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A study on treated recycled coarse aggregate to achieve different concrete target strength

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Abstract: The recycled aggregate prepared from the crushing of old concrete was studied. It was found that the recycled aggregate is covered with loose particles that may prevent good bonding between the new cement matrix and the recycled aggregate. The old cement paste that remained on the natural aggregate was porous and cracked, leading to weak mechanical properties of the recycled aggregate. In the present study, the recycled aggregate made from old concrete and treatment to improve material properties of the recycled aggregate by impregnation of ordinary Portland cement solution will be applied with the objective of overcoming the above-mentioned limitations. Previous experiment has shown that maximum strength of concrete is achieved at FM 1.23 for target strength 3000 psi. After experiment we can found that, the mechanical properties of recycled aggregate has been increased after treatment and an increase of 21.26% and 14% in the compressive strength at ages 7 and 28 days was observed after the OPC treatment for 3000 Psi concrete and an increase of 18.52% and 12.7% in the compressive strength at ages 7 and 28 days was observed after the OPC treatment for 4000 Psi concrete.

Keywords: *Treated recycled coarse aggregate, fine aggregate of FM 1.23, Physical properties of aggregate, Concrete, Compressive Strength.*

Introduction:

Concrete has been proved to be a leading construction material for more than a century. A report presented in 1999 to the European Commission estimated the amount of non-recycled construction waste to be 130 million t / year. The area required for landfilling this amount of waste is equivalent to the accumulation of waste, 1.3 m high, over the entire central Paris area (Symonds, 1999). When a sample from material discharged by a civil construction site is analyzed, it can be ascertained that, even with its heterogeneity, almost all of the substances in its composition are high valued and have good mechanical resistance, such as: sands, brittle stones, concretes and hardened mortars, bricks and ceramic fragments, woods and many others. All of them are potential raw materials. Therefore, civil construction waste can be real raw material deposits that could be explored. As such, means for reutilizing recycled discharged materials can be employment in pavement works, adjustment and grovel covering on soil streets, drainage works, mortar ballast execution and concrete production (B. Filho et al., 1999). It appears that recycling construction waste is vital both in order to reduce the amount of open land needed for landfilling and to reduce depletion of raw materials. At the same time, large quantities of natural aggregates are extracted for construction every year leading to the large scale depletion of natural aggregate and the increased amounts of C&DW. The construction and demolition waste are primarily used for landfill sites which are causing significant damage to the environment and developing serious problems. The use of the recycled aggregates created from processing of construction and demolition waste in new construction has become more important over the last two decades as it conserve the non-renewable natural resource of virgin aggregates.

Several methods to improve the properties of new concrete made from recycled aggregate were reported in the literature. Sri Ravindrarajah and Tam improved the properties of new concrete by altering the water/cement ratio, adding pozzolans, and blending recycled and natural aggregates (S. Ravindrarajah & Tam,1988).These techniques, however, refer to general concrete technology and not to the improvement of the recycled aggregate itself. Montgomery treated the aggregate with a ball mill in order to remove old cement paste from natural stone. He found that the cleaner the aggregate was, the stronger was the concrete (Montgomery,1998). Winkler and Mueller milled recycled fines and used them as a cement replacement (Winkler and Mueller, 1998).A reduction of 17% in the compressive strength of the concrete, at a replacement ratio of 33%, is reported by Montgomery. Compared to natural aggregate concrete the compressive strength of recycled aggregate was decreased by 18.76%. The recycled aggragate treated with water has increased 4.93%, nitric acid by 11.88%, sulphuric acid increased by 5.38% and hydrochloric acid increased by 7.17% than the recycled aggregate (G. Murali et al.). With a view to the above needs, aims of present study are treatment to improve material properties of the recycled aggregate (by impregnation of ordinary Portland cement solution),to improve the properties of new concrete made from recycled aggregate, to achieve the different target strength of recycled coarse aggregate and OPC coated recycled coarse aggregate using fine aggregate of FM 1.23,To compare percentage increase in 3000 psi and 4000 psi, to compare the strength of concrete of two types(3000 psi and 4000 psi).

Materials and Methods:

The Ordinary Portland Cement conforming was used for the preparation of test specimens. The natural fine aggregate (NFA) used throughout the study was natural river sand. The FM, specific gravity, water absorption and moisture content of sand used in this investigation were 1.23, 2.53, 3.94% and 2.31% respectively. On the other hand, Three different coarse aggregate were used for this investigation viz, natural coarse aggregate (NCA), recycled coarse aggregate (RCA), treated recycled coarse aggregate (TRCA). The natural coarse aggregate (NCA) was crushed granite angular aggregate. In this study, recycled coarse aggregate were collected as broken cylindrical specimen of compressive strength 3000 psi from strength of materials laboratory, Civil Engineering Department, CUET, and crushed into coarse aggregates manually, which are defined as recycled coarse aggregate. The recycled aggregates was washed and sieved by hand. After breaking into pieces, the aggregates were mixed as 5% from 25 mm to 20 mm, 57.5% from 20 mm to 10 mm, and 37.5% from 10 mm to 5 mm as per ASTM C33-93. The aggregates were tested for absorption capacity, specific gravity, unit weight, and abrasion. The specific gravity and absorption capacity are determined as per ASTM C128, unit weight as per ASTM C29, and abrasion value as per ASTM C131.

