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Assessment of Potential of Brick Masonry Waste for the Production of Cement Stabilized Masonry Blocks - Experimental Study

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Abstract: **The general practice of recycling brick waste is to crush and use them as aggregates in concrete or low grade road base or sent directly for landfill. The author of the present study is of the opinion, that, such practices of brick waste utilization are really not sustainable, as, this inert waste can be utilized, to produce durable and attractive (in terms of color and texture) building units. With this premise, this experimental study is pursued to assess the potential of brick masonry waste for making Cement Stabilized Masonry Blocks (CSMB). The Brick Powder (BP) is obtained by crushing the brick masonry waste obtained from dump yards and used in conjunction with Natural Fine Aggregate (NFA). Fifteen mix compositions are considered by varying BP, NFA as 60:40, 70:30 and 80:20 respectively, with the percentage of cement content as 5, 8, 10, 12 and 15. Wet and dry compressive strength of each of the mix variants is determined by performing tests on cube specimens of size 70. 6mm.The wet compressive strength is found to be 0.75 times the dry compressive strength. A minimum of 10% of cement content is required to achieve the strength in excess of 3.5 Mpa.**

Keywords: **Cement Stabilized Masonry Blocks (CSMB), Brick Powder (BP), Natural Fine Aggregate (NFA).**

I. INTRODUCTION

Bricks are considered to be the second most widely used material after concrete. Bricks are mostly treated as waste, when broken or damaged during their production, or, from construction and demolition activities. It is observed that brick waste contributes significantly to the waste stream in India. Recycling concrete waste has been widely investigated and has now figured in different national codes of practice for building design and construction. However, the recycling of brick masonry waste has not received much attention, despite their presence all over the world. The general practice of recycling brick waste is to crush and use them as aggregates in concrete or low grade road base or sent directly for landfill. In author opinion, these practices of brick waste utilization are really not sustainable, as, this inert waste can be utilized, to produce durable and attractive (in terms of color and texture) building using the techniques similar to those adopted in the production of Soil Cement Blocks(SCB), which have evolved as an alternative to burnt clay bricks.

II. LITERATURE REVIEW

Experimental studies are outlined in the literature with respect to recycling of brick masonry waste [1-7]. These studies are focused towards the making of concrete mixes with brick masonry waste being used as a partial replacement for aggregates [1-3, 6] and cement [4-6]. It has been observed that the higher water absorption and low unit weight, limits its usage in the concrete mixes [1, 3, 6, 7]. D.M Sadek [8] has investigated the possibility of manufacturing different grades of solid cement bricks by using crushed brick aggregates for load bearing and non-load bearing units.

III. RESEARCH HYPOTHESIS AND OBJECTIVE

The author of the present study considers, the BP recovered from the brick masonry waste has the potential for making blocks suitable for masonry. The processed BP is inert in nature and has the properties similar to that of fine grained soil. However, the absence of clay content may demand a higher percentage of cement. The author is also of the firm opinion, that such recycled units cannot be considered as an alternative to fired clay bricks or other environmentally sustainable and economically viable options, such as Soil Cement Blocks, Aerated Autoclaved Concrete blocks and Fly-ash bricks, as they cannot certainly meet the demand. However, such recycled masonry units can really coexist with them and form an integrated option for recycling masonry waste. With these considerations, this experimental study is pursued to assess the feasibility of BP as an ingredient in the production of CSMB units.

IV. MATERIALS AND METHODS

A. Properties of the materials

Brick masonry waste were collected from different dump yard locations and reduced to powder form using Los Angeles Abrasion Testing Machine in the laboratory. The process of recovery of BP from masonry waste is depicted in Fig.1. The NFA and cement were procured from the local vendor. The physical properties of BP and NFA were determined as per IS: 2386-1963[9] and the results are given in Table.1. The test results are based on two trails. The chemical analysis of the BP is carried out by an ISO certified laboratory and it is given in Table 2.

