Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

Mechanical Properties of Concrete with Partial Replacement of Portland Cement by Clay Brick Powder

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***Abstract*— Concrete is the most undisputable and indispensable material being used in infrastructure development throughout the world. Umpteen varieties of concretes (FAC, HVFAC, FRC, HPC, HSC, and others) were researched in several laboratories and brought to the field to suit the specific needs. Although natural fine aggregates (i.e., river sand) are so far and/or will be superior to any other material in making concrete, their availability is continuously being depleted due to the intentional overexploitation throughout the Globe. Hence, partial or full replacement of fine aggregates by the other compatible materials like sintered fly ash, crushed rock dust, quarry dust, glass powder, recycled concrete dust, and others are being researched from past two decades, in view of conserving the ecological balance. This study aimed to investigate the suitability of using ground clay brick GCB in concrete. Crushed clay brick originated from demolished masonry was ground in the laboratory and added to cement-based mixtures as partial cement replacement. Three replacement levels, 10%,20% and 30%, were compared with the control. The tests on concrete showed that the mechanical properties (compressive, flexural and splitting tensile strengths) of concrete containing ground brick were well comparable to those of the concrete without ground brick. The study undertaken proved that, when it is finely ground, clay brick obtained from demolished masonry can be recycled as a pozzolanic cementitious material in concrete. Conclusively, using waste bricks can be an effective measure in sustainable development.**

Keywords*— Ground clay brick, Concrete, Compressive Strength, flexural strength.

I. Introduction

Concrete is one of the oldest and the most widely used construction material in today's world. It is easily obtainable, relatively cheap, strong, and durable. On the other hand, the concrete industry is one of the major consumers of the natural resources. The annual concrete production is estimated as 11 billion metric tons,70–75% of the number is aggregate (mostly natural rock); 15% is water; and 10–15% is cementitious binder. The majority of the cementitious binder used in concrete is based on Portland cement clinker which is an energy-intensive process. Global cement production was 2.3 billion tons in 2005 which is almost four times the number in 1970. One ton of cement production is responsible for one ton of CO2 emission: half of the CO2 is from the chemical process of clinker production, 40% from burning fuel, and the remaining 10% is split between electricity use and transportation. According to the recent data, cement clinker production is the largest CO2 source among industrial processes: it contributes about 4% of global total CO2 emissions from fuel use and industrial activities. In the backdrop of such a bleak atmosphere, there is a large demand for alternative materials from industrial waste.

A. Objective of the Study

- To evaluate the utility of brick powder as a partial replacement of cementitious in concrete.
- To study and compare the performance conventional concrete and brick powder concrete.
- To understand the effectiveness of brick powder in strength enhancement.

B. Scope of the Study

This paper presents a comprehensive study on the use of brick powder produced from clay brick demolition wastes in concrete industry. The main focus of the research is to present an additional information in the field of recycling clay masonry rubbles in order to explore the possible uses of these recyclable materials in structural applications. The assessment of different properties of cement paste and concrete is presented. The current work concludes performance-based guidelines that are imperative from the cost and environmental aspects and that also can be recycled powder in concrete. Brick powder reduces weight of the concrete. With the increase in construction activities, there is heavy demand on concrete and consequently on its ingredient like aggregate also. So crushed brick waste can be used as an alternative to this demand.

