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Experimental Study on Properties of Cement Stabilized Recycled Blocks

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Abstract – *In most of the Countries, the fundamental building material used are traditionally burnt Clay Brick Blocks but they have many negative effects such as felling of trees for burning fuel, and degradation of soil near rivers where Clay for manufacturing of bricks is available. Most of the Construction and Demolition Wastes is predominantly disposed as Landfill which results in environmental degradation. It is important to incorporate the construction and demolition wastes in the production of Building Materials and reduce the burden on the Virgin Building Materials. So, this experimental program is designed to utilize the masonry and concrete waste as raw material for manufacturing of Cement stabilized Recycled blocks (CSRB). The masonry waste is recovered as Brick Powder and Concrete waste is crushed and recovered as Recycled Fine aggregates (RFA). The cement is used as a stabilizer and further it is replaced with the Pozzolanic materials such as Fly ash, Silica Fume, and GGBS. As per IS 1725:1991 the standard dimensions such as (190X90X90) mm and (290X190X90) mm are for experiment on CSRB. Initially, Pilot-Study was conducted on the cubes of size (70.6X7.0X70.6) mm to assess the admissible composition of mix for CSRB and then based on the test results of the pilot study, six different Combinations are considered to cast CSRB. After casting, all the blocks were cured for about 28 days and the parameters such as Compressive strength, density, Rate of water absorption and Dimensional Analysis of CSRB were conducted to determine the influence of Pozzolanic materials on CSRB.*

***Key words*: Cement stabilized recycled blocks, Pozzolanic materials, Compressive strength, Density, water absorption, Dimension Analysis**

1. INTRODUCTION

The construction industry has the largest impact on Nature and Environment. So, in order to reduce this impact Sustainable Environmental Construction should be adopted and make efficient use of resources. Construction and Demolition (C&D) waste is the material produced during the construction, renovation, demolition or de-construction of structures which includes debris, concrete masonry, asphalt, wood, metals, gypsum, wallboard, roofing etc. The estimated waste generation during construction is 40kg/m2 TO 60KG/M2 and the highest contribution of waste are from demolition of buildings which on average generates between 300kg/m2 to 500kg/m2 of waste. In India around12 million to 14.7million tonnes of construction and demolition wastes are produced every year and 7 to 8 million tonnes are from concrete and brick waste.

The disposal of waste materials strains on the landfill sites and on other hand, the construction industry uses large amount of natural resources all around the world damaging the environment which is no longer considered to be sustainable. So, the obvious solution lies in re-use and recycling of C&D waste materials by solving the issue of lack of raw materials for the production without affecting the environment.

1.1 Compressed Stabilized Earth Block (CSEB)

These are the solid blocks compacted using a machine with a mixture of soil, sand, stabilizer (Cement/lime) and Water. In CSEB stabilizer plays an important role in creating bond between soil -stabilizers mix combination which reduces the swelling properties of soil.

1.2 Cement Stabilized Recycled Block (CSRB)

CSRB includes materials such as Masonry waste such as Brick Powder (Brick waste Converted to granular form) along with Recycled Fine Aggregate used as main Ingredients for Manufacturing of CSRB with cement as Stabilizer with pozzolanic materials as a partial replacement to cement.

2. EXPERIMENTAL PROGRAMME

2.1 Problem Statement

The demand for construction materials are increasing day by day at same tempo. On the other hand, a huge amount of Construction and demolition wastes are being generated from the demolished and renovated structures. Therefore, the Utilisation of industrial and mine wastes; recycling of building wastes and use of renewable energy sources are some of the areas where sustainability can be achieved.

2.2 Objectives

1. To study the basic properties of demolished waste materials such as Brick Powder and Recycled fine

aggregate which is considered as potential material for making brick blocks
2. To ascertain the properties of CSRB by varying the percentage of Cement (6%, 8%, 10%)
3. To assess the influence of pozzolanic materials such as Silica fume, Fly ash, GGBS on CSRB
4. To study the dimensional effect on properties of CSRB

3. MATERIALS

3.1 Cement: Ordinary Portland cement is an important ingredient and variable in manufacturing of Recycled bricks. The function of OPC is to strongly bind the constituent materials together, in a dense, strong, dimensionally stable and durable unit. In this experimental study, OPC has been selected because of its unique and superior binding capacity its widely availability.

