Evaluation of Strength Characteristics of Pavement Quality Concrete Mixes Using GGBS and Manufactured Sand

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Abstract - *In this paper an experimental investigation is done to determine the suitability of GGBS (Ground Granulated Blast Furnace Slag) as a partial replacement of cement and manufactured sand as a partial replacement of fine aggregate (normal river sand). This paper focuses to manage the ebb and flow and future patterns of research on the reasonableness of Manufactured Fine Aggregate (MFA) in GGBS based Portland bond concrete. It has been watched that in late 10 years, the nature of regular sand is debasing day by day and nowadays the construction industry in the India is confronting a noteworthy issue because of intense lack of normal river sand. Subsequently it is extremely important to discover some appropriate substitutes for common sand by which we can keep the abundance stream disintegration and destructive ecological effect. The artificial sand (Robo sand/manufactured sand) is one of the better substitutes to characteristic sand. Manufactured sand is delivered from quires stone crusher.*

The construction industry is continually searching for extra cementitious material with the point of diminishing the strong by product generation issue. Ground granulated impact heater slag (GGBS), Rice husk debris (RHA) and Quarry sand (QS) are the significant strong squanders produced by industry. Durable energy and cost savings can be offered when waste of industries are used as partial use for the energy- intensive Portland cement. This research attempts to study the suitability of using locally available GGBS (Ground Granulated Blast Furnace Slag) as a partial application for cement in concrete. Ground granulated blast furnace slag (GGBS) 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 GGBS on the workability, compressive and flexural strength was investigated. The PQC (Pavement Quality Concrete) containing GGBS 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 20%, 40%, 60%, 80%, 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, GGBS and Manufactured Sand are also found to be beneficial in enhancing the compressive, flexure strength gain.

Key Words: PQC, GGBS, 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. Frequent extraction of river sand from river bed makes numerous issues to the environment and society like lessening water holding soil strata, bringing down the river beds and causing bank slides, loss of vegetation on the bank of rivers, interfers the aquatic life as well as disturbs agriculture due to alleviating the water level.

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 GGBS 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 GGBS offers better use of steel industry waste in a fruitful way that surely economizes 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 GGBS based concrete on the partial replacement of natural river sand by manufactured sand.

1.1 GGBS (Ground Granulated Blast Furnace Slag)

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of steel industry mainly. It is obtained when iron ore, coke and limestone are heated up to the temperature around 1400°C-1500°C.when these material are burnt in the furnace, two by-products are produced one molten iron and the another is molten slag. The chemical composition of a slag fluctuates impressively depending upon the crude materials in the iron manufacturing process.

GGBS 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 GGBS are mentioned below:

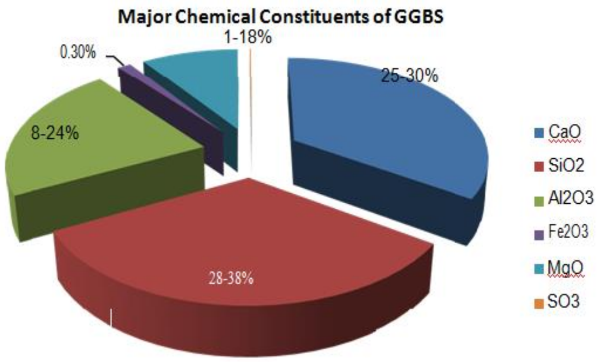

Fig -1: Composition of GGBS

Table -1: Typical Physical Property

S.No.	Property	Specification
1.	Color	Off white color
2.	Specific Gravity	2.9
3.	Bulk Density	1000-1100 Kg/m³(loose) 1200-1300 Kg/m³ (vibrated)
4.	Fineness	>350 kg/m³

1.1.1 Application of GGBS in Construction

- In Structural concrete
- Use in Pre-stressed concrete
- Use in Sulphate Resistance
- Use in Block making
- Use in Soil stabilization
- Use in Preventing Alkali Silica Reaction
- Use in Resistance to Chloride attack
- Use in Grout packs

1.2 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 less than 4.75mm. 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 GGBS 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 -2: Slump Test

2.2 Compressive Strength

The Compressive strength of pavement quality concrete based on various percentage of adjustment of fine aggregate with manufactured sand and cement replacement with GGBS were examined. 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.

$$f'c = Pc / A$$

Where,

Pc = Compressive Failure load, (kN)

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

Fig -3 Compressive Strength Testing Machine (CTM)

2.3 Flexural Strength

Flexural strength tests are conducted on universal testing machine (UTM) of 600 KN capabilities. 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 normal aggregate by manufactured sand in the area of 0%, 10%, 20%, 30% 40%and 50%. 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 -4: 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 ultra-sonic pulse velocity non-destructive test conforming to IS: 13311- 1992 (Part 1), was conducted on both GGBS-PQC and MS-PQC Mixes. 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 -5: Ultra-sonic Pulse Velocity Test being conducted on GGBS-PQC and MS-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 two phase, in 1st phase along with conventional PQC mix of M40 grade concrete.

