MAT JOURNALS

Journal of Ceramics and Concrete Sciences
Volume 3 Issue 3

Effect on Mechanical Properties of Concrete Using Recycled Coarse Aggregate Replacing Stone Chips

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Abstract

Due to the scarcity of stone chips, construction works are obstructed day by day specially in developing countries. However, many infrastructures are broken because of they have reached at design period or other reasons. They have no salvage value but produced a huge dust on the environment. The aim of this works is to produce concrete with the recycled materials and to compare the mechanical properties with concrete made with stone chips. In sub-continent clay burnt bricks are available and aggregate produce from bricks are also available. For this reason brick aggregate has been used in the research work. Several physical properties were studied such as gradation, unit weight, specific gravity, and water absorption capacity of recycled aggregate. In addition, compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, were determined as the mechanical properties of concrete made with recycled aggregate by replacing stone chips. Forty eight (48) cylinders of 4 in x 8 in and twelve (12) prisms of 18 in x 4 in x 4 in with an effective length of 13.5 in have been used. 10%, 20%, 30% and 100% recycled coarse aggregate have been used replacing stone chips for the research works. All tests have been carried out according to ASTM standard requirements. Water cement ratio was kept as 0.47 throughout the work. It has been seen that 10% percent replacement of recycled aggregate give optimum value of given mechanical properties which indicate recycled aggregate can widely used for construction.

***Keywords:** Mechanical properties; Stone chips; Brick chips; compressive strength; modulus of elasticity; W/C ratio;*

INTRODUCTION

Concrete is a stone like material obtained by permitting a carefully proportioned mixture of content, fine aggregate, coarse aggregate and water to harden in forms of the shape and dimensions of the desired structure, Sand and Surki are commonly used as fine aggregate and brick chips, stone chips are commonly used as coarse aggregate. Concrete is the most widely used man-made construction material. It is obtained by mixing cement, water and aggregates (and sometimes admixture) in required proportions. Aggregates impart higher volume stability and better durability than hydrated cement paste in concrete and provide around 75 per cent of the body of concrete [1].

The Aggregates which can be reused after completion of design period or before reaching their design period is called Recycled Aggregates. In subcontinent, clay burnt bricks are available compared to stone chips. Producing of clay burnt bricks causes a bad effect on the environment. If we reuse clay burnt bricks as recycled aggregates to fraction of stone chips we can reduce the bad effect of dust on environment & increase the salvage value. If the properties of recycled aggregates remain close enough compared to fresh aggregate, then recycled aggregates can widely used.

Relatively better performance of recycled aggregate concrete is found for W/C = 0.45. No significant change in compressive strength of concrete is found for up to 50% replacement of virgin aggregate by recycled aggregate [2]. It is not essential that the structures need to be demolished only after when they have completed their service life, but also due to change in fashion and ongoing trend of reconstruction of even healthy structures just for creating more space in order to meet the present demand. All such activities are generating waste in bulk, and this waste is called the Construction and Demolition (C&D) waste [3].

Background of the study

- The global demand for construction aggregates exceeds 26.8 billion tons per year.
- The annual amount of construction and demolition waste (CDW) in sub-continent is 4.0 million tons.
- While the current method of managing such waste is through disposal in landfills causing huge deposits of CDW and becoming an environmental problem.
- One of the possible solutions to these problems is to recycle construction and demolition concrete waste to produce an alternative aggregate for structural concrete.

MATERIALS AND METHODOLOGY

The Properties of Ingredient of Concrete

Following are the commonly used ingredients in concrete
Aggregate
Fine Aggregate
Coarse Aggregate
Binding Materials (Cement)
Water

***Table: 1.** Properties of fine aggregate (Sylhet sand)*

Properties	Value
Fineness Modulus	2.61
Water Absorption Capacity (%)	1.0%
Specific Gravity	2.54