Fig.1: The Process of recovery of BP from Brick masonry waste

Table 1: Physical Properties of BP and NFA

Attributes	**BP**	**NFA**
Specific Gravity	2.44	2.61
Fineness Modulus	1.77	2.1
Compacted Bulk Density (kg/m^3)	1713	1616

Table 2: Chemical Properties of BP

Composition	**Content (%)**
Silica	86.37
Alumina Oxide	0.32
Ferric Oxide	7.20
Calcium Oxide	0.78
Magnesium Oxide	0.24

The 43 grade Ordinary Portland cement conforming to IS: 8112-2013[10] is used throughout the study. The physical properties are, Specific Gravity = 3.04, Fineness (%) = 6.43, Standard Consistency (%) = 31, Initial and final setting time as 60 and 210 mins and Compressive Strength at 28 days = 46.22 Mpa.

B. Mix Constituents

The mix variants in the study are with respect to the composition of constituents based on the % weight of the mix. Fifteen mix compositions are considered by varying BP, NFA as 60:40, 70:30 and 80:20 respectively, with the percentage of cement content as 5, 8, 10, 12 and 15. The mix proportions along with their designations are indicated in Table 3. The water content of 16% of the total weight of the constituents is used for all the mixes considered in the study.

C. Casting and Curing

Ten cube specimens of size 70.6mm were cast for each mix combinations to determine the wet and dry compressive strength along with density at the end of 28 days. The mix constituents were spread into a tray and water is added and mixed thoroughly using a trowel. The mix is then filled into the moulds up to the top and with a collar in place excess material is filled and compacted up to a pressure of 3.0 MPa using Universal Testing Machine of 1000 kN capacity. The excess material above the mould is removed and the surface is finished with a trowel. The sequence of stages in the preparation of cube specimens is depicted in Fig. 2. The specimens were kept in the mould for a period of 10 hours for drying. Later the specimens were demoulded and it is subjected to intermittent spray curing for a period of 28 days.

D. Testing of Cube Specimen

1) Density and Compressive strength in wet condition

Five cube specimens of each mix constituents are tested for density and strength in wet condition. The specimens after 28 days of curing were immersed in water for 48 hours. After 48 hours of immersion period, the specimens were removed and water stains on the surface were wiped using a dry cloth to achieve saturated surface dry condition. Next, the weight of the specimens was recorded and it is tested for compression using compression testing machine with the rate of loading as 2.9 kN/sec.

2) Density and Compressive strength in Dry condition

Five cube specimens of each mix constituents are tested for density and strength in dry condition. The specimens after 28 days of curing were kept in the oven for 24 hours at a temperature of 100-110oC. After 24 hours, the specimens were removed from the oven and it is kept in ambient temperature for about 2 hours. Next, the weight of the specimens was recorded and it is tested for compression using compression testing machine with the rate of loading as 2.9 kN/sec.

Table 3: Mix Constituents

Sl.No	Mix Designation: C/BP/NFA	Cement (%)	BP (%)	NFA (%)
1	5/60/40	5	60	40
2	5/70/30		70	30
3	5/80/20		80	20
4	8/60/40	8	60	40
5	8/70/30		70	30
6	8/80/20		80	20
7	10/60/40	10	60	40
8	10/70/30		70	30
9	10/80/20		80	20
10	12/60/40	12	60	40
11	12/70/30		70	30
12	12/80/20		80	20
13	15/60/40	15	60	40
14	15/70/30		70	30
15	15/80/20		80	20

Fig.2: Casting of Cube Specimens

V. RESULTS AND DISCUSSIONS

The average values of density, compressive strength in wet and dry conditions along with their ratios, are listed in the following Table 4. The tested specimens are shown in Fig.3.The ratio of wet to dry compressive strength is always less than unity this observation is in line with the experimental studies conducted by Venkatarama Reddy B.V & Gupta. A [11] on Soil Cement Blocks.