Treatments to Improve the Recycled Aggregate: Two effects seem to have a detrimental effect on the quality of the recycled aggregates (apart from the water/cement ratio of the old cement matrix). These are (1) coating of aggregates with loose particles, which damages the bond between the new cement matrix and the recycled aggregate and (2) cracking of the old cement matrix, which decreases the mechanical strength of the recycled aggregate. The method was proposed to improve the quality of the recycled aggregates by impregnation with a solution of Ordinary Portland Cement that is intended to add a thin layer of Ordinary Portland Cement particles over the surface of the recycled aggregate. A solution of 10 L of water and 1 kg Ordinary Portland Cement was prepared by mixing small batches of solution in a mixer, super plasticizer (1% weight of Ordinary Portland Cement) was added to ensure proper dispersion of the Ordinary Portland Cement. The Recycled aggregate was dried, and soaked in the Ordinary Portland Cement solution for 12 h. Weight measurements were taken before the Ordinary Portland Cement treatment. The saturated aggregate was then dried to ensure proper penetration of the Ordinary Portland Cement particles into the surface of the aggregate and weighted again after drying.

The amount of Ordinary Portland Cement impregnated into the surface of the Recycled aggregate can be estimated at 1–1.5% of the aggregate weight based on the weight gain after it was taken out of the Ordinary Portland Cement solution.

Figure-1 presents the images of the recycled aggregate surface before and after the Ordinary Portland Cement impregnation respectively. After impregnation, the surface is covered with a layer of Ordinary Portland Cement particles and some crumbs are still seen, though in smaller quantities.

***Figure 1**: Recycled Aggregate and Treated Recycled Aggregate.*

***Table-1**: Property of recycled coarse aggregate and treated recycled coarse aggregate.*

Name of the Tests	Recycled Aggregate	Treated Recycled Aggregate
Los Angeles abrasion test	30.31%	27.50%
Aggregate Impact value test	17.4%	15.2%
Specific Gravity test	2.365	2.495
Absorption Capacity test	5.92%	4.825%
Unit Weight	1350 kg/m^3	1387 kg/m^3

Cylinders of diameter 150 mm and 300 mm height were prepared using the standard moulds. The concrete mix is designed as per ACI mix design for the normal concrete. The grade of concrete which we adopted was 3000 psi with water cement ratio of 0.68 and 4000 psi with water cement ratio 0.57. The samples are casted using the three different aggregate. Total mixing time of concrete was controlled at 5.5 minutes. After mixing concrete, the workability of concrete was measured by slump cone test. Cylinders are demoulded after 24 hours from casting and kept in a water tank continuously. The compressive strength of concrete was measured at 28 days by using Universal Testing Machine (UTM). The strain of concrete specimens was measured by a strain measurement setup with two dial gauges. The gauge length was 100 mm.

Results:
The results indicate an improvement in the properties of recycled aggregate after treatment. The treatment effect was more significant at an early age.

Table 2: *Compressive strength of Recycled coarse aggregate concrete (RCAC) with FM 1.23.*

Cylinder No.	Target Strength	Curing Days	Mix ratio	W/C ratio	Strength (Psi)	Average (Psi)
C1	3000	7	1: 2.26 : 3.95 : 0.86	0.68	1785	1761
C2					1737	
C3					1832	
C4					1690	
C6	3000	28	1: 2.26: 3.95 : 0.86	0.68	2495	2438
C7					2495	
C8					2400	
C9					2305	
C10					2495	
C11	4000	7	1: 1.77 : 3.31 : 0.72	0.57	2401	2315
C12					2258	
C13					2353	
C14					2306	
C15					2258	
C16	4000	28	1: 1.77 : 3.31 : 0.72	0.57	3206	3266
C17					3206	
C18					3491	
C19					3159	

Table 3: *Compressive strength of Treated Recycled coarse aggregate concrete (TRCAC) with FM 1.23.*

Cylinder No.	Target Strength	Curing Days	Mix ratio	W/C ratio	Strength (Psi)	Average (Psi)
C21	3000	7	1: 2.35 : 4.01 : 0.86	0.68	2211	2135
C22					2069	
C23					2164	
C24					2116	
C25					2116	
C26					2827	
C27	3000	28	1: 2.35 : 4.01 : 0.86	0.68	2732	2780
C28					2827	
C29					2780	
C30					2732	
C31	4000	7	1: 1.841 : 3.364 : 0.721	0.57	2685	2744
C32					2780	
C33					2732	
C34					2780	
C36	4000	28	1: 1.841 : 3.364 : 0.721	0.57	3728	3680
C37					3680	
C38					3633	
C39					3775	
C40					3585	

