durability of structures. There have been an increasing number of studies on the influence of recycled concrete aggregate as partial or total replacement of natural aggregates and its effect on the mechanical properties and durability of the recycled aggregate concrete [2-11]. In general, the properties of ordinary Portland cement concrete (OPC) depend on the characteristics and quality of its components; this is true also for recycled aggregate concrete. Due to the wide variety and quality of recycled aggregate available properties of local materials must be investigated to determine the effect the quality and amount of recycled material used have on the mechanical properties of concrete.

This study investigated the use of reclaimed concrete as aggregate and its influence on the compressive strength of new concrete. The replacement of both fine and coarse aggregate was tested. Three different mixes were prepared, the first mix, or control mix, was prepared with natural aggregate, two additional mixes were prepared with the same proportions as the control mix but with different percentage of substitution of recycled aggregates obtained from demolition of existing structures. Porosity of different mixes with the same water to cement ratio is compared. Additionally, this project is currently on its second phase, where the use of concrete from laboratory testing, the weight evolution of the concrete as a function of age measured on 2"x2"x2" concrete cubes subjected to different relative humidity conditions, and the effect of blended

cement and pozzolans are being evaluated. An analysis comparing physical and mechanical properties of the three mixes is presented.

2. Methodology

Three mixes were prepared in the lab. A control mix containing natural aggregates was used as control mix. Two additional mixes were prepared to test the effect of substitution of natural aggregate by recycled concrete aggregate on the compressive strength of the material. Table 1 shows the mix proportion for the three mixes.

Table 1. Mix Proportion for Testing

Material	Mix Proportions		
	Mix 1 (control)	Mix 2	Mix 3
Natural Coarse Aggregate	138.4 kg	110.72	96.52
Recycled Concrete Coarse Aggregate	0	27.68	41.52
Natural Fine Aggregate	80.7 kg	72.63	64.56
Recycled Concrete Fine Aggregate	0	8.07	16.14
Portland Cement Type I	71.5 kg	71.5 kg	71.5 kg
Water	25 kg	25 kg	25 kg
Plasticizer	500 cc	500 cc	500 cc
Air entrainment	75 cc	75 cc	75 cc

Characterization of the aggregates, mixing and preparation of concrete, slump tests, compressive strength testing, and porosity testing were performed following ASTM standards [ref]. A water-to-cement ratio of 0.35 was used in all mixes.

Three 4” x 8” cylindrical specimens were tested for compressive strength for each mix at 3, 7, 14, 21 and 28 days. Additionally, 3’x 6” cylindrical specimens were prepared to determine the porosity of the hardened concrete. Porosity tests were performed at age 28 days. All cylinders were cured by submersion in water.

3. Results

Table 2 shows the physical characteristics of the natural and recycled aggregates including the apparent and bulk specific gravities and the absorption capacity of coarse and fine aggregates. Figure 1 shows the particle size distribution (PSD) curves for all

aggregates. Figure 2 shows the evolution of compressive strength for all mixes tested at different ages. Figure 3 shows results of the porosity tests performed on triplicate specimens according to ASTM standards C-642 [ref].

Table 2. Physical characteristics of Aggregates.

Characteristic	Aggregate Type			
	Natural Coarse	Recycled Coarse	Natural Fine	Recycled Fine
Apparent Specific Gravity	2.69	3.17	2.69	2.93
Bulk Specific Gravity	2.28	3.15	2.66	2.85
Absorption (%)	0.96	9.17	1.07	5.57

