Evaluation of Strength Characteristics of Pavement Quality Concrete Mixes using Glass Powder and Manufactured Sand

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Abstract *- In this paper an experimental investigation is done to determine the suitability of Glass Powder as a partial replacement of cement and manufactured sand as a complete replacement of fine aggregate (normal river sand).As we know that Concrete being the most important and widely used construction material after water around the world, plays a leading role in the development of sustainability in construction industry. The concrete used for the construction of rigid pavements, runways etc. is known as pavement quality concrete (PQC). In highway pavements, due to varying traffic condition, the formation of micro cracks in the (PQC) layer takes place under the combined effect of wheel load stress and temperature stresses. Such formation of cracks leads to decrease in both compressive and flexural strength characteristics, thus PQC layer deteriorates rapidly. The aim of this study is to investigate the possibility to improve the compressive strength, flexural strength over a range of glass fined powder with using complete manufactured sand. Waste glass is the least expensive of all concrete ingredients and is much less expensive than natural aggregates and sand and cement, thus the idea is to replace as much of the natural sand by manufactured sand and cement by glass powder as possible to save money and to reduce the amount of disposable wastes. This research attempts to study the suitability of using locally available GP (Glass Powder) as a partial application for cement in concrete. Glass Powder (GP) was used at 10%, 20% and 30% cement replacement levels with the aim of reducing the cement consumption in concrete and the effect of the Glass Powder on the workability, compressive and flexural strength was investigated. The PQC (Pavement Quality Concrete) containing Glass Powder was also found to have 20-30% higher slump value, 12-14% higher compressive strength, 5-8% higher flexural strength as compare to conventional concrete which indicated good quality of concrete. Manufactured Sand was used at 100% replacement of natural river sand with the aim to make a proper balance with nature by minimizing the use of river sand which leads the disturbance in bed level of a river and offers other natural disasters like flood and drought as well. The concrete containing manufactured sand was also found to have 25-27% lower slump value, 14-16% higher compressive strength, 12-14% higher flexural strength as compare to conventional concrete which indicated good quality of concrete. By conducting various experimental investigation, Glass Powder and Manufactured Sand are also found to be beneficial in enhancing the compressive, flexure strength gain.*

Key Words: PQC, GP, Compressive Strength, Flexure Tensile Strength, Robo Sand /Manufactured Sand

1. INTRODUCTION

Concrete is one of the most extensively used construction material. Concrete is generally associated with Portland cement and Fine aggregate as the main constituent for making concrete. Due to restriction imposed on sand mining by government, results shortage of natural river sand. The price of natural river sand is increasing day by day due to immense material demand and infrastructure development in India. A huge number of construction industries use normal sand only as fine aggregate to make concrete. The alternatives for natural river sand (fine aggregate) admit manufactured sand, industrial waste (kind of slag, copper slag bottom ash), reusable aggregates, etc. Among the above mentioned materials, manufactured sand(artificial sand) is comparatively receiving consideration as a replacement for natural river sand. The M-sand/Robo sand is obtained by impact rock deposits to get a well graded fine aggregate. Generally, M- sand contains high fines. Stone dust is the major constituent of these fines. This paper very much highlight on the suitability of components to be replaced by normal sand which will give new era to concrete mix design and if it is being applied on large scale would change the construction industry by cutting down the construction expenditure on the other hand the use of Glass Powder can reduce the consumption of cement in construction industry which leads to the decrement in CO_2 emission and gives a health environment to live in. Along this Glass Powder offers better use of steel industry waste in a fruitful way that surely economize the project as well and enable us to preserve natural resources. This paper also enhances the potential of this particular area by providing the careful study of some research papers which is related to this topic. The particular review integrates all the important results. This review paper summarizes the conclusion on the basis of results that are obtained by researchers, conducted for various mechanical properties of concrete like strength, durability etc. The paper review shows the positive as well as negative changes in the mechanical properties of GP based concrete on the partial replacement of natural river sand by manufactured sand.