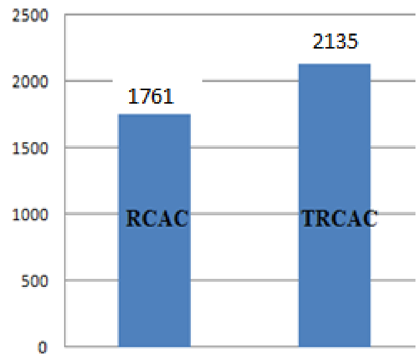

Figure 2*: Comparison of compressive strength at 4000 Psi in 7 days (increase 18.52%).*

Cost Analysis:
Price according to the Bangladesh Market (2014):
Cement = 450.00 TK Per bag (50 kg)
Sand = 1050.00 TK per m^3
Fresh stone chip = 4200.00 TK per m^3
Recycled coarse chip = 1150.00 TK per m^3

Table 4*: Cost per Cubic meter (In taka) of plain concrete.*

Materials	Price (TK) (Fresh coarse aggregate)	Price (TK) (Recycled coarse aggregate)
Coarse aggregate	3600.00	990.00*
Sand	450.00	450.00
Cement (OPC)	2893.00	2893.00
Total	6943.00	4333.00

*Manually broken & transportation cost. If we use recycled stone chips, safe 38% cost than use of fress stone chips.

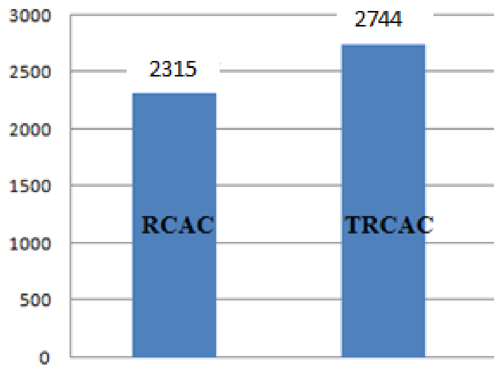

***Figure 3**: Comparison of compressive strength at 3000 Psi in 7 days (increase 21.26%).*

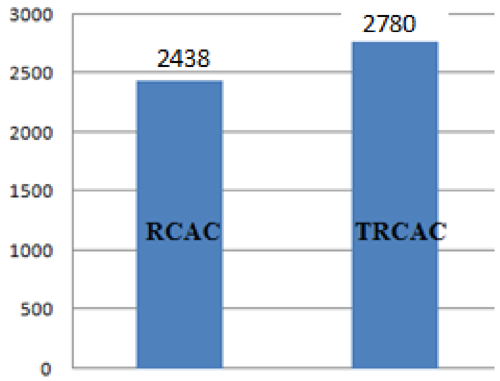

***Figure 4**: Comparison of compressive strength at 4000 Psi in 28 days (increase 12.69%).*

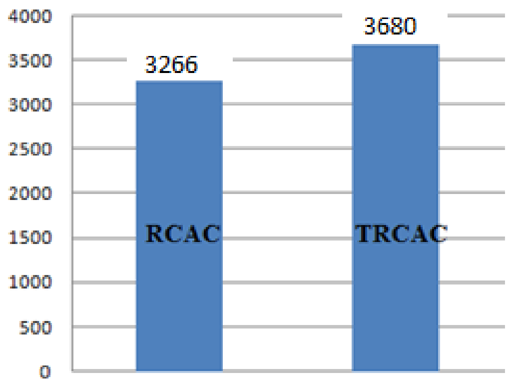

***Figure 5**: Comparison of compressive strength at 3000 Psi in 28 days (increase 13.99%).*

Discussions & Conclusion:

Treatment was evaluated, with the purpose of improving the surface and physical properties of the Recycled aggregate by impregnation of the recycled aggregate with a 10% by weight ordinary Portland cement solution. It was observed that an increase of 21.26% and 14% in the compressive strength at ages 7 and 28 days was observed after the OPC treatment for 3000 Psi concrete and an increase of 18.52% and 12.7% in the compressive strength at ages 7 and 28 days was observed after the OPC treatment for 4000 Psi concrete.

It appears that OPC impregnation improves both the interfacial transition zone between the Recycled aggregate and the new cement matrix, and the mechanical properties of the Recycled aggregate. As a result, the early strength of the new concrete increases significantly when the disparity between the properties of the Recycled aggregate and the new cement matrix is relatively small and the filler effect of the OPC is dominant. At a later age, after the cement matrix has strengthened, these effects are weaker, leading to a lesser influence on the strength. Cracking of the old cement matrix seems to have a strong influence on the properties of the Recycled aggregate.

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