We cast the cubes with replacement of 10%, 20%, 30% of GGBS, carried out to determine optimum percentage of replacement of cement by GGBS at which max. compressive, flexural strength, is achieved. In 2nd phase cement is replaced by 10%, 20%, 30% 60%, 80% & 100% of natural sand by manufactured sand. 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:1199-1959Compressive 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 GGBS-PQC

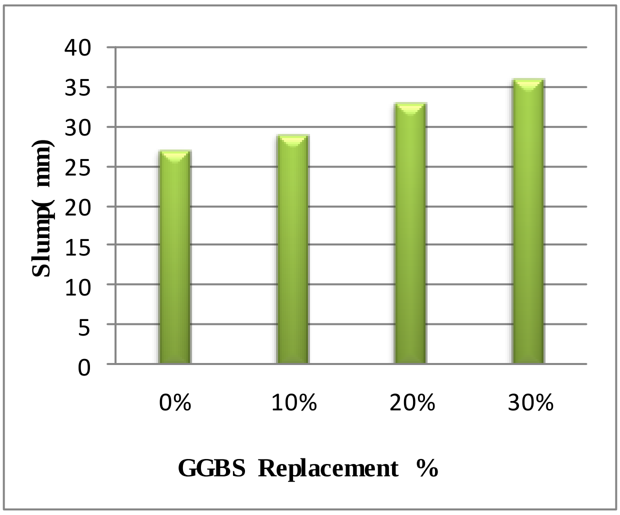

Fig -6: Results of Slump Test on GGBS-PQC Mixes

It can be seen that slump demonstrates an increased trend with addition of blast furnace slag. The slump value of unmodified PQC was obtained as 27 mm. On 10%, 20% and 30% replacement, a gradual increase of slump value is seen. On 10%, 20% and 30% replacement we are getting 29mm, 33mm and 36 mm slump value respectively.

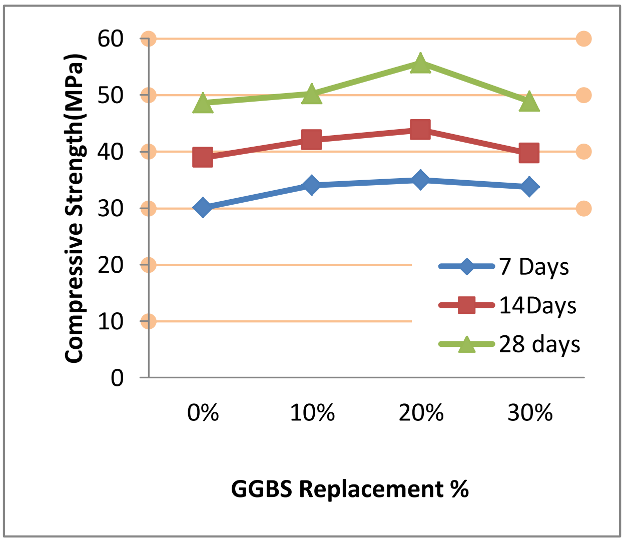

Fig -7: Graphical Representation of Compressive Strength Test on GGBS-PQC Mixes

It was observed that, with the addition of GGBS, the compressive strength of GGBS-PQC showed increasing trend upto 20% after that it shows a decrement in the present study.