1.2 Glass Powder

Glass is unshaped material with high silica content, in this way making it potencially pozzolanic when particle size is under 75µm Studies have determined that finely ground glass does not add to alkali – silica reaction process. and there is different tests and research have been made to utilize ground glass powder as a substitution of conventional ingredients in concrete making as a part of green house management. Glass powder strengthened cement comprises of 4 to 4.5 percentage by volume of glass fiber mix into cement or cement sand mortar. This glass reinforced cement mortar is utilized for manufacturing solid products having an diameter of 3 to 12 mm in thickness. Glass Powder comprises of same constituents which are available in ordinary portland cement like calcium oxide, silica, alumina, magnesium oxide. The major difference is that these constituents are available in different proportions. Proportions of ingredients of Glass Powder are mentioned below:

Table 1: Composition of Glass Powder

Ingredients	Proportions
SiO2	99. 5%
Al2O3	0. 08%
TiO2	0. 04%
CaO	0. 01%
MgO	0. 01%
L.O.I.	0. 28%
Alkalies	0. 29%
Fe2O3	0. 04%
Heavy Metal:	
Lead	N.A
Arsenic	N.A

1.2.1 Application of GP in construction

- Highly durable and safe
- Able to increases the compressive strength, flexural strength, split tensile strength, when used in different % by partial replacement of cement or by partial replacement of fine aggregates by weight.
- Available in very low cost approx 5 rupee per kg.
- When used in rigid pavement construction, it is able to increase the strength of pavement more than, when compared to convention PQC mixes.
- Design freedom since GP-PQC is able to be molded into almost any shape and color
- Pavement Requires very low maintenance
- Easy to use and cost effective
- Weather and fire resistant
- Economical

1.3 Manufactured Sand

Artificial sand (M-Sand) is a substitute of river sand for concrete construction. M-sand is delivered from hard rock stone by smashing. The pounded sand is of cubical shape with grounded edges, washed and reviewed to as a construction material. The measure of artificial sand (M-Sand) is under 4.75mm. It is a result of running stones through a crushing machine to make pounded stone. Its correct structure will clearly rely upon what sort of stone was go through the machine. For example, now and then stone is go through such a machine; in different cases, it could be limestone, for instance. The machine has a screen that traps the bigger material (that is, the squashed stone). The littler material or "screenings" falls through the screen. Contingent upon the extent of the openings in the screen utilized, it can be so fine in surface that it is essentially a powder.

2. METHODOLOGY

2.1 Workability

Slump test is adopted as the primary measure of concrete workability confirming to IS: 1199-1959, and was performed to evaluate the influence of Glass Powder and manufactured sand on workability. The apparatus for conducting the slump test consist of metallic mould in the form of frustum of cone having internal dimensions, bottom diameter 20 cm, top diameter 10 cm and height 30 cm. For the concrete used for Pavement Quality Concrete, a slump value between 25mm to 50mm is desirable. The Slump test was conducted for mixes with required slump value and then, those mixes were used for casting of specimen.

Fig 1: Slump Test

2.2 Compressive Strength

The cube specimens are tested for compression and the ultimate compressive strength is determined with the help of compressive testing machine (CTM). The average value of compressive strength of three specimen for each percentage replacement at the age of 7,14 28 days were studied.

Fig. 2: Compressive Strength Testing Machine(CTM)

$$f'c = Pc / A$$

Where,

Pc = Compressive Failure load, (kN)

A = Loaded area of cube, (mm^2)

2.3 Flexural Strength

Flexural strength tests are conducted on universal testing machine (UTM) of 600 KN capability. Generally three beams of 700*150*150 mm from each batch are subjected to this test. The relatively study is done on assets of concrete with percentage replacement of cement by glass powder in the area of 0%, 10%, 20%, 30%. The flexural strength of concrete beam specimen was calculated as

$$F_b = PL/bd^2$$

Where,

F_b=flexural stress, MPa,

b=measured width in cm of the specimen d=depth in mm of the specimen.

l=length in mm of the span on which the specimen was supported

p=maximum load in kg applied to the specimen.