I. Literature Review

Abdelghani Naceri[1] *et.al.*, investigated the use of waste brick powder as a partial replacement for cement in the production of cement mortar. A substitution of cement by 10% of waste brick increased mechanical strengths of mortar. The results of the investigation confirmed the potential use of this waste material to produce pozzolanic cement. Paulo B. *Cachim*[6] evaluated the properties of concrete made with crushed bricks replacing natural aggregates. Observed results indicate that ceramic residuals could be used as partial replacement of natural aggregates in concrete without reduction of concrete properties for 15% replacement and with reductions up to 20% for 30% replacement. Ge[3] et.al., have presented a research that studied the effect of clay-brick-powder (CBP) on concrete mechanical properties, including compressive strength, static elastic modulus, and flexural strength. Experiment results showed that recycled CBP could be used as partial replacement of cement in concrete. Ali[2] et.al., studied the effect of using crushed clay brick as an alternative aggregate in aerated concrete. A comparatively uniform distribution of pore in case of foamed concrete with natural sand was observed by scanning electron microscope, while the pores were connected mostly and irregularly for mixes containing a percentage higher than 25% clay brick aggregate. Kamal Uddin's[4] investigated the overview of the physical and chemical properties of brick dust as a mineral admixture (BDMA), which is dumped as waste from brick and tile factories in Bangladesh. Various properties of brick dust have been studied. Concrete prepared with 20% cement replaced by BDMA also shows good resistance to chemical attack, especially the sulphate attack. Mohammad Abdur Rashid[5] et.al., conducted an investigation to achieve concrete of higher strength using crushed brick as aggregate and study the mechanical properties. Test results show that the compressive strength of brick aggregate concrete can be increased by decreasing its water-cement ratio and using admixture whenever necessary for workability. The cylinder strength is found about 90% of the cube strength.

II. MATERIALS USED

A. *Cement, water and Aggregates*

Concrete is prepared by mixing various constituents like cement, aggregates, water etc. which are economically available. Ordinary Portland cement of 43 grade conforming to IS 8112 was used throughout the work. The fine aggregate used in this investigation was clean river sand, whose maximum size is 4.75 mm, conforming to grading zone II. Machine crushed blue granite stone angular in shape was used as coarse aggregate. The properties of the materials are presented in Table.1.

B. *Brick powder*

Locally available waste brick powder, which has been sieved and grains passing through 90 microns was the primary material used. Before adding brick powder in the concrete it has to be powdered to desired size. The chemical composition of brick powder are presented in the Table.2

III. METHODOLOGY

A. *Experimental Programme*

The aim of the experiment was to assess the properties of concrete made with brick powder and to study the various important aspects such as compressive strength, flexural strength and split tensile strength of concrete prepared by using brick powder with different percentage of replacements with cement. The concrete mix design was proposed using Indian Standard for control concrete. The grade was M25. The Proportion of materials shown in Table 3. The replacement levels of cement by brick powder were used in terms of 10%, 20%, and 30% in concrete.

B. *Casting of the Specimens*

In order to study the effect of replacement of cement in various ratio of brick powder 36 numbers of cube of 150mm size, 36 numbers of beams of size 100 mm x 100 mm x 500 mm and 36 numbers of cylinders of 150mm diameter to a height of 300mm were cast and used as test specimens to determine the compressive strength, flexural strength and split tensile strength respectively at the age of 7,14 and 28 days. Three specimens were tested every time at the required days and mean value was taken. The workability of fresh concrete was measured in terms of slump values. The ingredients of concrete were thoroughly mixed till uniform consistency was achieved. The cubes, beams and cylinders were compacted on a vibrating table.

IV. RESULTS AND DISCUSSIONS

The experimental investigations carried out in the laboratory to determine the strength properties of the concrete with the additional mixture of brick powder and test results are discussed.

A. *Effect of Brick Powder on Compressive Strength*

As per design obtained in accordance to code IS-10262, mix proportion of various materials (viz. Cement, Sand, Aggregate and Water) is calculated for M-25 grade of concrete. The cubes were tested in the laboratory in accordance to code IS 1343-1980. The results of compressive strength of cubes for 7, 14 and 28 days for various mixes are compared and presented in Figure.1 The compressive strength for 10% , 20% and 30% (M2,M3 and M4 Mix) replacement of cement by brick powder were compared with conventional concrete (M1 mix). It is observed that the compressive strength of cubes (cement is partially replaced by brick powder) increases initially at 10% and 20% brick powder in 7,14 and 28 days strength . When the percentage of brick powder increased to 30% reduces the strength. In 7 days test results the increase in value of 3.528% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 7.838% when M3 is compared with M1 series specimens. The decrease in value of 4.983 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 4.467 % was noted when M2 mix specimens compared with M3 mix specimens. In 14 days test results the increase in value of 4.124% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 8.314% when M3 is compared with M1 series specimens. The decrease in value of 3.795 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 4.371 % was noted when M2 mix specimens compared with M3 mix specimens. In 28 days test results the increase in value of 4.451% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 8.239% when M3 is compared with M1 series specimens. The decrease in value of 3.704 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 4.261 % was noted when M2 mix specimens compared with M3 mix specimens.