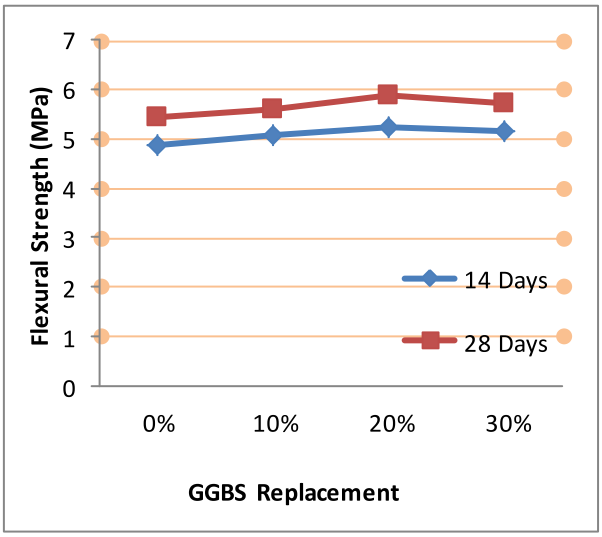

Fig -8: Graphical Representation of Flexural Strength Test on GGBS-PQC Mixes

When the cement is replaced by 20% GGBS 14 days and 28days flexural strength are increased by 6.95% and 7.71%. When the cement is replaced by 30% GGBS 14 days and 28days flexural strength are increased by 5.32% and 4.95%.

4.2 Results and analysis of MS-PQC

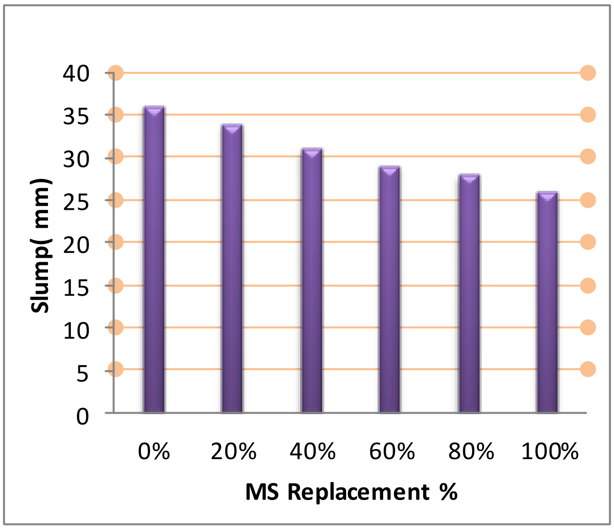

Fig -9: Results of Slump Test on MS-PQC Mixes

It can be seen that slump demonstrates a decreased trend with addition of manufactured sand. The slump value of unmodified PQC was obtained as 36 mm.

On 20%, 40%, 60%, 80%and 100% replacement, a gradual decrease of slump value is seen. On 20%, 40%, 60%, 80% and 100% replacement we are getting 34mm, 31mm, 29mm, 28mm and 26 mm slump value respectively.

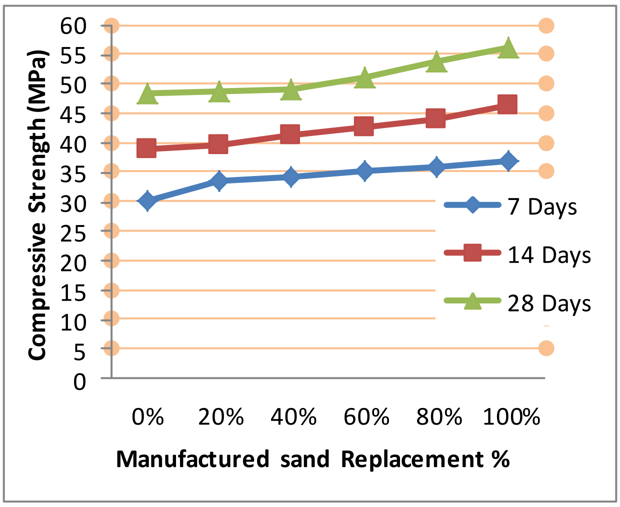

Fig -10: Graphical Representation of Compressive Strength Test on MS-PQC Mixes

The maximum compressive strength at 7 days obtained was 36.82 MPa with optimum 100% MS replacement, while it was 46.45 MPa at 14days and 56.07MPa at 28 days which is 15.39% higher than the Conventional PQC mix.

While with 20 % replacement the 28-days compressive strength was 48.81 N/mm2 and with 40%, 60%, 80% replacement the 28 days compressive strength are 49.18, 51.19, 53.85N/mm2 respectively which are 0.45% , 1.21%, 5.35%, 10.83% greater than conventional PQC.

