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Influence of GGBS on Mechanical Properties of Low Traffic Concrete Paver Blocks

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Abstract: Supplementary cementitious materials (SCM) are the integral part of modern concrete with significant enhancement in concrete performance. Low cost of production, low heat of hydration along with improved mechanical properties encourage the replacement of ordinary Portland cement (OPC) with SCMs to a greater extent. The study focusses on influence of Ground granulated blast furnace slag (GGBS) as SCM in production of concrete paver blocks. Compressive strength, split tensile strength, and flexural strength are the properties under consideration. Improved compressive strength and flexural strength was observed in blended concrete with 20% and 40% GGBS replacement levels.
Keywords: GGBS, M-Sand, Paver Blocks, Split tensile strength, Flexural strength

I. INTRODUCTION

Interlocking concrete pavements are special dry mix precast piece of concrete, commonly used in exterior landscaping pavement applications. Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. Interlocking paver blocks are installed over a compacted stone sub base and leveling bed of sand. Concrete paver blocks are made with concrete basically consisting of cement, fine Aggregates, coarse aggregates (10 mm and below), water, chemical pigments, etc. Overall performance of concrete paver blocks is mainly depending upon properties of materials, water cement ratio, mixing process and curing process. There is a growing interest to increase the basic properties of concrete by using waste materials as alternative aggregate materials. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. The use of many different materials as aggregate substitutes such as blast furnace slag and Manufactured sand. Slag is a by-product generated during manufacturing of pig iron and steel. Primarily, the slag consists of limestone (CaO) and silica (SiO_2). Other components of blast furnace slag include alumina oxide (Al_2O_3) and magnesium oxide (MgO), as well as a small amount of sulfur (S), while steelmaking slag contains iron oxide (FeO) and magnesium oxide (MgO) .Blended mixes using OPC, GGBS alongwith M-sand prove to be effectively satisfying the physical and mechanical properties of concrete in addition to reduction in overall cost of concrete. Higher GGBS replacement for OPC can be tried in the production of paver blocks for low traffic thereby reducing cost of paver blocks significantly and contributing to reduction in environmental pollution.

II. LITERATURE REVIEW

Ms. Vaishali.N Badwaik, Mr. Chaitanya P. Zade etal.(1), investigated the use of BFS and GGBS in the production of concrete paver blocks along with slag sand. Different mixing proportions of BFS and GGBS were tested for compressive strength. Enhancement in the strength of these blocks was observed compared with the conventional concrete paver blocks. The paver blocks obtained with this combination were lighter and economical compared to the conventional concrete paver blocks.

Daware Sanket S., Phadatare Shital U.etal.(2) studied the effect of utilization of induction furnace slag aggregates as partial replacement to coarse aggregate for producing concrete. A replacement percentage of 20% resulted in maximum strength of concrete compared with other replacement percentages. Further it was observed that the strength of concrete decreased with the increase in the replacement percentage of induction furnace slag aggregates.

P. Malliga, J. Ashthava Moorthy, M. Hiran(3) studied influence of GGBS, Fly Ash, M Sand in geopolymer paver blocks. Compressive strength, split tensile strength, flexural strength, and abrasive strength were studied. The maximum compressive strength of 35.5 MPa , was achieved at 30:70 replacement of FLYASH and GGBS respectively as compare to 34 Mpa of strength of conventional concrete for 14 days curing in potable water. Maximum strength was achieved in 70 % of GGBS replacement than other replacement levels.

Leni stephen, Amjad Raji, Sachin Rajan, Visakh N V(4) carried out study on Failure of Interlocking Pavement blocks. The results showed inadequate thickness of bedding sand, improper gap filling between the paver blocks, lack of proper compaction, and inferior sub grade are the main causes of failure.

Alety Shivakrishna, Pulivarthi Venkata Shivakumar(5) examined compressive strength, flexural strength, and water ingestion of paver piece by supplanting part of bond with the fly ash debris in M35 concrete. Glass filaments were used to enhance mechanical properties. Usage of GGBS and Fly ash enhanced mechanical properties of paver blocks at a later stage in comparison with conventional concrete paver blocks.

M. P. Karthik, Dr. V. Sreevidya, R. Kesavamoorthi, J. Rex(6) studied strength properties of paver blocks using Fly ash, Rice husk Ash. Natural and artificial fibres were used to enhance flexural strength. Studies revealed that articial fibres were more efficient in enhancing flexural properties. Mineral admixtures lowered strength of paver blocks in the early days. Rajbir Singh, Dr. Sanjay Goel (7) carried out a study on evaluation of strength parameters concrete using steel slag and PET fibre. Optimum combinations for compressive strength and flexural strength were found to be 0.5% pet fibre and 25% steel slag as fine aggregates.

Kalingarani.K, Harikrishna Devudu.P etal(8) studied physical and chemical properties of concrete using industrial wastes such as copper slag, fly ash, phosphogypsum, and sludge. Binder proportion of 70% OPC and 30% flyash along with copper slag as fine aggregate showed strength properties on par with the convetional concrete used for producing interlocking paver blocks.