In M1 mix the percentage increase in value of 21.613% was noted in 14 days strength when compared with 7days strength. Whereas those noted as 32.081% when 28days strength was compared with 7days strength. The percentage increase in value of 13.354 % was noted when 14days strength compared with 28days strength specimens. In M2 mix the percentage increase in value of 22.096% was noted in

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

14 days strength when compared with 7days strength. Whereas those as 32.729% when 28days strength was compared with 7days strength. The percentage increase in value of 13.649 % was noted when 14days strength compared with 28days strength specimens. In M3 mix the percentage increase in value of 22.018% was noted in 14 days strength when compared with 7days strength. Whereas those as 32.585% when 28days strength was compared with 7days strength. The percentage increase in value of 13.551 % was noted when 14days strength compared with 28days strength specimens. . In M4 mix the percentage increase in value of 21.987% was noted in 14 days strength when compared with 7days strength. Whereas those as 32.464% when 28days strength was compared with 7days strength. The percentage increase in value of 13.429 % was noted when 14days strength compared with 28days strength specimens.

B. Effect of Brick Powder on Split Tensile Strength

The cylinders were tested in the laboratory in accordance to code IS 5816:1999. The results of split tensile strength for 7, 14 and 28 days for various mixes are compared and presented in Figure.2 The split tensile strength for 10% , 20% and 30% (M2,M3 and M4 Mix) replacement of cement by brick powder were compared with conventional concrete (M1 mix). It is observed that the tensile strength (cement is partially replaced by brick powder) increases initially at 10% and 20% brick powder in 7,14 and 28 days strength . When the percentage of brick powder increased to 30% reduces the strength. In 7 days test results the increase in value of 1.812% was observed in M2 Mix specimens when compared with M1 mix specimens. Whereas those noted as 1.221% when M3 is compared with M1 series specimens. The decrease in value of 2.115 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 1.262 % was noted when M2 mix specimens compared with M3 mix specimens. In 14 days test results the increase in value of 2.069% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 4.237% when M3 is compared with M1 series specimens. The decrease in value of 1.909 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 1.562 % was noted when M2 mix specimens compared with M3 mix specimens. In 28 days test results the increase in value of 6.993% was observed in M2 Mix specimens when compared with M1 mix specimens. Whereas those noted as 8.968% when M3 is compared with M1 series specimens. The decrease in value of 1 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 2.124 % was noted when M2 mix specimens compared with M3 mix specimens.

In M1 mix the percentage increase in value of 11.479% was noted in 14 days strength when compared with 7days strength. Whereas those as 17.741% when 28days strength was compared with 7days strength. The percentage increase in value of 7.071 % was noted when 14days strength compared with 28days strength specimens. In M2 mix the percentage increase in value of 11.709% was noted in 14 days strength when compared with 7days strength. Whereas those as 22.081% when 28days strength was compared with 7days strength. The percentage increase in value of 11.747 % was noted when 14days strength compared with 28days strength specimens. In M3 mix the percentage increase in value of 11.716% was noted in 14 days strength when compared with 7days strength. Whereas those as 22.016% when 28days strength was compared with 7days strength. The percentage increase in value of 11.666 % was noted when 14days strength compared with 28days strength specimens. . In M4 mix the percentage increase in value of 11.657% was noted in 14 days strength when compared with 7days strength. Whereas those as 19.025% when 28days strength was compared with 7days strength. The percentage increase in value of 8.339% was noted when 14days strength compared with 28days strength specimens.