Table-3.1: Properties of Cement

Sl.no	Test Particulars	Results
1	Specific Gravity	3.08
2	Fineness (%)	5.94
3	Standard Consistency (%)	30
4	Initial setting time (min)	80
5	Final setting Time (min)	210
6	3-Day Compressive strength, N/mm²	16.49
7	7-Day Compressive strength, N/mm²	33.47
8	28-Day Compressive strength N/mm²	46.22

According to the IS 8112-1989, All the test results of Cement are found to be within the permissible limits.

3.2 Water: The water used for making concrete should be clean and free from harmful impurities like oil, alkalis, acids etc. The water with PH value of 7.55 is used in the study

3.3 Brick Powder: Brick material are obtained by crushing of demolished brick bats that is collected and its processed through Los Angeles Abrasion testing Machine with 8 spheres for 30 revolutions. The processed materials are in the form of powder and it is separated through IS 2.36mm sieve.

3.4 Recycled Fine Aggregate (RFA): RFA is a material recovered by crushing tested laboratory concrete specimen. The Material is separated through IS 2.36mm sieve. In the present experimental study, an RFA passing through IS sieve size of 2.36mm is used for the analysis.

3.5 Properties of Brick Powder and Recycled Sand
Following are the tests conducted to ascertain the properties of the materials which are used in the manufacturing of CSRB:

1. Specific Gravity.
2. Sieve Analysis.
3. Bulk Density
4. Standard Proctor's Compaction Tests.

Table-3.2: Physical Properties of Brick Powder (BP) and Recycled Fine aggregates (RFA).

Sl.no	Test Particulars	BP	RFA
1	Specific Gravity	2.41	2.2
2	Fineness Modulus (%)	1.4	2.2
3	Loose Bulk Density (kg/m³)	1181.46	1039.16
4	Compacted Bulk Density (kg/m³)	1302.87	1172.32
5	Optimum Moisture Content (%)	16	25

4. METHODOLOGY

The mix proportion comprising 70% of Brick powder and 30% of Recycled Fine Aggregates (RFA) are considered in the study. For the Mix, the cement content is varied at 6, 8 and 10%. Further the cement is replaced by pozzolanic materials such as Fly Ash, Silica Fume and GGBS. The properties of all the blocks are assessed as per Indian Standards. The water content of the mix is determined by the OMC of mix. Each mix is compacted by applying a pressure of 3MPa using universal testing machine of 1000 KN. The Casted blocks are cured for 28 days by method of spray curing. Initially pilot studies are conducted on cubes of size 70.6mm in order assess the properties of the mix. Two Sizes of CSRBs are used in the Study

- (190x90x90) mm
- (290x190x90) mm

4.1 Mix Proportions

The materials composition constitutes 70% of the brick powder and 30% of RFA, to this cement content are varied from 6 to 10% and the properties of CSRB is assessed. Further the cement is replaced by pozzolanic materials to assess its viability in the production of CSRB.

4.2 Determination of water content

The water content of each mix is decided based on density and void ratio. To fix the water content for mix, a pilot study is conducted by casting the series of cubes varying water content from 12 to 20%.

Step-1: The quantity of each mix is proportioned as per the mix composition.

Figure 4.1: Process of Proportioning of the ingredients.

Step-2: For the mix water content is varied from 12 to 20% at an interval of 1%. The mix is compacted by applying the pressure of 3Mpa using Universal testing Machine.

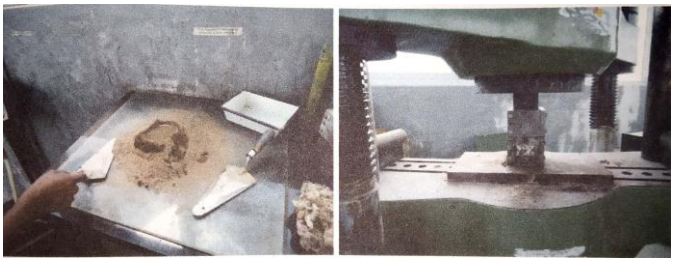

Figure4.2: Determination of Water Content.

