Study of Strength and Workability of Different Grades of Concrete by Partial Replacement of Fine Aggregate by Crushed Brick and Recycled Glass Powder

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Abstract: ***Concrete is the most indisputable and indispensable material being used in infrastructure development throughout the world. Umpteen varieties of concretes 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 but their availability is continuously being depleted due to the intentional overexploitation throughout the globe due to rapid urbanisation and construction of other amenities. Hence, partial replacement of fine aggregate by the other compatible material like sintered fly ash, crushed rock dust, quarry dust, glass powder, recycled concrete dust and others are being researched from the past two decades, in view of conserving the ecological balance. In this direction, an experiment investigation of strength and durability was undertaken to use "Spent Fire Bricks" (SFB) (i.e. waste material from foundry bed and walls; and lining of chimney which is adopted in many industries) and "Glass Powder" for partial replacement of fine aggregate in concrete. This paper recommends that glass powder and brick powder can be used as an alternate construction material to fine aggregate in concrete.***

Keywords: Glass powder; brick powder; workability; fine aggregate; ASR (Alkali Silica Reaction); Compressive strength.

1. Introduction

Concrete is the most widely used man-made construction material in the world and is second to water as the most utilized substance on the planet (Gambhir, 2006). A major portion of this concrete volume is occupied by coarse and fine aggregate. The demand for aggregate is enormous in liberalization, privatization and globalization, and in the construction of important infrastructure projects like Expressways, Airports, nuclear plants etc. The increased extraction of coarse and fine aggregate from the natural resources is required to meet this high demand. The increasing use of natural fine aggregate creates an ecological imbalance. Thus, partial replacement of fine aggregate is vital in construction industries. Aggregates are the most important constituents in the concrete mix that help in reducing shrinkage and impart economy to concrete production. Most of the aggregate used are naturally occurring aggregates. On the other hand, the modern technological society is generating substantially high amounts of solid wastes both in municipal and industrial sectors; posing an engineering task for effective disposal. Hence, partial or full replacement of fine aggregate by other compatible materials like sintered fly ash, quarry dust, glass powder, brick powder etc. is needed in view of conserving the ecological balance.

In region such as Bangladesh and West Bengal (India), where natural aggregate deposits are scarce, brick powder is used as an alternative source of aggregate. Here, construction of rigid pavement, small to medium span bridges, culverts and buildings up to six stories high using brick aggregate concrete are quite common (Mansur et.al., 1999). Brick chips are easily available in the region and are much cheaper than the crushed stone aggregate. In spite of its extensive use and the apparent satisfactory performance of structure built by concrete using brick aggregate, no systematic investigation on mix design of brick aggregate concrete has been conducted and properly documented (Akhtrauzzaman and Hasnat, 1983).

In order to make concrete industries sustainable, the use of waste material in place of natural resources is one of the best approaches. In India, 0.7% of total urban waste generated comprises of glass [1]. UK produces over three million tons of waste glass annually [2]. Waste glass is crushed into specified sizes for use as aggregate in various applications such as water filtration; girt plastering, sand cover for sport turf and replacement in concrete [3]. The use of river sand as fine aggregate leads to exploitation of natural resources, lowering of water table, sinking of bride piers and erosion of river bed. If fine aggregate is replaced by waste glass by specific percentage and in specific size range, it will decrease fine aggregate content and thereby reducing the ill effects of river dredging and thus making concrete manufacturing industry sustainable. Utilization of this waste is the need of the hour. There is huge potential for using waste glass in the concrete construction sector. When waste glasses are reused in making concrete products, the production cost of concrete will go down [4]. This move will serve two purposes; first it will be environment friendly; second, it will utilize waste in place of precious and relatively costlier natural resources. The usage of waste glass as fine aggregate in concrete creates a problem in concrete due to ASR (Alkali Silica Reaction).The reaction between alkalis in Portland cement and silica in aggregate forms silica gel. This gel is prone to swelling. It absorbs water and the volume of the gel increases. Under confinement by cement matrix and aggregate, the swelling of the ASR gel generates hydrostatic pressure. If the reaction continues and internal pressure exceeds the tensile strength of the matrix, cracks will form around the reactive aggregate particles [5]. Ground waste glass was used as fine aggregate in concrete and no reaction was detected with fine particle size, thus indicting the feasibility of the waste glass reuse as fine aggregate in concrete. Larger the particle size of waste glass, more is the chance of ASR occurrence. Shayan and Xu reported fine glass powder for incorporation into concrete up to 30% as a pozzolanic material the ASR [7]. Hence, the size of waste glass used was in range 75 micron to 4.75 mm.