Table 4: Average values and Ratio of Density and Compressive strength in Wet and Dry Conditions

Mix Designation C – BP/NFA	$\mu_{Density}$ (kg/m^3)		$\mu_{Compressive\ Strength}$ (MPa)		Ratio of $\mu_{Compressive\ Strength}$ (μ_{wet}/μ_{dry})	Ratio of $\mu_{Density}$ (μ_{wet}/μ_{dry})
	Wet	Dry	Wet	Dry		
5 - 60/40	1970	1847	1.7	2.3	0.74	1.07
5 -70/30	1951	1814	1.6	2.2	0.73	1.08
5 - 80/20	1932	1795	1.3	2.0	0.65	1.08
8 -60/40	1975	1824	3.5	4.0	0.88	1.08
8 - 70/30	1980	1823	3.3	3.7	0.88	1.09
8 - 80/20	1942	1771	3.1	3.5	0.88	1.10
10 - 60/40	1989	1866	4.7	5.7	0.83	1.07
10 -70/30	2008	1871	4.4	5.5	0.81	1.07
10 - 80/20	1980	1810	3.8	4.8	0.79	1.09
12 - 60/40	1999	1904	5.7	7.3	0.78	1.05
12 - 70/30	1970	1866	5.2	6.7	0.79	1.06
12 - 80/20	2008	1899	5.1	6.2	0.82	1.06
15 - 60/40	1984	1857	7.2	9.6	0.75	1.07
15 - 70/30	1961	1852	6.9	8.9	0.77	1.06
15 - 80/20	1913	1781	6.0	8.3	0.72	1.07

Fig.3: Cubes stacked after compressive strength test

E. Descriptive Statistics

The statistical parameters such as mean, standard deviation, minimum and maximum values of the average values of compressive strength and density in wet and dry condition are presented in Table 5 and 6. The ratios of average values of strength and density in both wet and dry conditions are found to be 0.79 and 1.07 respectively. Thus, under wet condition, a 21% decrease in strength and 7% increase in density when compared with the corresponding values in the dry condition is observed. The minimum wet compressive strength of 3.5MPa is attained with a minimum cement content of 10%. This is one of the compliance as per IS: 1725-2013[12]

The statistical analysis of experimental results of ninety cube specimens with respect to the average values wet and dry compressive strength are shown in the form of a scatter diagram in Fig.4. The correlation coefficient between the two parameters is found to be 0.99. This indicates that a perfect positive correlation exists between them. Further, the very high value of R^2 = 0.981, justifies, that a linear relationship also exists between them. The slope of the line, dy/dx = 1.3159, indicates that, the ratio μ_{Dry} / μ_{Wet} = 1.32. This leads to a useful conclusion, that, *"the wet compressive strength is about 0.75 times the dry compressive strength".*

Table 5: Statistical Parameters of Compressive Strength

Parameters	□□ $_{\text{Compressive Strength}}$ (MPa)										(□$_{wet}$ /□$_{dry}$)
	Wet					Dry					
	5%	8%	10%	12%	15%	5%	8%	10%	12%	15%	
μ	1.5	3.3	4.3	5.3	6.7	2.2	3.7	5.3	6.7	8.93	0.79
σ	0.2	0.2	0.5	0.3	0.6	0.15	0.25	0.5	0.6	0.65	0.07
Min	1.3	3.1	3.8	5.1	6.0	2.0	3.5	4.8	6.2	8.3	0.65
Max	1.7	3.5	4.7	5.7	7.2	2.3	4.0	5.7	7.3	9.6	0.88

Table 6: Statistical Parameter of Density

Parameters	$\mu_{Density}$ (kg/m^3)		□$_{wet}$/□$_{dry}$
	Wet	Dry	
μ	1971	1839	1.07
σ	27.3	40.3	0.01
Min	1913	1771	1.05
Max	2008	1904	1.1