Step-3: The compacted cubes are kept in the mould for 24 hours in the room temperature.

Step-4: After 24 hours the cubes are demolded and weight of the cubes are recorded to assess bulk density of the cube.

Figure-4.3: Process of testing the Bulk Density of Cubes.

Step-5: In this step the cubes are kept in the oven for 24 hours and the consequently the dry weight is evaluated.

Step-6: The oven dried cubes are kept in the water container for 24 hours to assess the of water absorption of each cube in the mix.

Figure-4.4: Accessing the Water Absorption.

Step-7: With Known water absorption value the voids ratio and porosity of each cube is determined. The cube at particular water content that possess maximum density, minimum voids ratio and minimum porosity is considered as optimum water content.

Table-4.1: Composition and Designation of mix used and Water Content (WC)
(Cement: Pozzolanic Materials: Brick Powder: RFA)

Sl.No	Mix Designation	Material Composition				WC
		C	Pozzolanic Material	BP	RFA	
1	(6+0) CSRB-(6:0:70:30)	6	Nil	70	30	16
2	(8+0) CSRB-(6:0:70:30)	8	Nil	70	30	16
3	(10+0) CSRB-(6:0:70:30)	10	Nil	70	30	16
4	(7+0) CSRB-(6:0:70:30)	7	3 (Silica Fume)	70	30	16
5	(7+0) CSRB-(6:0:70:30)	7	3 (Fly Ash)	70	30	16
6	(7+0) CSRB-(6:0:70:30)	7	3 (GBBS)	70	30	15
7	(5+0) CSRB-(6:0:70:30)	5	5 (Silica Fume)	70	30	15
8	(5+0) CSRB-(6:0:70:30)	5	5 (Fly Ash)	70	30	17
9	(5+0) CSRB-(6:0:70:30)	5	5 (GBBS)	70	30	16
10	(6+0) CSRB-(6:0:70:30)	6	2 (Silica Fume)	70	30	17
11	(6+0) CSRB-(6:0:70:30)	6	2 (Fly Ash)	70	30	16
12	(6+0) CSRB-(6:0:70:30)	6	2 (GBBS)	70	30	17
13	(4+0) CSRB-(6:0:70:30)	4	4(Silica Fume)	70	30	16
14	(4+0) CSRB-(6:0:70:30)	4	4(Fly Ash)	70	30	16
15	(4+0) CSRB-(6:0:70:30)	4	4 (GBBS)	70	30	15

4.3 Preparation of Cubes and Blocks

(i) **Preparing and Proportioning of the Materials:** . Brick powder is prepared by crushing brick bats in the laboratory using Los Angeles Abrasion testing machine, whereas recycled fine aggregate is obtained by crushing concrete cubes. The proportioning of the ingredients of the mix done by weight batching.

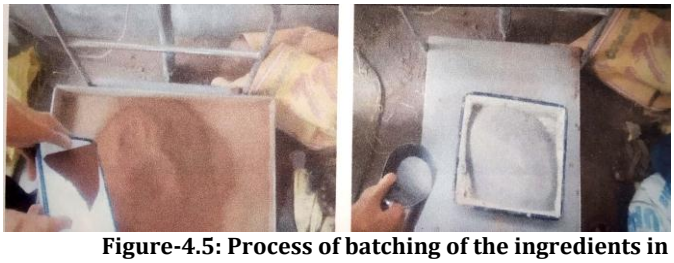

Figure-4.5: Process of batching of the ingredients in the study weighing

(ii) **Mixing of the Ingredients:** A dry mixing is carried out till the homogeneity of the mix is achieved. Water is added to the dry ingredients and the

process of mixing is continued. In order to maintain the uniformity in mixing process, mixing time duration between 4-5 mins is maintained.