C. Effect of Brick Powder on Flexural Strength

The beam prism were tested in the laboratory in accordance to code IS 516:1959. The results of flexural strength for 7, 14 and 28 days for various mixes are compared and presented in Figure.3 The flexural strength for 10% , 20% and 30% (M2,M3 and M4 Mix) replacement of cement by brick powder were compared with conventional concrete (M1 mix). It is observed that the flexural strength (cement is partially replaced by brick powder) increases initially at 10% and 20% brick powder in 7,14 and 28 days strength. When the percentage of brick powder increased to 30% reduces the strength. In 7 days test results the increase in value of 1.770% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 3.960% when M3 is compared with M1 series specimens. The decrease in value of 2.153 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 2.333 % was noted when M2 mix specimens compared with M3 mix specimens. In 14 days test results the increase in value of 2.092% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 4.248% when M3 is compared with M1 series specimens. The decrease in value of 1.874 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 2.220 % was noted when M2 mix specimens compared with M3 mix specimens. In 28 days test results the increase in value of 2.264% was observed in M2 Mix specimens when compared with M1 mix specimens. Where as those noted as 4.359% when M3 is compared with M1 series specimens. The decrease in value of 1.846 % was noted when M4 compared with M1 series specimens. The percentage increase in value of 2.143 % was noted when M2 mix specimens compared with M3 mix specimens.

In M1 mix the percentage increase in value of 11.442% was noted in 14 days strength when compared with 7days strength. Whereas those as 17.573% when 28days strength was compared with 7days strength. The percentage increase in value of 6.923 % was noted when 14days strength compared with 28days strength specimens. In M2 mix the percentage increase in value of 11.732% was noted in 14 days strength when compared with 7days strength. Whereas those as 17.987% when 28days strength was compared with 7days strength. The percentage increase in value of 7.086 % was noted when 14days strength compared with 28days strength specimens. In M3 mix the percentage increase in value of 11.707% was noted in 14 days strength when compared with

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

7days strength. Whereas those as 17.914% when 28days strength was compared with 7days strength. The percentage increase in value of 7.031% was noted when 14days strength compared with 28days strength specimens. In M4 mix the percentage increase in value of 11.684% was noted in 14 days strength when compared with 7days strength. Whereas those noted as 17.821% when 28days strength was compared with 7days strength. The percentage increase in value of 6.949 % was noted when 14days strength compared with 28days strength specimens.

V. CONCLUSION

Based on the experimental study investigating the use of GCB in concrete, the following conclusions which are limited to the materials used in the study.

- The specific gravity of brick powder being higher than the raw materials of concrete, it helps in increasing the density of concrete which results in less pores and high compact concrete.
- This is an eco-friendly concrete as it subsides the stagnation of demolished brick waste by consuming it.
- As much as of the total cost of cement in conventional method can be saved by this procedure. Cost saving percentage increases with increase in richness of mix design.
- The W/C ratio has being kept constant even as the surface area is increasing with increase in % of brick powder. This helped in reducing the unwanted bleeding and segregation in concrete.
- The compressive, flexural strength and split tensile strength increases up to 10%, 20% replacement of cementitious material compared to the respective conventional concrete strength.
- Concrete gains early strength and hence shuttering can be removed early thereby reducing the secondary overhead cost.
- We can achieve more strength concrete mix with lesser quantity of cement, which indirectly reduces the primary overhead cost per m3of concrete.

TABLE I. PROPERTIES OF THE CONSTITUENT MATERIALS

Sl.No	Parameter	OPC used	Brick Powder	Fine Aggregate	Coarse Aggregate
1	Normal Consistency	29%	-	-	-
2	Fineness by Sieving (%) 90 micron	80	85	-	-
3	Initial Setting Time (minutes)	38	-	-	-
4	Final Setting Time(minutes)	300	-	-	-
5	Specific Gravity	3.15		2.55	2.69
6	Bulk density	-	2000	1747	1590
7	Fineness modulus	-	-	2.81	7.16
8	Water Absorption	-	-	1%	0.52%

TABLE II. CHEMICAL COMPOSITION OF BRICK POWDER

Material	OPC	Brick Powder
SiO2	21.4	46.52%
Al2O3	5.3	10.62%
Fe2O3	3.2	4.29%
CaO	61.6	24.48%
Na2O	-	1.02%
K2O	-	1.84%
MgO	0.8	8.56%
TiO2	-	0.514%
MnO	-	0.079%
P2O5	-	0.199%
SO3	2.2	0.895%
LOI	-	0.66%
Cl	-	108 ppm