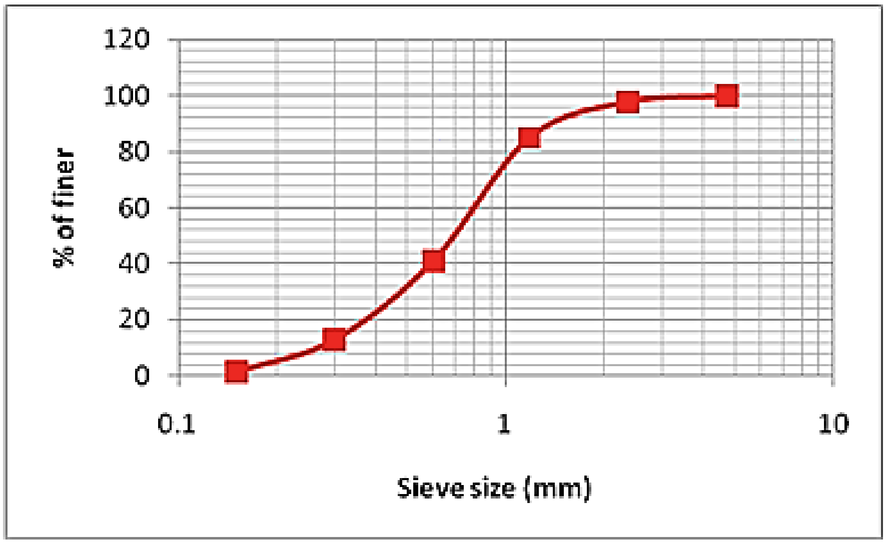

***Fig: 1.** Grain size distribution curve of Sylhet Sand*

***Table: 2.** Properties of Coarse Aggregates*

Properties	Stone Aggregate	Recycled Brick Aggregate
Dry Unit Weight (kg/m^3)	94	87
Absorption Capacity (%)	0.8%	1.0%
Bulk Specific Gravity (SSD)	3.36	3.01
Fineness Modulus	6.97	6.5

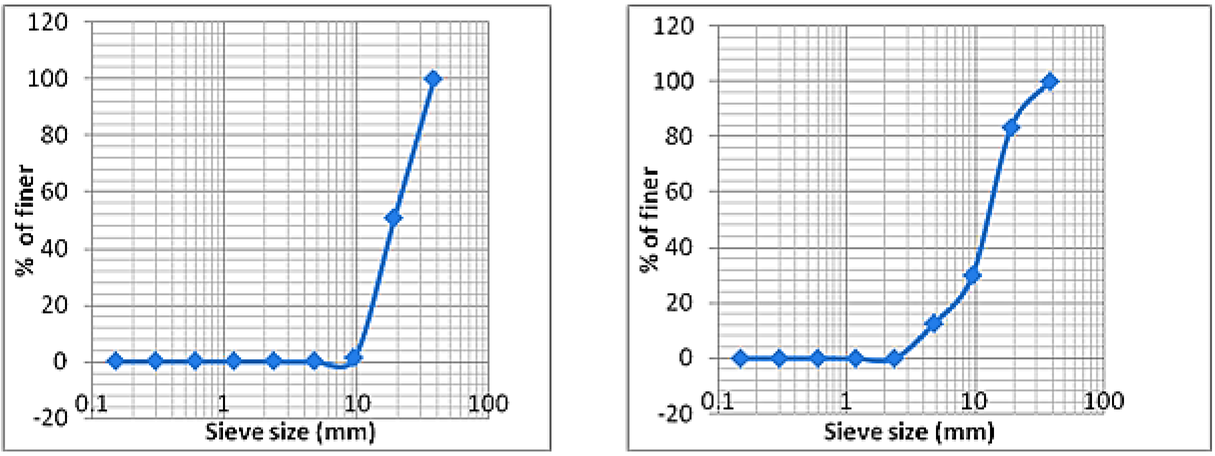

***Fig: 2.** Gradation curve of **Stone** Chips & recycled Brick Chips*

Cement
A cementing material is one which has the adhesive and cohesive properties necessary to bond inert aggregates into a solid mass of adequate strength, durability. For making structural concrete, so called hydraulic cements are used exclusively. Water is needed for the chemical process (hydration) in which the cement powder sets and hardens into solid mass. Various hydraulic cements have been developed, Portland cements, this was first patented in England in 1824, is by far the most common. In hydraulic cement that hardens by interacting with water resisting compound when it receives its final sets. It is highly durable and compressive strength in mortar and concrete. Its specific gravity ranges from 3.12 to 3.16 and weight 1208 kg/m3 (94 lb/ft3). Its measured fineness by particle size ranges from 10 micron to 50 micron. The specific gravity of cement used in this study was 3.15.

Water
Water is essential in the production of concrete in order to precipitate chemical with the cement, to wet the aggregate, and to lubricate the mixture for easy workability. Since the quality of water affect the strength it is necessary to go into the purely of water. In this study drinking water has been used in mixing of concrete.

Concrete Mix Design
Most of the available mix design methods are based on empirical relationships, charts and graphs developed from extensive experimental investigations. In this study ACI mix design method has been used. This method if based on the fact that for a given maximum size of coarse aggregate, the water content determines the workability of mix. Using the steps of ACI method of mix proportioning, the mix proportion was found 1:1.5:3.