Figure-4.6: Process of mixing of the ingredients.

(iii) **Casting and Compacting**: The Mixed ingredient are placed in the cube and brick mould and compacted in universal testing Machine with a load of 3Mpa.

Figure-4.7: Casting of CSRB

(iv) **Demoulding of the specimens**: The casted bricks and cubes are kept in the room temperature for 24 hours and later the specimens are demoulded.

(v) **Curing of Specimen**: The spray curing is adopted for curing period of 28 days for both cubes as well as blocks. The stacked cubes and bricks are cured by sprinkling water on to face of brick blocks. Later the specimens are covered by wet gunny bags. To maintain the dampness

Figure-4.8: Curing of Demoulded cubes and Bricks

4.4 Tests on Cubes and Blocks:

The pilot study is conducted on the cubes to assess the density and compressive strength of the pre-determined mixes. After 28 days of curing, the specimens are immersed in the water for 48 hours and it is About 15 different mix compositions are tried in the study.

(i) **Compressive Strength**: Compressive strength determines the quality of bricks. The Block are tested in accordance with the procedure laid down in IS: 3495 (Part 1)-1976 shall have a minimum average compressive strength of not less than 20 kgf/cm^2 for Class 20 and 30 kgf/cm^2 for Class-30.

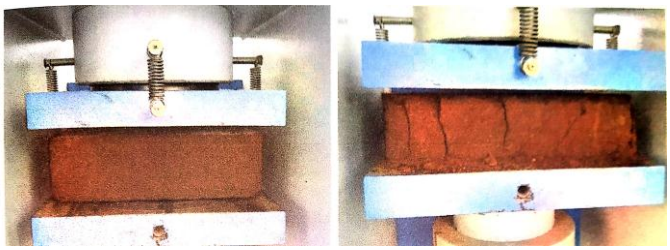

Figure-4.9: Compressive strength test of CSRB in UTM

(ii) **Density:** Density of compressed stabilized earth bricks is within the range of 1500 to 2000 kg /mº. Density of the compressed earth brick is consistently related to its compressive strength

(iii) **Dimension Test:** As per IS 1725:1982 the standard dimension of brick is (190X90X90) mm. The dimensions shall be tested in accordance with the procedure given in code and shall be within following limits per twenty blocks.

Block Size (in cm)	Length (in cm)	Breadth (in cm)	Height (in cm)
19x 9x9	312 to 388	174 to 186	174 to 186
29x 19 x 9	570 to 590	312 to 388	174 to 186

(iv) **Water Absorption and Moisture Content:** Water absorption is a function of clay and cement content and usually related with the strength and durability of earth bricks and therefore it is important to determine the rate of water absorption of earth .

Figure-4.10: Water Absorption Test of CSR

5. RESULTS AND DISCUSSION

5.1 Compressive Strength: The wet compressive strength is more critical factor as it considered as a least strength of the block (brick yields lower strength when it in SSD condition).

Hence the blocks are tested in SSD condition and the results are tabulated.

A. Compressive Strength of the cube: A pilot study is conducted for 15 cube samples of different mix compositions.

Tables 5.1: Compressive Strength of the cubes at 28days (Average of 6 Specimens)

Sl.No	Mix Designation (Composition in%)	Compressive Strength (Mpa)
		Cube size of 70.6mm
1	(6+0) CSRB-(6:0:70:30)	3.53
2	(8+0) CSRB-(6:0:70:30)	6.19
3	(10+0) CSRB-(6:0:70:30)	6.88
4	(7+0) CSRB-(6:0:70:30)	6.67
5	(7+0) CSRB-(6:0:70:30)	5.54
6	(7+0) CSRB-(6:0:70:30)	7.27
7	(5+0) CSRB-(6:0:70:30)	4.06
8	(5+0) CSRB-(6:0:70:30)	4.44
9	(5+0) CSRB-(6:0:70:30)	4.44
10	(6+0) CSRB-(6:0:70:30)	4.65
11	(6+0) CSRB-(6:0:70:30)	4.82
12	(6+0) CSRB-(6:0:70:30)	5.44
13	(4+0) CSRB-(6:0:70:30)	3.17
14	(4+0) CSRB-(6:0:70:30)	2.95
15	(4+0) CSRB-(6:0:70:30)	3.33

From the pilot study, six combinations are selected to cast CSRB of size (190X90X90) and 3 combinations is considered to cast CSRB of size (290X190X 90) mm. A comparative study is carried between two sizes by varying cement content 6%, 8% and 10%.