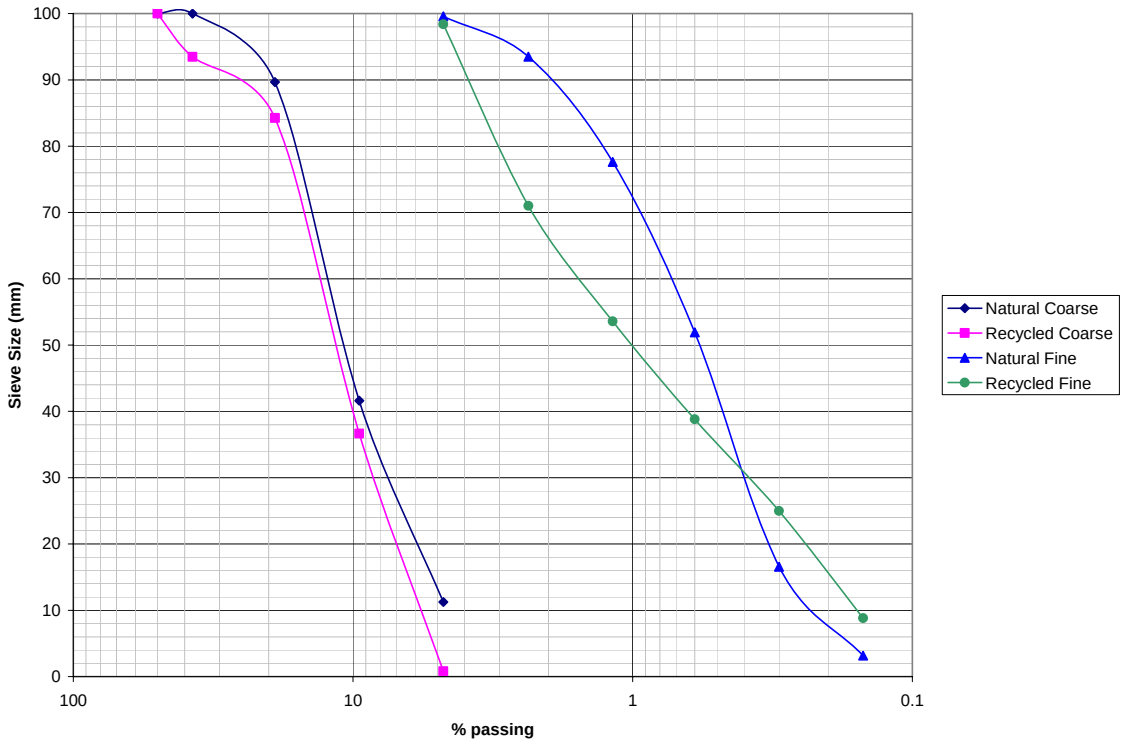

Figure 1. Particle size distribution for coarse and fine aggregates.