2. Literature Survey

Common river sand is expensive due to its cost of transportation from natural sources to desired place. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas. Whose continued use has started posing serious problems with respect to its availability, cost and environmental impact?

3. Concrete Mix Design

The requirement which forms the basis of selection and proportioning of mix ingredients are:

(1) The minimum compressive strength required from structural consideration.

(2) The adequate workability necessary for full compaction with the compacting equipment available.

(3) Maximum water cement ratio and/or maximum cement content to give adequate durability for the particular site conditions.

(4) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

3.1 Types of mix

a) **Nominal Mix:** The past specifications for concrete prescribe the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio ensure adequate strength, termed as nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

b) **Standard Mix:** The nominal mix of fixed cement-aggregate ratio (by volume) varies widely in strength and may result in under or over rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed as standard mixes.

c) IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30 M35 and M40. The mixes of grade M10 M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

d) **Designed Mix:** In these mixes, the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide, since; this does not guarantee the concrete mix proportion for the prescribed performance.

e) For the concrete with undemanding performance, nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28 days strength of concrete does not exceed 30 N/mm^2.

4. Material Used

In conducting the experimental studies in the laboratory following materials are used:

Cement: PPC (Portland Pozzolana Cement) conforming to IS 1489-1991 part 1 brand name ACC Cement is used in the entire work. Specific gravity of cement is 3.15.

Table 1: Lab Test Result Conducted on cement

S. No.	*Name of Test*	*Result Obtained*	*Requirement as per IS:*
1	Consistency	33.21%	-
2	Initial setting Time	191 Min	Not less than 30 Min
3	Final Setting Time	254 Min	Not less than 600 Min
4	Compressive Strength 3Days	26 MPa	Not less than 16 MPa
5	7 Days	30.7 MPa	Not less than 22 MPa
6	28 Days	46.8 MPa	Not less than 43 MPa

Sand: Fine aggregate resulting from natural disintegration of rock and which passes 4.75 mm IS sieve and contains 75 micron and conforms to IS 383-1970, zone-2 used in entire work. River sand with fineness modulus of 2.24 is used in this study.

Table 2: Grading of Fine Aggregate

Sieve Size	*Percentage passing*	*Requirement IS: 383-1970*
4.75 mm	99.2	90–100
2.36 mm	85.2	85–100
1.18 mm	68.7	75–100
600 micron	55.3	60–79
300 micron	21.4	12–40
150 micron	4.6	0 –10

Coarse Aggregate: Coarse aggregate which passes 20 mm IS sieve and retained 4.75 mm, naturally occurring crushed stone used in the work.

Table 3: Grading of coarse aggregate

Sieve Size	*Percentage passing*
40 mm	100
20 mm	98.7
10 mm	15.4
4.75 mm	3.6

Brick Powder: Brick bats crushed in coarse powder form were used as a fine aggregate for making concrete. The waste bricks as obtained from garbage of a broken building were collected and pulverized to get the particle passing 4.75 mm sieve and retained on 0.075 mm sieve to get the grading of fine aggregate. 10, 20 and 30% brick powder is used as replacement of sand in the experiments.

Glass Powder: Glass is widely used in our day to day life through manufactured products such as sheet glass, bottles, glassware and vacuum tubing. Glass is an ideal material for recycling. The waste glass was obtained from the dump of broken windows and doors panels. It was pulverized to get the particles ranging 4.75 mm and 0.075 mm in order to achieve the grading of fine aggregate. The different percentage of sand replaced by glass powder was 10%, 15%, & 20%.

Water: The potable water was used here for making concrete mix.