Fig.3: Flexural Strength Testing Machine (UTM)

2.4 Ultra-sonic Pulse Velocity Test

The ultrasonic pulse velocity method can be used to evaluate the homogeneity of the concrete, presence of cracks, voids and other inadequacies, changes in the structure of the concrete which may occur with time, the quality of the concrete in relation to standard requirements, the quality of one element of concrete as compare to others. The pulse velocity can be used to assess the quality and uniformity of the material. The path length for the UPV through the concrete specimen is of 150 mm.

$$V = L/T$$

Where;

V = Pulse velocity

L = Path length

T = Transit time

Fig 4: Ultra-sonic Pulse Velocity Test being conducted on GP-PQC specimens

3. Experimental Investigation

This particular section shows the review of literature including research papers, reports and case studies.

3.1 Mix Proportioning

The M40 pavement quality concrete mix is designed as per IS:44-2008.This Research is conducted in single phase, in that phase along with conventional PQC mix of M40 grade concrete we cast the cubes with partial replacement of cement by 10%, 20%, 30% of Glass Powder and replacement of natural river sand by 100% Manufactured sand, carried out to determine optimum percentage of replacement of cement by Glass Powder at which max. Compressive, flexural strength, is achieved. Mixing time of concrete by manual means is totally 5 minutes. Compaction is done by using a 16mm rod in layers with 25 strokes for each layer. Before curing, concrete is left for 24 hours in the moulds and then demoulded and placed in curing tanks until the day of testing. 3 specimens were prepared for each set, and tested after 7, days & 28 days of curing from the date of casting.

3.2 Method of Testing

Workability of concrete is tested as per IS:1199-1959

Compressive strength and flexural strength of cubes are tested as per IS: 516-1959.

4. Results & Discussions

After 7, 14 & 28 days of curing, workability, compression, & flexural strength tests were conducted on concrete and there results have been discussed below

4.1 Results and analysis of GP-PQC

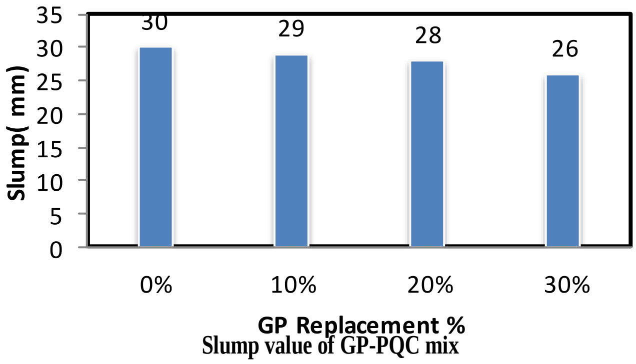

Fig 5: Results of Slump Test on GP-PQC Mixes

On 10%, 20% and 30% replacement, a gradual decrease of slump value is seen. On 10%, 20% and 30% replacement we are getting 29mm, 28mm and 26 mm slump value respectively. Hence it is observed that replacing 10%, 20%, 30% cement with GP there is an decrement of 3.44%, 7.14%, 15.38% in slump value with respect to conventional PQC.

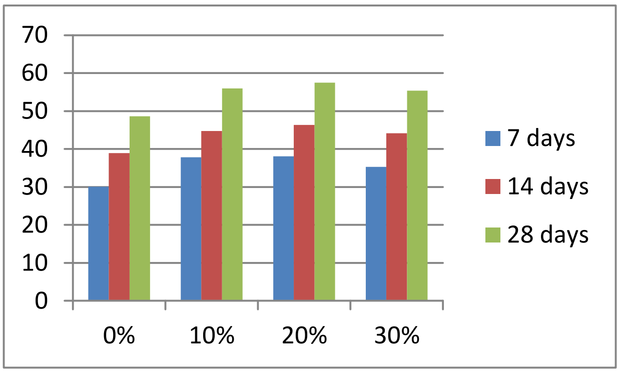

Fig 6: Graphical Representation of Compressive Strength Test on GP-PQC Mixes

It was observed that, with the addition of GP, the compressive strength of GP-PQC showed increasing trend upto 20% after that it shows a decrement in the present study. After these experimental program we can say that GP gives optimum results with 20% replacement.

