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Use of Recycled Brick Masonry Waste in Concrete

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Abstract: Recycle and reuse of construction and demolition waste (crushed brick masonry waste- recycled fine aggregate (RFA)) as replacement for fine aggregate is one of the effective methods to reduce the environmental effects due their landfills. To experimentally explore the feasibility of using RFA as a replacement of fine aggregate, this paper investigates the property of fresh concrete like workability and properties of hardened concrete like compressive strength, split tensile strength, density test and water absorption test. Four mixes of different percentage replacement of fine aggregate were used (20%, 40%, 60%, 80% RFA in concrete) and was compared with the standard mix (0% RFA) to find the change in the above properties.

Keywords: *Demolished brick masonry waste, crushed brick masonry, recycled aggregates, fine aggregate replacement*

1. Introduction

India is one of the world's fastest growing economies and this growth has brought with it a significant boost in construction activities. With the rapid growth in construction activities, it is important to assess the amount of construction and demolition waste being generated and the practices needed to handle waste. It has become essential to study construction and demolition waste generation and handling. With the growing population and increasing demand, the volume of wastes generated from daily activities are also increasing. With the environmental regulations being more restrictive, there is need to find the alternative methods to manage and utilize the wastes being generated has to be determined [1].

Large amount of building waste is produced in a shorter period of time, when the buildings are demolished and it varies with the type of demolition technique [2]. A number of wastes generated today are having a potential for reuse in construction. Such wastes include waste rock, mill tailings and coal refuse from the mining industry, sludges from ore processing, fly ash, bottom ash and flue gas scrubber sludges from combustion processes, slag from the metallurgical industry municipal refuse, and demolition wastes[3].

In the recent decades the use of waste material as a source for aggregate in new construction materials has become more common. The use of demolition waste as a source for aggregate in the production of new concrete has been encouraged due to the increasing landfills and depletion of natural resources for aggregates [4].

On the other hand, scarcity of natural resources like river sand is another major problem. Sand has by now become the most widely consumed natural resource after fresh water. Over the last two centuries sand has become a vital commodity for our modern economies. Hence it becomes necessary to protect and preserve the natural resources. For good quality concrete river sand is required.

This paper presents a study carried out, to study the feasibility of using recycled fine aggregates from demolished brick masonry in concrete. The concrete is expected to achieve a 28 day compressive strength of not less than 30 MPa. The fine aggregate was replaced by 0%, 20%, 40%, 60% and 80% by weight, with the crushed brick masonry waste. The effect of replacing natural fine aggregates with crushed brick aggregates on the properties of concrete is reported. Properties of both fresh and hardened concrete were reported, which includes density, compressive strength, split tensile strength in case of hardened concrete and slump cone test in the case of fresh concrete.

2. Methodology and materials:

2.1. Demolition waste:

The RFA used for the mix is crushed brick masonry waste. The demolished brick masonry waste was collected from local sources and was crushed in a brick manufacturing plant to get recycled fine aggregate (RFA). Then the crushed brick masonry waste was sieved to fine aggregate size (passing through 4.75mm, retained on 75 microns IS sieve). It was found to have a specific gravity of 2.34, bulk density of 1.422kg/l and water absorption of 5.22%. By sieve analysis it was found conforming to zone II and had a fineness modulus of 2.43.

2.2. Materials:

Portland pozzolanic cement (PPC) (ACC brand cement) of specific gravity 3.03 was used in casting of the specimens. Fine aggregate of fineness modulus 3.49, bulk density 1.692 kg/l, specific gravity 2.62, conforming to zone II, Coarse aggregate of size 20 mm (maximum), bulk density 1.612 kg/l, fineness modulus 8.71 and specific gravity 2.73 was used (Well graded aggregates). Water used was conforming to the requirements for concreting and curing.

2.3. Mix proportions:

To study the influence of recycled fine aggregate in concrete, five different mixes including one control mix were used. The concrete was design mixed for M30 concrete (according to IS 10262: 2009), with the above obtained material properties, a mix ratio of 1: 1.52: 2.69 (cement: fine aggregate: coarse aggregate) was arrived. The control mix (CM) did not contain any recycled fine aggregate (0%). The mixes designated as CM20, CM40, CM60, CM80 contains 20%, 40%, 60%, 80% of recycled fine aggregates (replaced by weight). A water cement ratio of 0.45 was used in all the mixes. Details of the mixes are shown in table 1.

***Table 1:** Mix proportions*

S. NO	Mix designation	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	recycled fine aggregate (kg)
1	CM	426	674.14	1149.33	0
2	CM20	426	517.17	1149.33	129.43
3	CM40	426	388.29	1149.33	258.86
4	CM60	426	258.86	1149.33	388.29
5	CM80	426	129.43	1149.33	517.17

3. Casting, curing and testing of specimens:

Six cubes of size 150 x150 x150 mm and six cylinders of size 10mm diameter, 20 mm height for each of the above mix were casted using steel moulds and compacted using needle vibrator. The cast specimen was kept in an ambient temperature for 24 hours and after 24 hours it was demoulded and cured. The casted Concrete specimens were tested for 7 day and 28 day compressive strength, split tensile strength and density. Tests on fresh concrete were also conducted.