5. Methodology

After procuring the ingredient for making the design of concrete mixes of M-20, M-25 & M-30 grades was done for natural fine and coarse aggregate. Concrete cubes of sufficient number were casted by mixing the different proportions as obtained in the design mix. The workability of concrete mixes was measured by the slump tests. Curing of concrete cubes for 3 days, 7 days and 28 days was done. Three cubes of concrete of size 150 x 150 x 150 mm of all designed grades were tested for crushing strength at the end of 3 days, 7 days and 28 days. The specimens were demoulded after 24 hours of casting and cured at 27 ± 2 °C until the test age. Fine aggregate is then replaced by brick powder. Now the workability and crushing strength of concrete at the end of 3 days, 7 days and 28 days was determined. Similar procedure was adopted for glass powder.

6. Results and Discussion

6.1 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-20, M-25 and M-30 grade of concrete. The cubes were crushed in the laboratory in accordance to code IS 1343-1980. The results of crushing strength of cubes for 3, 7 and 28 days of various grades of concrete prepared as per mix design are shown below:

It is observed that the compressive strength of cubes (sand is partially replaced by brick powder) of M-20 mix decrease initially at 10% brick powder. But as percentage of brick powder increased to 20% strength increases and further increase in brick powder again reduces the strength.

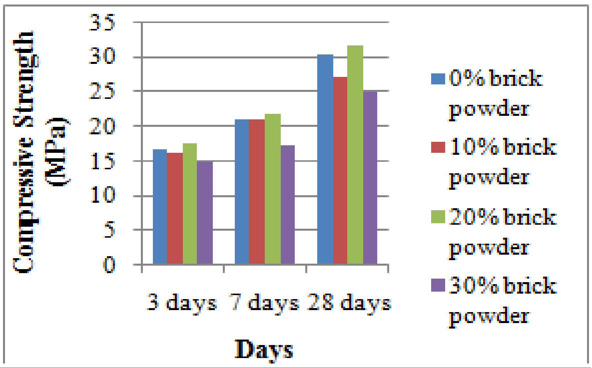

Figure 1: Comparison of compressive strength of M-20 mix for different percentage of brick powder

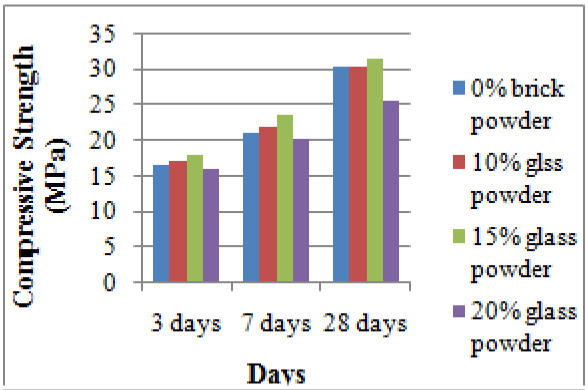

Figure 2: Comparison of compressive strength of M-20 mix for different percentage of Glass powder

Compressive strength of cubes (sand is partially replaced by brick powder) of M-20 mix increases up to 15% glass powder. As glass powder exceeds 15%, compressive strength decreases. In M-25 and M-30 concrete mix, compressive strength also follows the same trend as it did in the M-20 mix. Compressive strength is maximum at 20% brick powder, and then it starts decreasing.

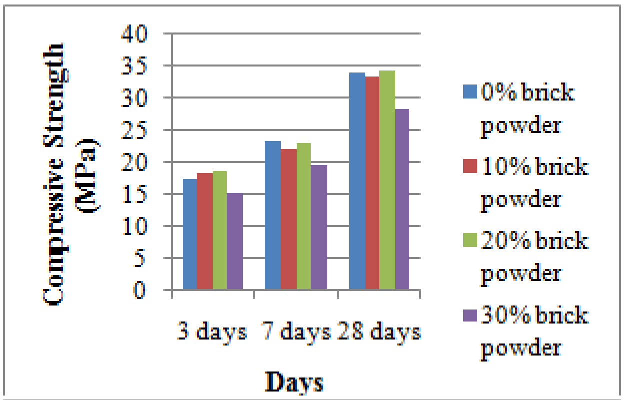

Figure 3: Comparison of compressive strength of M-25 Mix for different percentage of brick powder