TABLE III. MIX PROPORTIONS OF THE CONCRETE

Sl.No	Ingredient	kg / m^3	Proportion
1	Portland Cement	450	1: 1.12 : 2.687 W/ C = 0.425
2	Water	191.60	
3	Fine Aggregate	504	
4	Coarse Aggregate	1209	

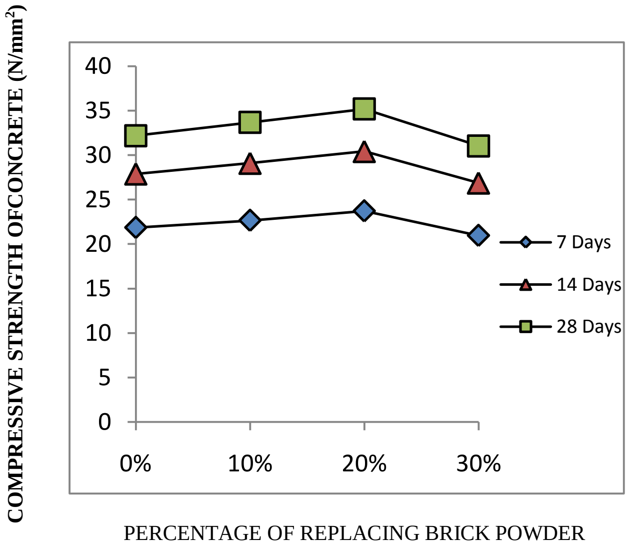

Fig. 1. COMPRESSIVE STRENGTH OF CONCRETE

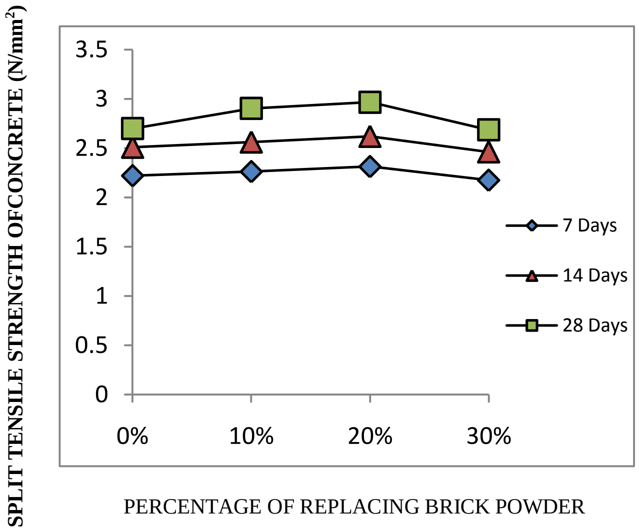

Fig. 2. SPLIT TENSILE STRENGTH OF CONCRETE

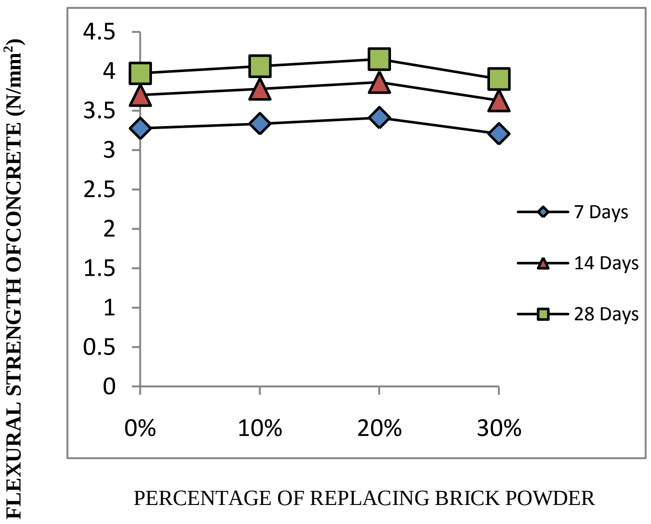

Fig. 3. FLEXURAL STRENGTH OF CONCRETE

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