3.1. Test on fresh concrete:

3.1.1 Slump cone test:

The slump cone test gives a measure of the workability of the concrete. A standard slump cone of 100mm top diameter, 200mm bottom diameter and height 300mm and a tamping rod of size 16mm diameter, 600mm long, round straight steel with tamping ends rounded to a hemispherical tip was used (IS 7320:1974). It was observed that as the percentage RFA is increased the workability of the concrete decreases. The decrease in workability can be accounted to the presence of clay particles in the demolished brick masonry waste which absorbs water, which can eventually decrease workability. The values of the slump obtained are tabulated in table 2 and the decrease in pattern is shown in the figure 1.

***Table 2:** Results of slump cone test on fresh concrete*

S. NO	Specimen designation	Slump cone value (mm)
1	CM	105
2	CM20	80
3	CM40	55
4	CM60	40
5	CM80	40

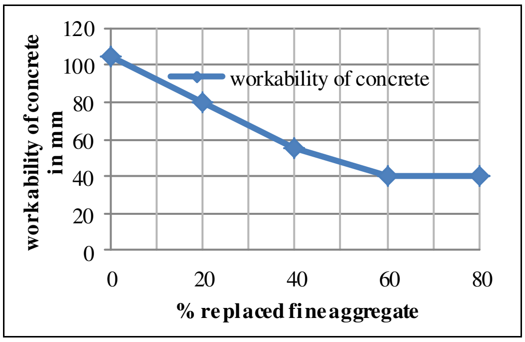

***Figure 1:** %RFA vs workability of concrete*

3.2. Test on hardened concrete:

3.2.1. Density of concrete:

The density of concrete, after 7days and 28 days curing was found. Density values are expressed in kg/m^3 and the details are shown in the table 3. A decrease in density can be observed with increase in percentage of recycled fine aggregate (RFA). The same trend was observed in both 7 days and 28 days cured concrete. The decrease in density can be observed from the figure 2.

***Table 3:** Results of density test on concrete*

S.No	Specimen designation	Density of concrete 7days (kg/m^3)	Density of concrete 28days (kg/m^3)
1	CM	2598.81	2611
2	CM20	2585.28	2606.61
3	CM40	2572.64	2589.23
4	CM60	2545.58	2567.11
5	CM80	2489.87	2526.02

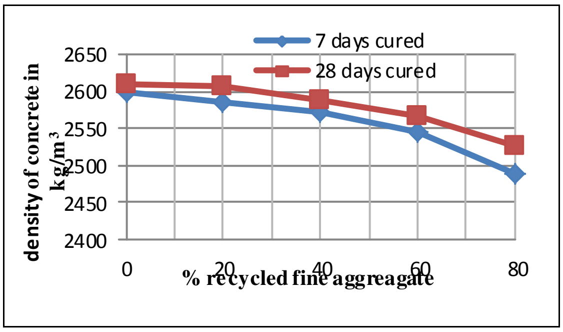

***Figure 2:** %RFA vs density of concrete*

3.2.2. Compressive strength:

The compressive strength of concrete was found using concrete cubes of size 150 x 150 x 150 mm. The test specimens were cured for 7 and 28 days. The results show that when there is an increase in percentage of RFA, there is a decrease in compressive strength of concrete. This trend is same in the case of both 7 days and 28 days cured concrete cubes. The results are tabulated in table 3 and pattern observed is shown in figure 4. The compressive strength of the concrete specimen for 60% RFA is 32.298 N/sq.mm, which is above the required design value of 30 N/sq.mm. From the results, we can see that there is a possibility to use 60% RFA in concrete to get a satisfactory strength.

Table 4: *Results of compressive strength test on concrete*

S. No	specimen designation	7-days compressive strength (N/mm^2)	28- days compressive strength (N/mm^2)
1	CM	27.25	39.92
2	CM20	25.1	36.74
3	CM40	23.84	34.532
4	CM60	22.66	32.298
5	CM80	21.92	28.740

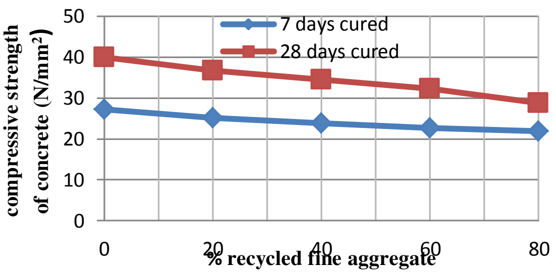

Figure 3: *%RFA vs compressive strength of concrete*

3.2.3. Split tensile strength:

A cylindrical specimen of diameter 100mm and height 200mm (having height to diameter ratio 2) was cast for testing the split tensile strength of concrete. The concrete specimens were tested for split tensile strength of concrete. The test was conducted at 7days and 28 days. It was observed that both the 7 day as well as 28 day split tensile strength shows a decreasing trend. The minimum split tensile strength is observed at 80% replacement of fine aggregate. The results are tabulated in table 5 and are plotted in figure 4.