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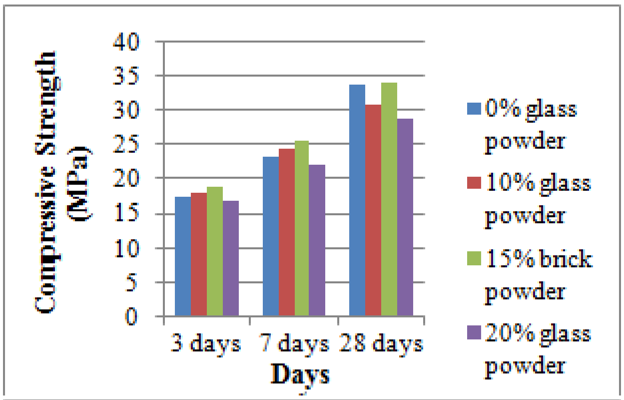


Figure 4: Comparison of compressive strength of M-25 Mix for different percentage of Glass powder

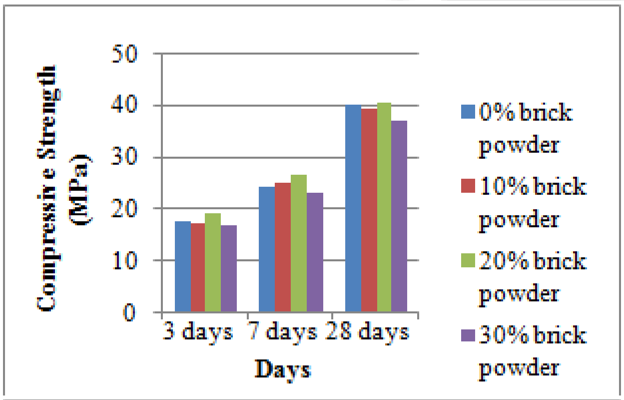


Figure 5: Comparison of compressive strength of M-30 Mix for different percentage of brick powder

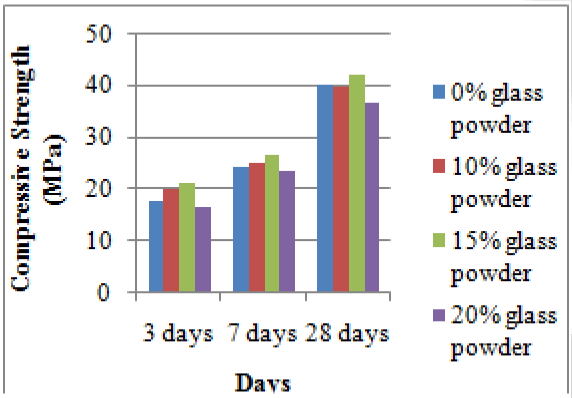


Figure 6: Comparison of compressive strength of M-30 Mix for different percentage of brick powder

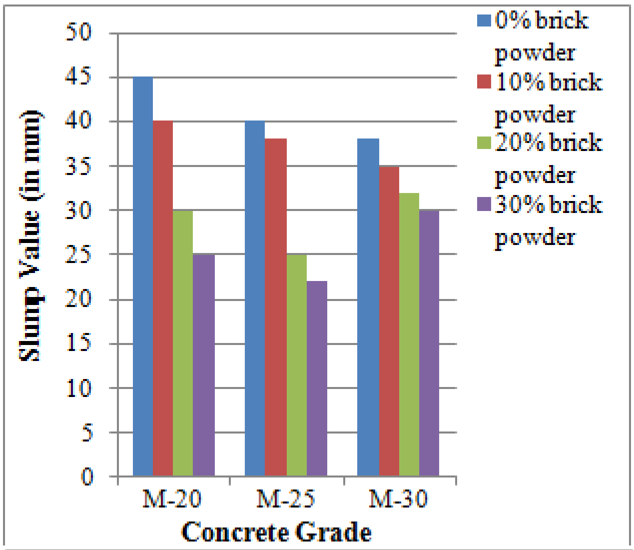
Optimum percentage of glass and brick which can replace sand is 15% and 20% respectively. Compressive strength of cubes corresponding to these percentages of glass and brick powder is more than the strength corresponding to 0% glass and brick powder which clearly indicates that sand can be partially replaced by glass or brick powder.