Process of Casting
Production of quality of concrete requires meticulous care exercised at every stage of manufacture of concrete. The various stages of casting of test specimens are:

- Batching
- Mixing
- Compacting
- Curing
- Finishing

EXPERIMENTAL PROGRAM

Compressive Strength of Concrete

Compression test is the most common test conducted on hardened concrete. In this study cylindrical specimens were used. The size of the cylinder specimens were 4 in. dia. and 8 in. height. Universal testing machine was used to loading. Capacity of the testing machine 1000 kN and rate of loading was 250 KN/minute. The test method conforms to the ASTM standard requirements of specification C39 for cylinder. Figure 3 shows the set-up of compressive strength test.

Fig: 3. *Set-up for cylinder compressive strength test*

Tensile Strength of Concrete

Although concrete is not normally designed to resist direct tension, the knowledge of tensile strength is of value on estimating the load under which cracking will develop. In this study we have consider two types of test for strength of tension:

- Flexural test and
- Splitting cylinder test

Fig: 4. *Set-up of beam during flexural strength test*

Modulus of Elasticity of Concrete

The modulus of elasticity is determined by subjecting a cube or cylinder specimen to uniaxial compression and measuring the deformation by means of dial gauges fixed between certain gauge lengths. Dial gauge reading divided by gauge length will give the strain and loads are divided by area of cross-section will give the stress. A series of reading is taken and the Stress-Strain relationship is established. Thus the modulus of elasticity Ec (in psi units), that is, the slope of the initial straight portion of the stress-strain curve, is seen to increase as the strength of the concrete increases.

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RESULTS AND DISCUSSIONS

Table: 3. *The Mechanical properties of concrete*

Percent of replacement	Compressive Strength, f'_c (MPa)	Modulus of Elasticity, E_c (MPa)	Modulus of Rupture, f_r(MPa)	Splitting Strength, f_{sp}(MPa)
0%	24.682	19963.00	8.64	2.49
10%	22.103	17750.00	8.46	1.93
20%	18.76	16639.36	7.83	1.86
30%	17.842	14891.37	7.56	1.75

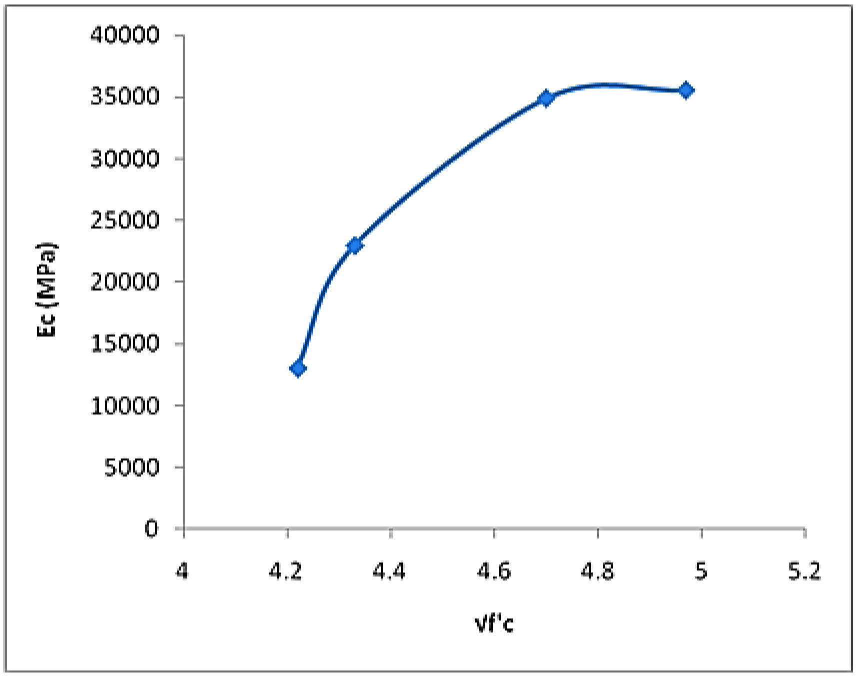

Fig: 5. *Modulus of Elasticity versus square root of compressive strength*

It is clear from the above Fig. 5 that the modulus of elasticity E_c= $30000\sqrt{f'_c}$ which is 47.5% less than stone aggregate.