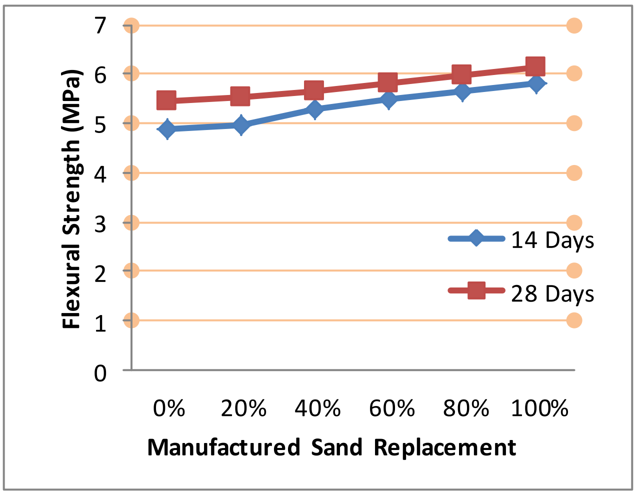

Fig -11: Results of Flexural Strength Test on MS-PQC Mixes

The maximum compressive strength at 7 days obtained was 36.82MPa with optimum 100% MS replacement, while it was 46.45 MPa at 14days and 56.07MPa at 28 days which is 15.39% higher than the Conventional PQC mix.

While with 20 % replacement the 28-days compressive strength was 48.81 N/mm2 and with 40%, 60%, 80% replacement the 28 days compressive strength are 49.18, 51.19, 53.85N/mm2 respectively which are 0.45% , 1.21%, 5.35%, 10.83% greater than conventional PQC.

4.3 Results and analysis of GGBS+MS-PQC

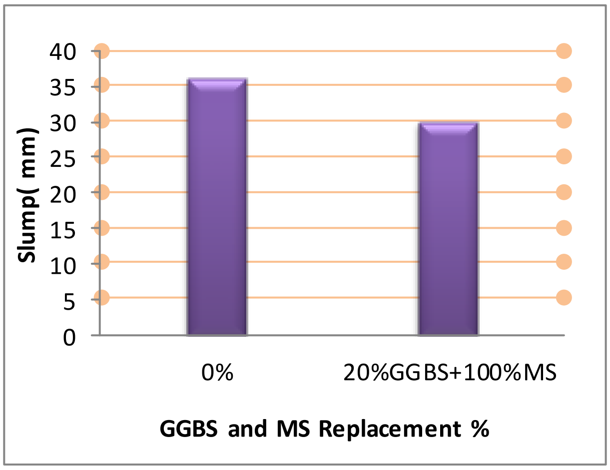

Fig -12: Results of Slump Test on GGBS+MS-PQC Mixes

It can be seen that slump demonstrates a decreased trend with addition of GGBS and manufactured sand. The slump value of unmodified PQC was obtained as 36 mm. On 20% replacement of cement with GGBS and 100% replacement of natural sand with manufactured sand replacement we are getting 30mm slump value.

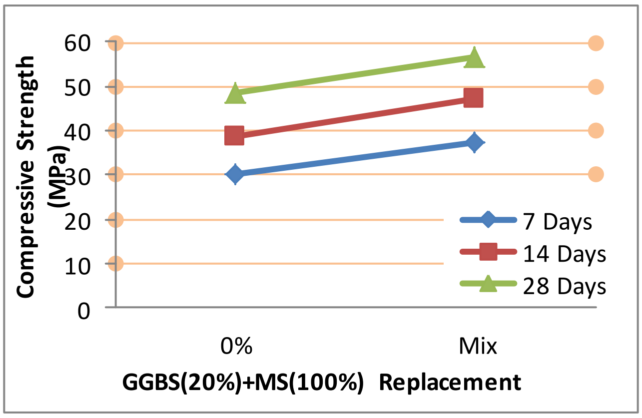

Fig -13: Results of Compressive Strength Test on Combined GGBS and MS-PQC Mixes

The results indicate that when (GGBS+MS)-PQC included 20% GGBS and 100% manufactured sand as a replacement of cement and natural sand respectively the compressive strength at 7 days increased by 23.90% than the conventional PQC.

Similarly, for 14 days and 28 days these value increased by 21.46 % and 15.96% than the conventional PQC.

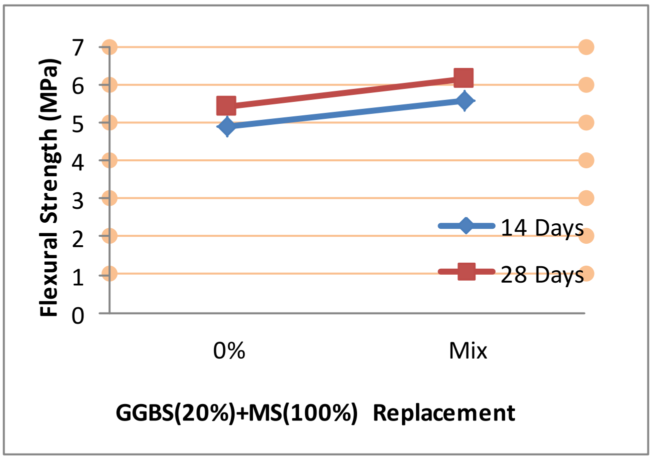

Fig -14: Results of Flexural Strength Test on Combined GGBS and MS-PQC Mixes

The results indicate that when (GGBS+MS)-PQC included 20% GGBS and 100% manufactured sand as a replacement of cement and natural sand respectively the flexural strength at 14 days increased by 14.52% than the conventional PQC. Similarly, for 28 days and 28 days these value increased by 13.03% than the conventional PQC.