Table 5: *Results of split tensile strength on concrete*

S No	Specimen designation	7-days split tensile strength (N/mm^2)	28- days split tensile strength (N/mm^2)
1	CM	2.11	3.13
2	CM20	1.974	2.758
3	CM40	1.62	2.599
4	CM60	1.34	2.38
5	CM80	1.2	2.022

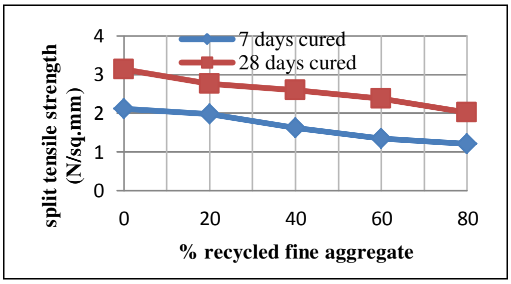

Figure 4: *% RFA vs split tensile strength of concrete*

3.2.4. Percentage water absorption of concrete:

Concrete is a porous material which interacts with the surrounding environment. The durability of mortar and concrete depends largely on the movement of water and gas through it. Permeability is a measure of flow of water under pressure in a saturated porous medium while absorption is material's ability to absorb and transmit water through it by capillary suction. Uptake of water by unsaturated, hardened concrete has an effect on durability on concrete. This is a simple parameter to determine and is increasingly being used as a measure of concrete's resistance to exposure in aggressive environments. The test was done in two major steps- saturating the specimen, followed by drying. The concrete specimen were first immersed in water until the change in mass during 24 hours is less than 0.1% Then the specimen was surface dried and saturated mass was obtained (M_s). The specimen was oven dried at a temperature of 105 ± 5°C until the difference in mass during 24 hours is less than 0.1 %. The dried mass was obtained (M_d) [14].

The water absorption of concrete is expressed as the water uptake relative to the dry mass,

$$\% \text{ water absorption} = \left(\frac{Ms - Md}{Md}\right) \times 100$$

Table 6: *Results of water absorption of concrete*

S.NO	Specimen	Water absorption, %
1	CM	1.933
2	CM20	2.713
3	CM40	3.186
4	CM60	3.470
5	CM80	4.343

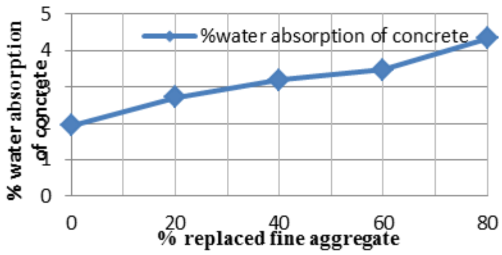

Figure 5: *%RFA vs % water absorption of concrete*

4. Inference

Based on the results of this study, the following inferences can be drawn for properties of concrete containing Recycled Fine Aggregate (RFA).

- As the percentage RFA is increased the compressive strength of the concrete decreases. At 60% the compressive strength obtained was 32.298 N/sq.mm, which is 7.11% greater than the design strength. Beyond 60% the strength decreases and is less than the design strength.
- The split tensile strength of the concrete decreases as the percentage of RFA is increased in the case of both 7 days and 28 days cured concrete cylinder specimen. There was a maximum of 35.39% decrease from the control mix's split tensile strength.
- As the percentage RFA is increased the density of concrete gets decreased. The decrease in density of the concrete with RFA is due the less density of the RFA which is 1.422kg/l, when compared to the normal fine aggregate which has a value of 1.692kg/l.
- The percentage water absorption of concrete increases as the percentage of RFA increases. This increase can be attributed to fineness of RFA when compared to natural fine aggregate, so the water absorption increases.
- The workability of the concrete decreases as the percentage RFA increased. This decrease in workability can be accounted for the presence of clay particles in the demolished brick masonry waste, which will absorb water. Due this absorption of water the workability decreases, so when percentage RFA increases the workability decreases.

5. Conclusion:

The effect of increasing percentage of RFA on concrete was studied. Based on this study, it can be recommended to use a replacement upto 60% of RFA in new concrete to get a satisfactory strength. The decrease in workability of concrete due to increase in RFA can be counteracted by the use proper admixtures [11]. The labor cost incurred in extraction of building waste and use of admixture to increase the strength of waste aggregates should not exceed the cost of fresh aggregates [12]. Further studies can be done on financial analysis of waste aggregate and environmental benefits gained through the promotion of use demolished waste in new concrete.

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