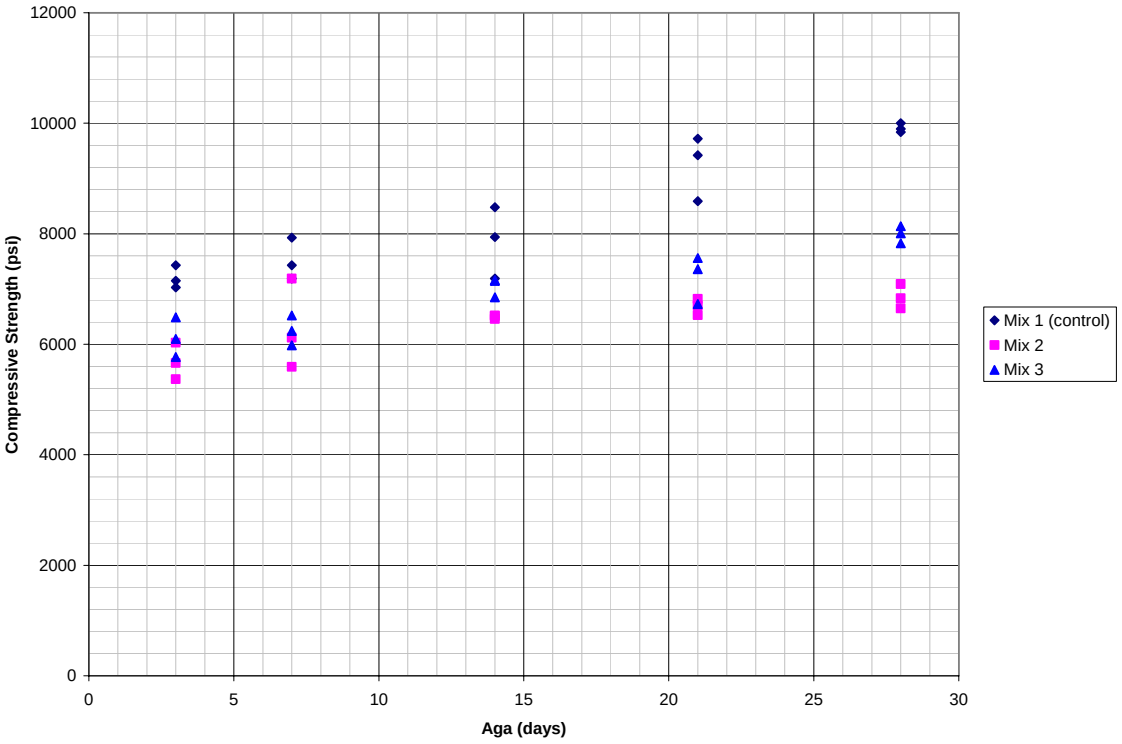

Figure 2. Compressive Strength versus Age – all concrete mixes.

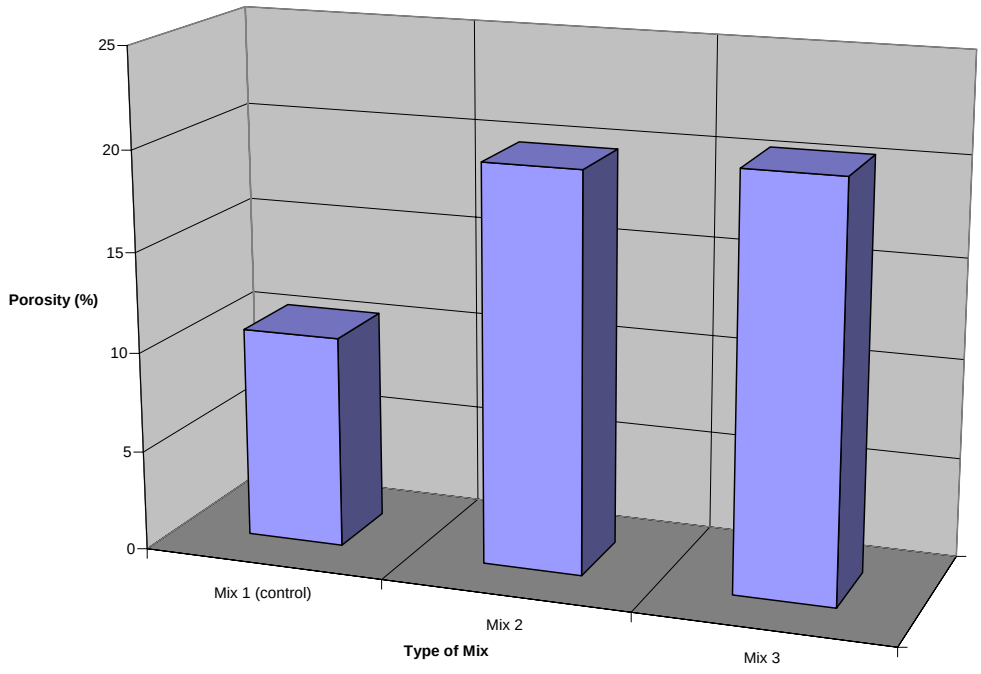

Figure 3. Porosity of concrete mixes.

4. Discussion

Test of the fresh concrete mixes show a decrease of the slump with respect to the control mix. Due to the use of a superplasticizer the control mixes showed a slump of 8 inches, while mixes 2 and 3 showed slumps of 4 and 2 inches respectively. The reduction in slump, as is known, is an indication of the increased amount of energy that would be required to cast the concretes. It is believed that this reduction in slump is due to the higher absorption capacity of the recycled aggregates.