5. UPV Test

In this section the results of ultra-sonic pulse velocity is presented which is conducted on the specimens of GGBS-PQC, MS-PQC and GGBS+MS –PQC Mixes

It shows that the pulse velocity more than 3.5(Km/sec) gives higher quality of concrete. The graph is mentioned for GGBS and manufactured based concrete.

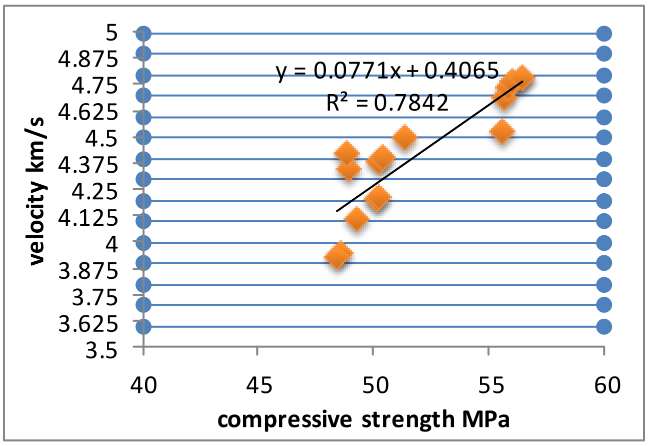

Fig -15: Results of Ultra-Sonic Pulse Velocity Tests on GGBS-PQC and MS-PQC Mixes

6. Conclusions

The present study focuses on the usage of blast furnace slag as cement replacement and manufactured sand as a natural sand replacement in PQC mixes and their effect on workability, compressive strength and flexural strength characteristics of both GGBS-PQC and MS-PQC is evaluated. The ultra-sonic pulse velocity test was conducted on GGBS-PQC, MS-PQC and GGBS+MS-PQC for the assessment of dispute settlement (quality and uniformity in quality) of concrete. The result obtained showed that GGBS-PQC and MS-PQC mixes are having good quality. It is observed from the study that both blast furnace slag and manufactured sand can be used in the Pavement Quality Concrete mixes. An increase in compressive strength and flexural strength was observed with using both blast furnace slag and manufactured sand. Further following points are concluded from the present study:

1. Addition of GGBS to the PQC mixes has been found to increase slump of GGBS-PQC mixes. The optimum value of slump obtained was in 30% GGBS replacement. Yet workability was still deemed sufficient adequate without the need for admixtures (plasticizers) for replacement.

2. The optimum percentage of GGBS for maximum compressive strength of GGBS- PQC mixes was 20%. Addition of GGBS to PQC mixes up to the optimum value has shown an increasing trend in compressive strength. With further increase of GGBS content, compressive strength has shown decreasing trend. The maximum compressive strength 55.70MPa, at 28 days was obtained at optimum GGBS content. Reduction in compressive strength of GGBS-PQC may due to higher shrinkage of concrete.

3. The optimum percentage of GGBS for maximum flexural strength was 20%. Flexural strength of GGBS-PQC mixes has shown an increasing trend up to the optimum content of GGBS and the maximum value obtained after 28 days was 5.72 MPa. The flexural strength of concrete mixes containing GGBS generally followed the compressive strength trend and the reduction in flexural strength may be due to the decrease in adhesion between the smooth surface GGBS and the cement paste.

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% FWGA 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 53.67MPa, at 28 days was obtained at optimum 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 6.11 MPa.

7. Combination of GGBS (20%) and Manufactured Sand (100%) in a mix the slump value (30mm) is increased as compare to MS-PQC.

8. The compressive strength of GGBS+MS-PQC is increased by 12.62% at 28 days as compare to Conventional PQC.

9. The flexural strength of GGBS+MS-PQC is increased by 8.81% at 28 days as compare to Conventional PQC.

10. The results of ultra-sonic pulse velocity tests for GGBS(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 GGBS(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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