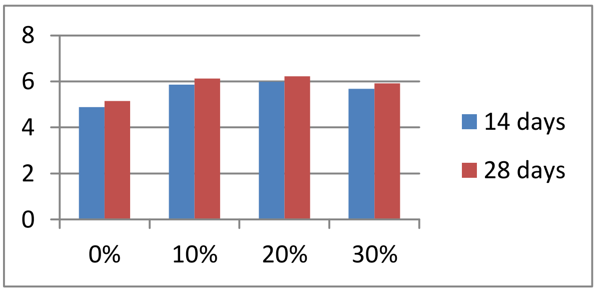

Fig 7: Graphical Representation of Flexural Strength Test on GP-PQC Mixes

The optimum value for flexural strength of GP-PQC mixes was found corresponding to 20 % GP replacement. A steady increase in flexural strength was seen with 10 %, 20 % GP replacement but 30 % GP replacement gives the lower flexure strength as compare to that of 20% GP replacement.

4.2 Results and analysis of MS-PQC

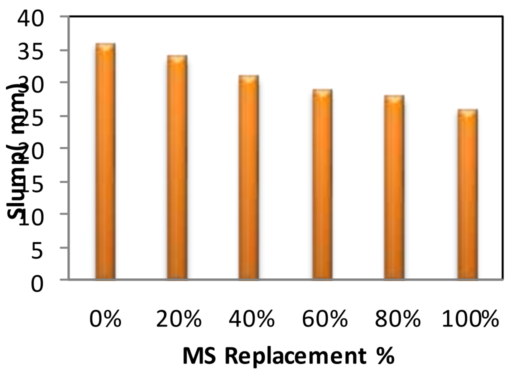

Fig 8: Results of Slump Test on MS-PQC Mixes

It can be seen that slump demonstrates a decreased trend with addition of manufactured sand.

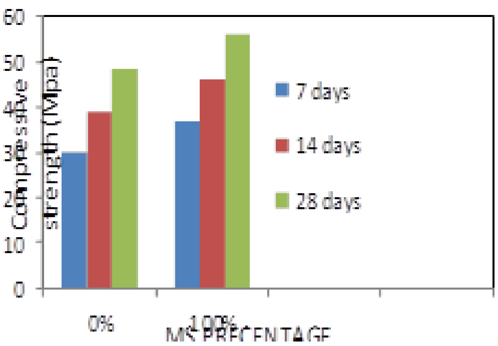

Fig 9: Graphical Representation of Compressive Strength Test on MS-PQC Mixes

An increasing trend in compressive strength can be seen along with the addition of manufactured sand. The optimum value for compressive strength of MS-PQC mixes was found corresponding to 100 % MS replacement.

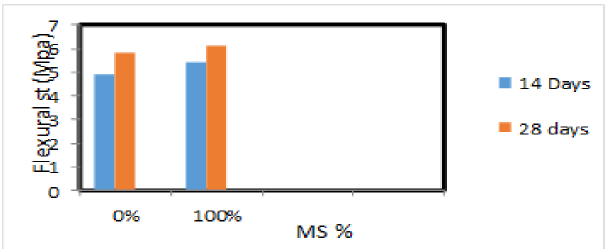

Fig 10: Graphical Representation of Flexural Strength Test on MS-PQC Mixes

An increasing trend in flexural strength can be seen along with the addition of manufactured sand. The optimum value for compressive strength of MS-PQC mixes was found corresponding to 100 % MS replacement.