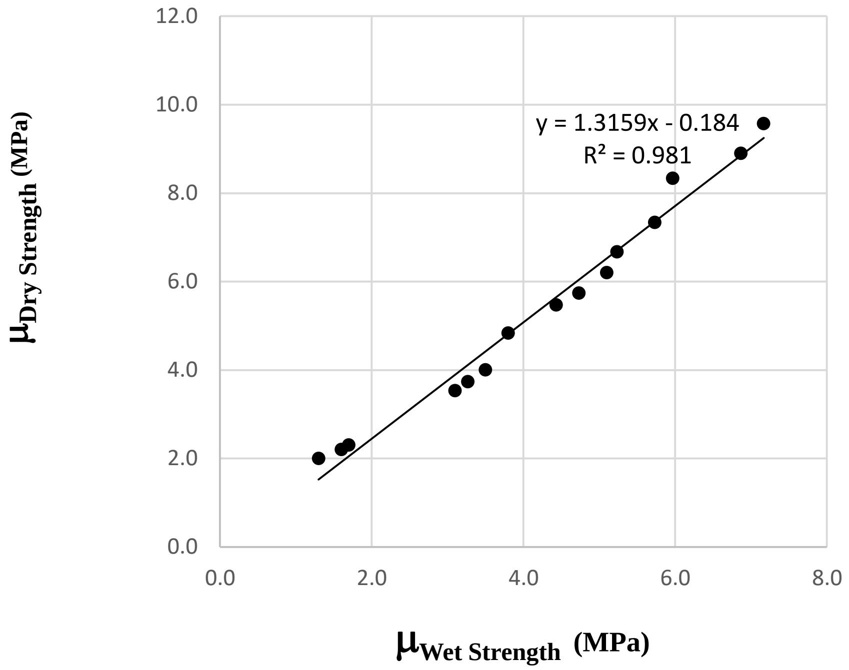

Fig.4: Scatter Diagram

F. Influence of Cement Content on Average Compressive Strength

The average wet and dry average compressive strength, for different percentages of cement content as 5, 8, 10, 12 and 15, as well as, for three different proportions of BP and NFA as 60:40, 70:30,80:20 are shown in Fig.5, Fig.6, and Fig.7 respectively. The value of R^2, being very nearly equal to one in all the cases, indicates a perfect linear trend in their variation. For all the three different proportions of brick powder and NFA, both wet and dry average compressive strength, are found to increase linearly, with an increase in the percentage of cement content. This is in line with the observation made by Venkatarama Reddy B.V & Gupta. A (2005). It is observed that, even for different mix compositions with BP and NFA, the slope (dy/dx) of the trend lines is close to about 0.7 and 0.5 in dry and wet conditions respectively. This strongly reflects the dominance of cement content on compressive strength.