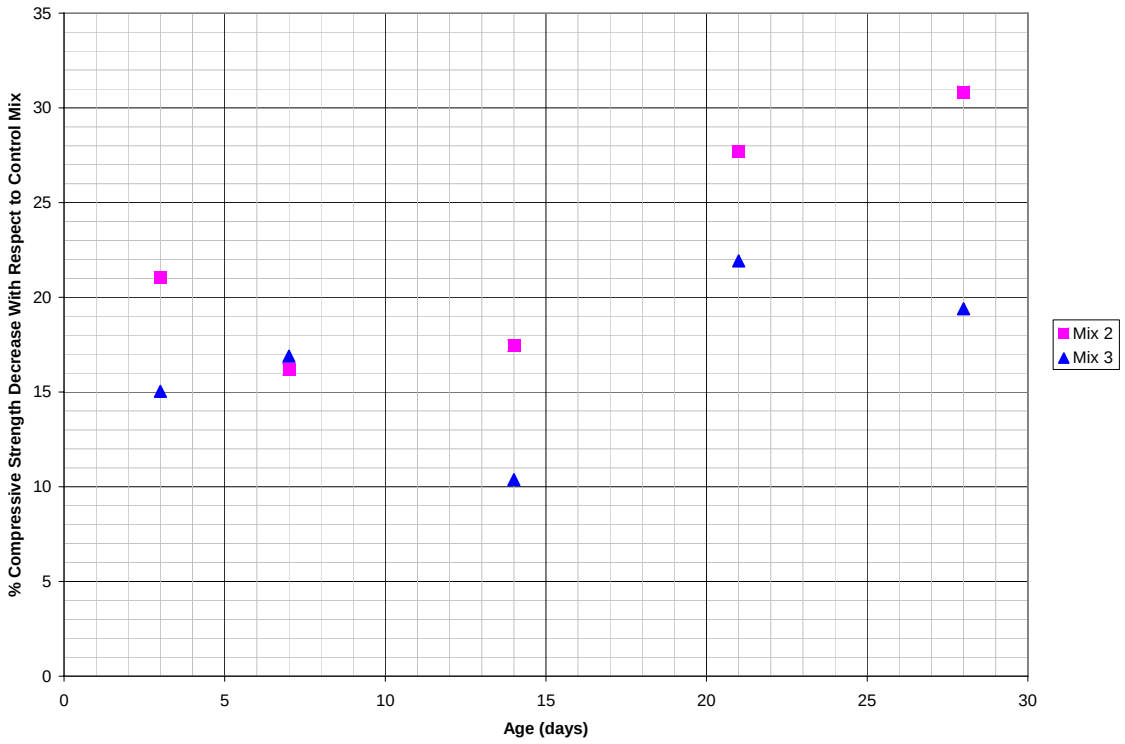

Figure 4. Percentage decrease of compressive strength with respect to control mix for all ages.

For each of the three mixes prepared triplicate specimens were tested for compressive strength. Results of these tests are shown in figure 2 were it can be observed that the results for each mix at each age were consistent showing low scattering. The two mixes containing recycled aggregate show a decrease in the compressive strength with respect to the control mix. Figure 4 show the percentage average decrease of compressive strength for each mix at different ages. The percentages shown in figure 4 do not seem to show a pattern that could lead to any conclusion regarding the evolution of compressive strength loss. In general, the loss of compressive strength may be due to the quality of the

recycled aggregate, since although the recycled aggregate was obtained from demolition of concrete without the presence of masonry or other materials, the demolition and crushing process itself may introduce microcracks in the recycle aggregate particles. Upon visual inspection of the cylinders tested, it was noted that the failure of the cylinders tend to be of the columnar type with the plane of failure going mostly through the recycled aggregate and around the natural aggregate. Based on the slump and compressive strength tests it can be said that strength development of concrete mixes containing recycled aggregate require adjustment of the water content.

5. Conclusions

In general, replacement of natural aggregates by recycled concrete aggregate shows comparable results with respect to compressive strength, however, further studies to determine the effect on durability and improvement on workability are necessary. As it was mentioned before, these results comprise only the first phase of a broader study when the absorption capacity of the concrete, the diffusion of chlorides and oxygen and the permeability characteristics of concrete containing recycled concrete aggregate and the effect of pozzolans and blended cement is currently being studied.

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