5. UPV Test

It is observed that GP (20%) and manufactured sand (100%) replacement resulted in a higher UPV, which may indicate a more compact or consistent structure of GP and Manufactured Sand concretes. In this section the results of ultra-sonic pulse velocity is presented which is conducted on the specimens of GP+MS-PQC MIXES.

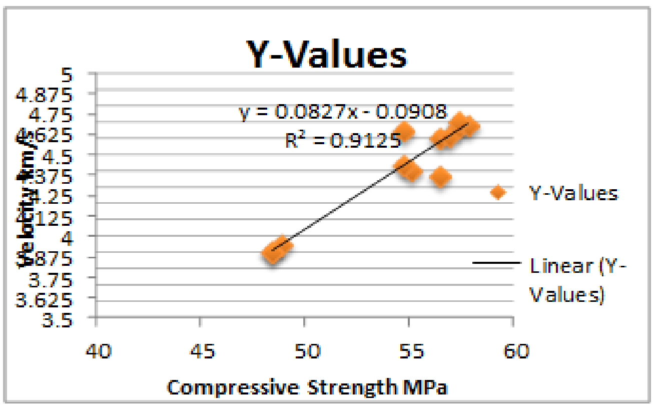

Fig. 11: UPV vs Compressive Strength Graph

6. Conclusions

The present study focuses on the usage of glass powder in PQC mixes and its effect on workability, compressive strength and flexural strength characteristics of GP-PQC. The ultra-sonic pulse velocity test was conducted on GP-PQC for the assessment of dispute settlement (quality and uniformity in quality) and post damage investigation of concrete. The result obtained showed that GP-PQC mixes are having good strength. Further following points are concluded from the present study:

1) Addition of glass powder to the PQC mixes has been found to increase slump of GP-PQC mixes. It was observed that adding 10%, 20%, 30% glass powder there is an increment of 7.41%, 18.51%, 22.22% in slump value with respect to conventional PQC.

2) The optimum percentage of glass powder for maximum compressive strength of GP-PQC mixes was 20%. Addition of glass powder to PQC mixes up to the optimum value has shown an increasing trend in compressive strength. The maximum compressive strength 57.48 MPa, at 28 days was obtained at optimum glass powder content with complete manufactured sand. With further increase of glass powder content, compressive strength has shown decreasing trend.

3) The optimum percentage of glass powder for maximum flexural strength was 20%. Flexural strength of GP-PQC mixes has shown an increasing trend up to the optimum content of glass powder and the maximum value obtained after 28 days was 6.22MPa. With further increase of glass powder content, flexural strength has shown decreasing trend.

4) Addition of manufactured sand to the PQC mixes has been found to decrease slump of MS-PQC mixes. The optimum value of slump obtained was in 100% natural sand replacement. Yet workability was still deemed sufficient adequate without the need for admixtures for replacement levels up to 100%. This reduction in slump is due to the angular geometry of manufactured sand, which reduces the availability of cement paste and hence the fluidity of the mix.

5) The optimum percentage of manufactured sand for maximum compressive strength of MS- PQC mixes was 100%. Addition of manufactured sand to PQC mixes up to the optimum value has shown an increasing trend in compressive strength. The maximum compressive strength 56.07MPa, at 28 days was obtained at optimum 100% MS content.

6) The optimum percentage of MS for maximum flexural strength was 100%. Flexural strength of MS-PQC mixes has shown an increasing trend up to the optimum content of MS and the maximum value obtained after 28 days was 6.13 MPa.

7) The results of ultra-sonic pulse velocity tests for Glass Powder(20%)-PQC mixes obtained are above 4.5 km/sec which according to IS: 13311- 1992 (Part 1), means that in

relation to standard requirements, concrete quality is good and the result of ultra- sonic pulse velocity tests for MS(100%)-PQC mixes and Glass Powder(20%)+MS(100%) PQC mixes are above 4.5 km/sec which according to IS: 13311- 1992 (Part 1), means that in relation to standard requirements, concrete quality is excellent with respect to homogeneity of the concrete, presence of cracks, voids and changes in the structure of the concrete which may occur with time.

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