6.2 Workability

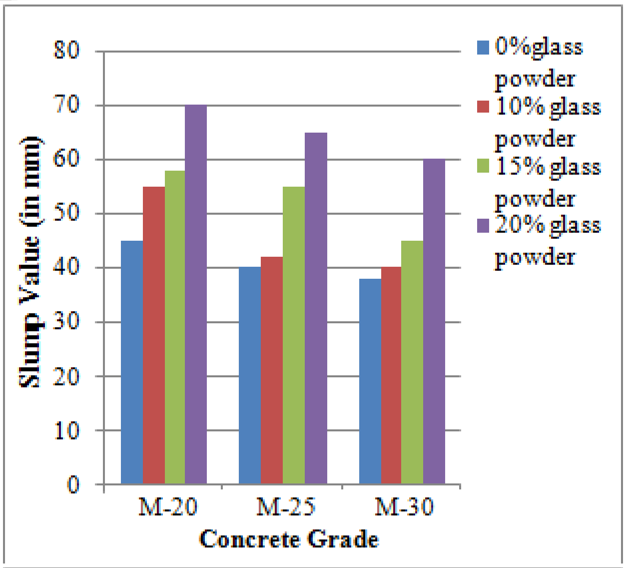
The slump tests were performed according to IS 1199-1959. The value is presented in table below:

Table 4: Slump value of concrete

Waste material (%)	*Slump (mm)*		
Brick Powder	M-20	M-25	M-30
0	45	40	40
10	40	38	35
20	30	25	32
30	25	28	30
Glass Powder			
10	55	40	40
15	58	55	45
20	70	65	60



Figurer 7: Variation of slump value of concrete with brick powder content



Figurer 8: Variation of slump value of concrete with glass powder content

The results show that with increase in brick powder, the slump value decreases and with increase of glass content, the slump value increases.

7. Conclusions

On the basis of results obtained, following conclusions can be drawn:

(1) The replacement of fine aggregate by crushed brick powder is found to be very effective. The optimum replacement is found to be 20% at which the strength of concrete at 3 days, 7 days & 28 days are higher than those of concrete prepared without replacement of sand. Even at 30% replacement of sand, there is a marginal decrease in the achieved strength at 3, 7 & 28 days. The target strength is 26.6 MPa for M-20 grade of concrete whereas at 28 days, the achieved strength is 25.10 MPa, thus, there is a deficiency of only 5.6%. The target strength is 31.6 MPa for M-25 grade of concrete whereas at 28 days, the achieved strength is 28.5 MPa, thus there is a deficiency of only 9.81%. The target strength is 38.25 MPa for M-30 grade of concrete, whereas at 28 days the achieved strength is 37.40 MPa, thus there is a deficiency of only 2.22%.

(2) Similarly replacement of fine aggregate by crushed glass powder is also found to be very effective. The optimum replacement is found to be 15% at which the strength of concrete at 3 days, 7 days & 28 days are higher than those of concrete prepared without replacement of sand. Even at 20% replacement of sand there is marginal decrease in the achieved strength at 3, 7 & 28 days. The target strength is 26.6 MPa for M-20 grade of concrete whereas at 28 days the achieved strength is 25.80 MPa, thus there is a deficiency of only 3%. The target strength is 31.6 MPa for M-25 grade of concrete whereas at 28 days the achieved strength is 28.8 MPa, thus there is a deficiency of only 8.86%. The target strength is 38.25 MPa for M-30 grade of concrete whereas at 28 days the achieved strength is 35.90 MPa, thus there is a deficiency of only 6.14%.

(3) Where ever brick bat aggregates are used made from slightly over brunt bricks, this will be hard and eventually absorb less water.

(4) Results of this investigation suggest that brick powder or glass powder could be very conveniently used in structural concrete.

8. Future Scope

Large scale exploitation of natural sand and expensive transportation cost, it has become necessary to find any other alternative of sand. Replacement of sand will not only save the natural sources for future generation but will also prevent the environment by using waste material as fine aggregate.

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