B. Compressive strength of CSRB: The compressive strength of CSRB of size (190X90X90) mm lies in a range of 4.88 to 8.11 Mpa for the cement content variation of 6% and 12%. The compressive strength of CSRB of size (290X190X90) mm lies in a range of 8.41 to 11.41 Mpa for the cement content variation in the range of 6% and 12%.

Table 5.2: Compressive Strength of CSRB

Sl.No	Mix Designation	Compressive Strength of CSRB at 28 days`	
		(190X90X90) mm	(290X190X90) mm
1	(6+0) CSRB-(6:0:70:30)	4.88	8.41
2	(8+0) CSRB-(6:0:70:30)	6.32	11.14
3	(10+0) CSRB-(6:0:70:30)	8.11	11.41

The pozzolanic materials are used as replacement for cement. For this study, The CSRB of size (190X90X90) mm with 8% cement is considered. The block of size with 8% cement is considered for extended study by replacing 25% of cement with pozzolanic materials such as Fly ash, Silica Fume, and GGBS.

Table-5.3: Compressive Strength of CSRB size (190X90X90) mm

Sl.No	Mix Designation	Compressive Strength of CSRB at 28 days`
1	(8+0) CSRB (8:0:70:30)	6.32
2	(6+2S) CSRB (6:2:70:30)	5.69
3	(6+2F) CSRB (6:2:70:30)	5.73
4	(6+2G) CSRB (6:2:70:30)	5.29

From the test results, the compressive strength of the CSRB is decreased as cement is replaced by pozzolanic materials. However, the difference in compressive strength among replacement of pozzolanic materials is quite marginal. The Maximum Compressive strength of 5.73 Mpa is noticed for the mix containing 25% of Fly ash. The percentage reduction in compressive strength is 10%, 9.33% and 16.3% for the 25% replacement of Silica Fume, Fly Ash and GGBS.

5.2 Density: Density is determined by measuring the weight of the specimen prior to the testing depending up on the specific gravity of the materials as well as compaction efforts. The density of CSRB of varies from 2000 to 2100 kg/m.

Table-5.4: Density of CSRB in SSD condition

Sl.No	Mix Designation	Density (Kg/m^3) of CSRB at 28 days	
		(190X90X90) mm	(290X190X90) mm
1	(6+0) CSRB-(6:0:70:30)	2046.24	2073.53
2	(8+0) CSRB-(6:0:70:30)	2058.15	2104.42
3	(10+0) CSRB-(6:0:70:30)	2053.82	2078.04

5.3: Dimensional Analysis of CSRB: The measurement of the length, breadth and height of the CSRB of both sizes is carried out as per the Indian standards.

Table-5.5: Measured Dimensions of CSRB (190x90x90) mm

Descriptions	Size (in cm)	Length (in cm)	Breadth (in cm)	Height (in cm)
As per IS Standards	19x 9x9	312 to 388	174 to 186	174 to 186
Measured Dimensions		384	184	184

Table-5.6: Measured Dimensions of CSRB (290X190X90) mm

Descriptions	Size (in cm)	Length (in cm)	Breadth (in cm)	Height (in cm)
As per IS Standards	29x 19x9	(570 to 590)	(312 to 388)	(174 to 186)
Measured Dimensions		584	385	185

From the test results, the dimensions of the brick are within the permissible limit as specified in the standards.