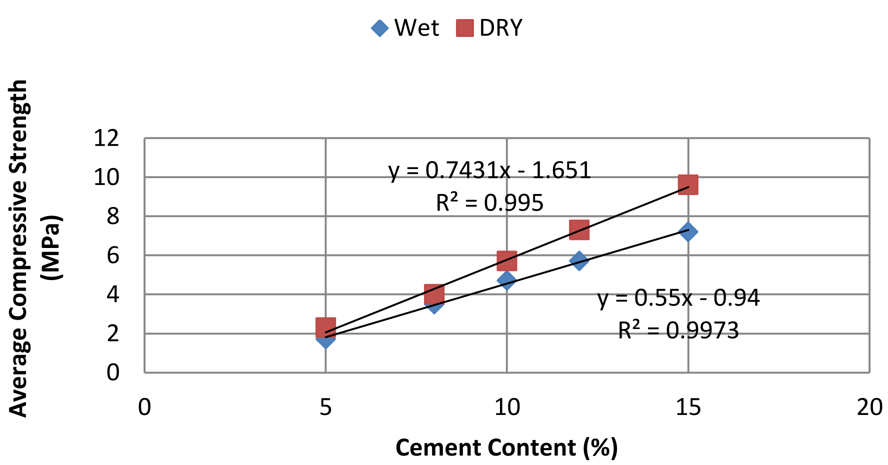

Fig.5: Average Compressive Strength for the mix with 60:40 of BP and NFA

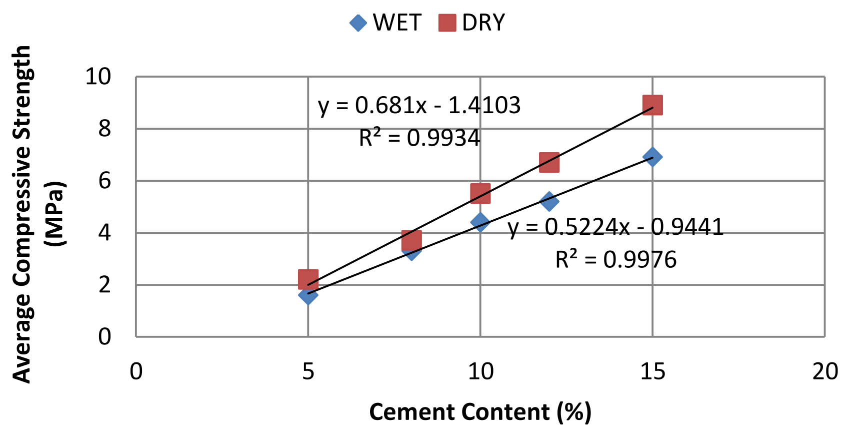

Fig.6: Average Compressive Strength for the mix with 70:30 of BP and NFA

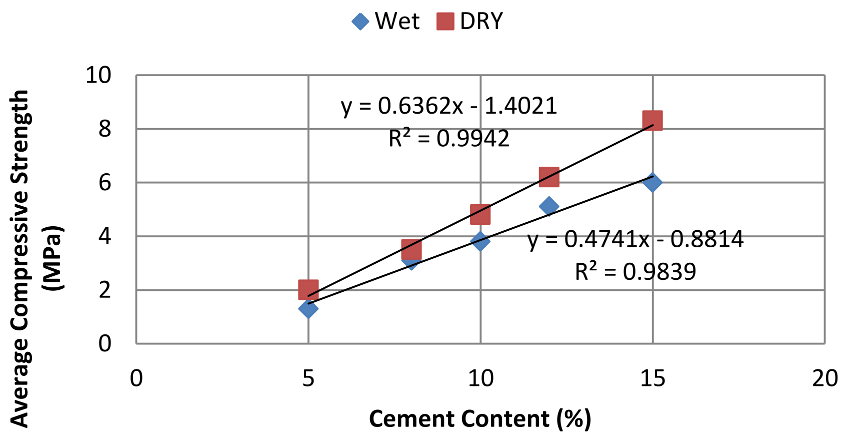

Fig.7: Average Compressive Strength for the mix with 80:20 of BP and NFA

G. Influence of BP or NFA content on Average Compressive Strength

The average compressive strength both in wet and dry conditions for different NFA and cement contents are tabulated in Table 7. The correlation coefficients between compressive strengths and NFA contents for different percentages of cement content are found to be very nearly equal to unity. This indicates that a perfect positive correlation exists between them. One interesting observation is that, as NFA content decreases or BP content increases, both wet and dry compressive strengths are found to decrease. This also justifies the necessity of blending the BP with NFA with a view to improving the workability of the mix.

Table 7: Average compressive strength both in wet and dry conditions for different NFA and cement contents

Cement	**5%**		**8%**		**10%**		**12%**		**15%**	
NFA (%)	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
40	1.7	2.3	3.5	4.0	4.7	5.7	5.7	7.3	7.2	9.6
30	1.6	2.2	3.3	3.7	4.4	5.5	5.2	6.7	6.9	8.9
20	1.3	2	3.1	3.5	3.8	4.8	5.1	6.2	6.0	8.3
CC*	0.96	0.98	1.00	0.99	0.98	0.95	0.93	1.00	0.96	1.00

CC*: Correlation Coefficient between NFA(%) and Average Compressive Strength

The plots of variation of average compressive strength versus NFA content, for different percentages of cement content, are also shown in Fig. 8. The plots reveal almost a perfect linear trend. This is also confirmed, by the value of R^2 being very nearly equal to unity. The regression equations, for different cases of the study, are listed in the following Table 8. In all the cases, the slope (dy/dx) of the trend lines is very less, for both dry and wet conditions. This strongly reflects the lesser dominance of NFA content, on compressive strength when compared with cement content.