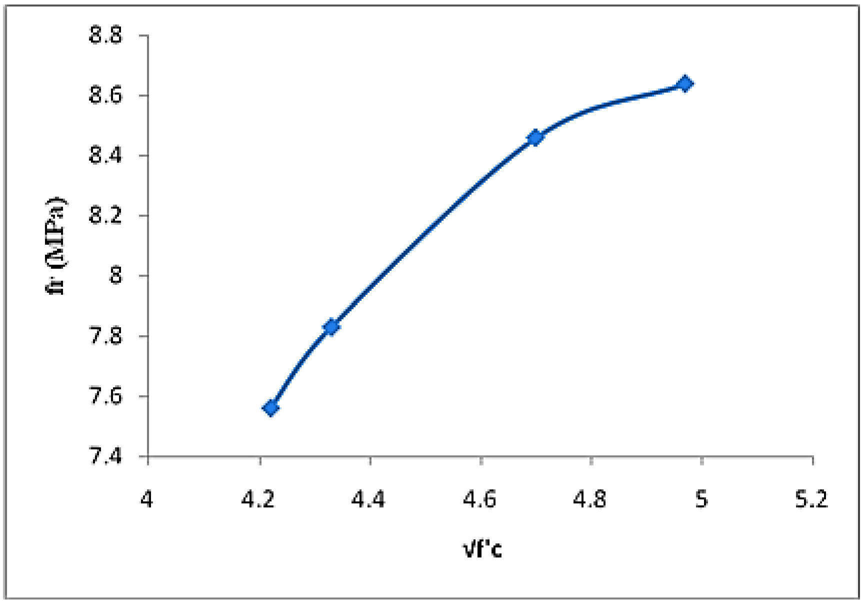

Fig: 6. *Modulus of rupture versus square root of compressive strength*

It is clear from the above Fig. 6 that the modulus of rupture, f_r= $1.57\sqrt{f'_c}$ which is 79% less than stone aggregate.

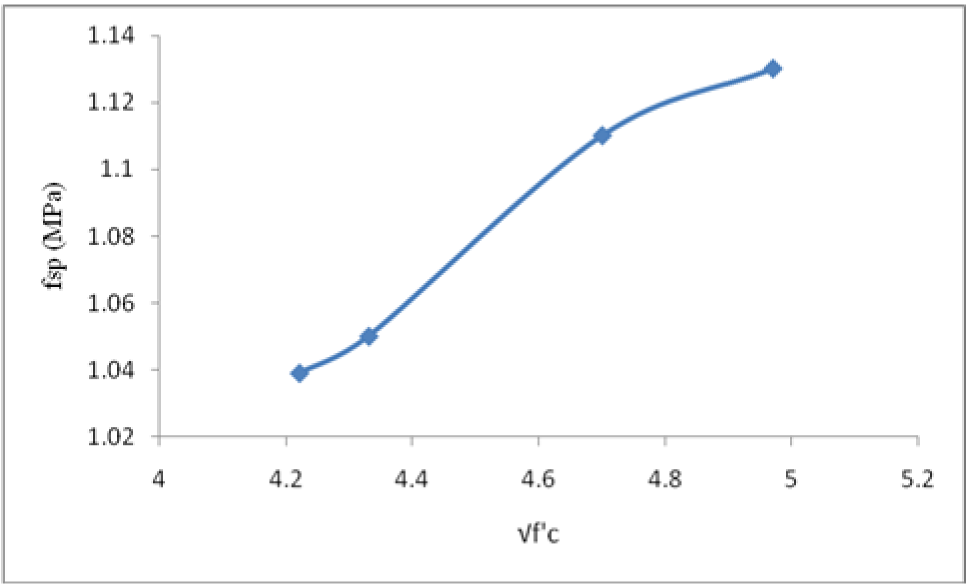

***Fig: 7.** split cylinder strength versus compressive strength*

It is clear from the above Fig. 7 that the split cylinder strength aggregate f_{sp} = 2.01 f'_c , which is 70% less than stone aggregate.

CONCLUSIONS

An experimental study was perform to examine the important properties of concrete such as workability and compressive strength with recycled aggregate as a replacement to natural aggregate. The data assembled during the course of research lead to the following conclusions,

Workability

Firstly, the workability of concrete manufactured with recycled concrete aggregate as well as natural course aggregate was investigated, keeping in view the variation of proportion of RBA to NCA for a constant water cement ratio and mixed design. It has been observed that the workability has been reduced by increasing the ratio of RBA to NCA.

Compressive strength

When the behavior of RBA has been investigated keeping in view the variation of proportion of RBA to NCA with constant water cement ratio and mixed design. It was observed that the performance of concrete with RBA was somehow near then NCA. It was also observed that the concrete manufactured with RBA provided approximately equal or greater compressive strength as compared to NCA. It can be concluded that 10% replacement of RBA give the maximum desired value of compressive strength.

Modulus of elasticity, rupture & split cylinder strength

When the behavior of RBA has been investigated keeping in view the variation of proportion of RBA to NCA with constant water cement ratio and mixed design. It was observed that the performance of concrete with 10% replacement of RBA give the optimum value of above properties

Recycled aggregates may be used successfully in concrete replacing natural concrete. Coarse aggregate replacements 20% to 50% are very reasonable due to recent market demand especially in case of reduces the impact on the landscape due to the exploitation and quarrying of natural aggregates. The durability of concretes must be studied in the future.

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