5.4 Rate of Water Absorption: The water absorption of CSRB is measured at a time interval of 15, 30, 60 and 120 minutes.

Table-5.7: Water Absorption of CSRB size (190X90X90) mm

Sl.No	Mix Designation	Soaking Duration in Minutes			
		15	30	60	120
		Water Absorption in %			
1	(6+0) CSRB (6:0:70:30)	5.73	8.47	10.42	12.1
2	(8+0) CSRB (6:0:70:30)	5.73	7.37	8.87	10.32
3	(10+0)CSRB (6:0:70:30)	4.03	5.54	7.01	8.66

Table-5.8: Water Absorption of CSRB size (290X190X90) mm

Sl.No	Mix Designation	Soaking Duration in Minutes			
		15	30	60	120
		Water Absorption in %			
1	(6+0) CSRB (6:0:70:30)	5.73	8.47	10.42	12.1
2	(8+0) CSRB (6:0:70:30)	5.73	7.37	8.87	10.32
3	(10+0)CSRB (6:0:70:30)	4.03	5.54	7.01	8.66

At the end of 120 minutes the Water absorption varies from 8 to 12% for the block of size (190 X 90 X 90) mm. The absorption value varies from 6 to 7% for the blocks of size (290X190X90) mm at the end of 120 minutes. The rate of water absorption of the mix containing GGBS is high as compared to the other mixes, this is attributed to presence of high percentage of calcium oxide in GGBS.

Table-5.9: Influence of Pozzolanic Materials on Rate of Water Absorption

Sl.No	Mix Designation	Soaking Duration in Minutes			
		15	30	60	120
		Water Absorption in %			
1	(6+28)CSRB(6:2:70:30)	5.70	7.37	9.13	10.51
2	(6+2F)CSRB(6:2:70:30)	6.8	7.26	9.09	10.71
3	(6+2G)CSRB(6:2:70:30)	5.7	9.57	10.89	12.23

5.5 Water absorption: The water absorption value of CSRB of size (190X90X90) mm varies from 11 to 14% and for size (290X190X90) mm varies from 6.5 to 8.5%. Both the values are within the permissible limit as per the Indian standards (should not be greater than 15%).

Table-5.10: Water absorption at 28 days maturity age

Sl.No	Mix Designation	Water Absorption in %	
		(190X90X90) mm	(290X190X90) mm
1	**(6+0) CSRB-(6:0:70:30)**	**14.05**	**6.77**
2	**(8+0) CSRB-(6:0:70:30)**	**11.43**	**7.28**
3	**(10+0) CSRB-(6:0:70:30)**	**11.41**	**8.31**

Further the water absorption value varies with replacement of cement with pozzolanic materials for designated mixes. The mix containing GGBS exhibits higher water absorption value as compared to other two. The reason may be the presence of Cao content in GGBS.

Table-5.11: Water absorption of CSRB comprising Pozzolanic Materials.

Sl.No	Mix Designation	Water absorption in %
1	(6+2S) CSRB (6:2:70:30)	**11.08**
2	(6+2F) CSRB (6:2:70:30	**11.69**
3	(6+2G) CSRB (6:2:70:30)	**13.39**

6. CONCLUSIONS

Based on the Experimental study the following conclusions were drawn:

1. The water content for CSRB mix is a n important factor which varies from 15 to 17% for the mixes considered in this study.
2. The compressive strength of the 15 mixes, considered on the pilot study is more than 3Mpa and hence these values are acceptable as per IS1725:1991.
3. For the same mix composition, the compressive strength of CSRB of size (290X190X90) mm exhibits higher strength than CSRB of Size (190X90X90) mm.
4. The least compressive strength of 4.88Mpa is observed for CSRB of size (190X90X90) mm comprising of 6% of Cement.
5. The specific gravity of the brick powder and the recycled sand is much lower as compared to that of river sand, Hence the proportion of the sand content in the mix plays an important significant role on the influencing the strength of Bricks.
6. The density of CSRB of both Dimensional Sizes varies from 2000 to 2150 Kg/$m^{3.}$
7. The maximum water absorption of CSRB size (190X90X90) mm is about 13% for the mix comprising of 2% of GGBS.
8. The dimensions of the brick casted in two different size are within the permissible limits as per Bureau of Indian Standards.

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