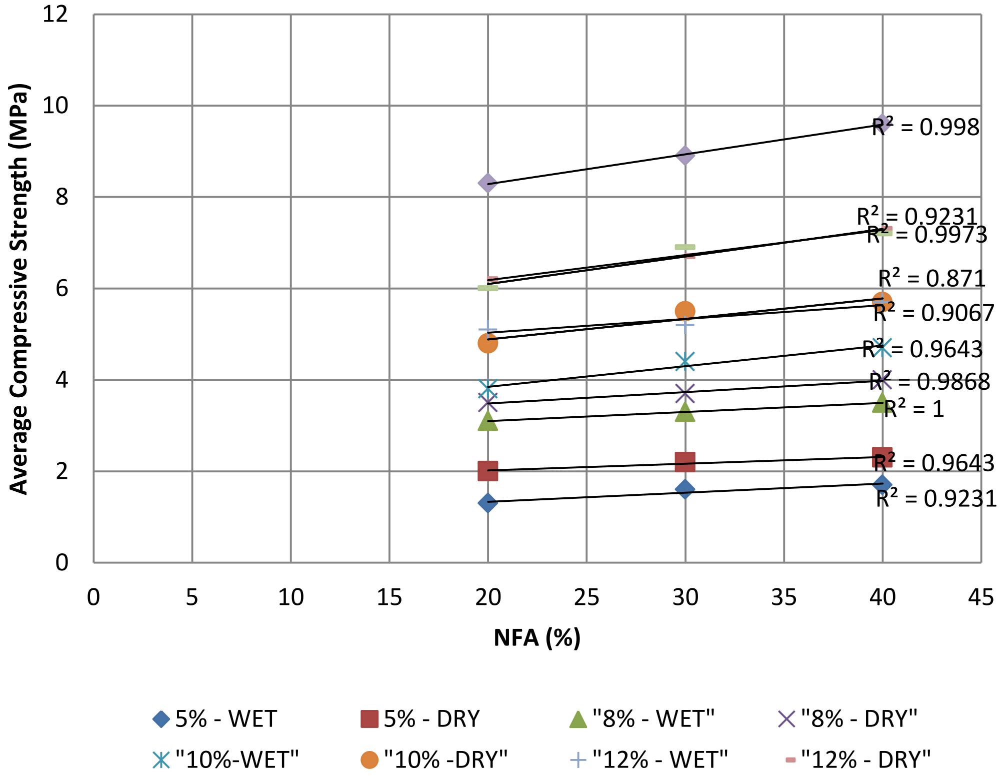

Fig.8: Average Compressive Strength versus NFA content

Table 8: Regression equations

Cement (%)	Wet	Dry
5	y = 0.02x + 0.93	y = 0.015x + 1.72
8	y = 0.02x + 2.70	y = 0.025x + 2.98
10	y = 0.045x + 2.95	y = 0.045x + 3.98
12	y = 0.03x + 4.43	y = 0.055x + 5.08
15	y = 0.06x + 4.90	y = 0.065x + 6.98

VI. CONCLUSIONS

The primary outcome of the study is that the processed brick waste can be utilized in the production of CSMB units. The utilization of BP leads to waste minimization and natural resources conservation. The statistical analysis of experimental results of ninety cube specimens, with cement, BP and NFA contents as prime variants, indicate the following tangible inferences.

i. Wet compressive strength is about 0.75 times the dry compressive strength.

ii. Cement content has a major influence on compressive strength. Minimum cement content should be 10%, so as to achieve a minimum compressive strength of 3.5 MPa. 15% cement content results in higher strength beyond what is necessary, and, as such can be considered only under special requirements.

iii. Brick powder or NFA content has a relatively minor influence on compressive strength, but, is still justifiable to blend both of them, as an increase in NFA content results in 10% improvement in compressive strength as well as yield a workable mix

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