G.Pragna, P.M.S.S.Kumar (9) investigated compressive strength, flexural strength and water absorption of paver block wereevaluated by replacing portion of cement with the flyash and GGBS in M30 grade concrete. An optimum fiber content of 0.4% by weight of binder was also used. 30% GGBS or Fly ash along with OPC in the concrete was proved to enhance strength of concrete.

C.Banupriya, Sharon John, R. Suresh, E. Divya, and D. Vinitha(10) carried out investigation on compressive strength, split tensile strength, and flexural strength of geopolymer concrete bricks using quarry dust as a replacement to river sand. Results showed that Geopolymer concrete blocks with 50% sand and 50% quarry dust produced excellent compressive strength, flexural strength and split tensile strength. Paver block using 75% GGBS and 25% fly ash showed excellent compressive strength.

Vireen Limbachiya, Eshmaiel Ganjian, Peter Claisse(11) studied strength, durability and leaching properties of concrete paving blocks incorporating GGBS and Silica Fume. The study reported on the optimised mix from analysis of cement paste cubes. The study successfully reduced the cement content of concrete paving blocks by 40% and managed to achieve greater strengths than the control mix. The leaching analysis reported that the higher permeability of mixes containing cement replacements resulted in these mixes absorbing less leachate, however gave satisfying performance for protection of leachate to ground sources.

B.A.V.Ram Kumar, J.Venkateswara Rao(12) evaluated compressive strength, flexural strength and water absorption of paver block by replacing portion of cement with the GGBS (ground granulated blast furnace slag). Glass fibers were also incorporated along with the GGBS to further enhance the mechanical properties. Different proportions of glass fiber starting from 0.1% to 0.4% by weight of cement in the paver block were added. The optimum fiber content from test results was found to be 0.2% by weight of cement. 10% to 40% by weight of cement was replaced with the GGBS. From the test results obtained the optimum ggbs and glass fiber content were found to be 30% and 0.2% respectively.

Rajendra Kumar Neekhra, Raja Rawat etal(13) evaluated compressive strength of concrete paver blocks using Nylon fibres. 0.3% of Nylon fibre exhibited maximum strength for paver blocks.

Thakur Anil Kumar, Saxena Anil Kumar etal(14) used fly ash and Nylon fibers to increase the compressive strength of paver blocks. 20% fly ash, 0.3% nylon fibres by weight of binder showed enhanced strength compared with the conventional concrete paver blocks.

Hanan A. El Nouhy(15) investigated the effect of using Portland slag cement in the production of interlocking paving units. The results indicated that Portland slag cement exhibits satisfactory strength requirement at 180 days in comparison with the concrete made with ordinary Portland cement. Osman Gencel, Cengiz Ozel etal.,(16) studied physical and mechanical properties of paver blocks by partially replacing aggregates by marble waste. Mechanical strength decreased with increasing marble content while freeze-thaw durability and abrasive wear resistance increased.

A. Objectives Of Present Study

1) To produce paver blocks using low cost construction alternatives.
2) To improve strength and reduce water absorption of paver blocks.
3) To decrease the overall cost of paver block production.
4) Contribute to reduction of global warming and environmental pollution by using industrial by-products as alternatives to conventional concrete constituents.

To achieve the above objective, GGBS, Manufactured Sand(CSS) are used as alternatives to OPC and Natural river sand for producing concrete paver blocks.

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III. MATERIALS AND METHODOLOGY

A. Materials

1) *Cement:* Ordinary Portland Cement (OPC) 53 grade
2) *Cementitious Materials:* Ground Granulated Blast Furnace Slag (GGBS)
3) *Chemical Admixtures:* PCE based Super plasticizers
4) *Fine Aggregates:* Manufactured sand
5) *Water:* Potable water
6) *Coarse Aggregates:* 10 mm

B. Methodology

1) Study on characteristics concrete ingredients.
2) Study on strength properties of blended concrete paver blocks.
3) Study on water absorption of paver blocks.
4) Cost analysis of conventional paver blocks and blended concrete paver blocks.

IV. EXPERIMENTAL WORK

The following experimental works have been carried out:

A. Tests on concrete ingredients such as specific gravity test, sieve analysis, water absorption.
B. Marsh Cone analysis to check compatibility of chemical admixtures and to fix dosage.
C. Concrete Mix design using IS:10262-2019 and IS:15658-2006 for low traffic paver blocks(M35).
D. Experimental Investigation on fresh properties of Blended concrete.
E. Water absorption of binary blended concrete paver blocks.

Compressive strength, Split Tensile strength test of binary blended concrete paver blocks.

Table 4.1 Mix codes for the concrete mixes

Mix Designation	Binders
C100	100% OPC
C80G20	80% OPC + 20 % GGBS
C60G40	60% OPC + 40 % GGBS
C40G60	40% OPC + 60 % GGBS

Table 4.2 Concrete Mix constituents

Concrete Mix	C100	C80G20	C60G40	C40G60
OPC, kg/m^3	347	277.60	208.20	138.80
GGBS, kg/m^3	-	69.40	138.80	208.20
Water, kg/m^3	170	165	165	165
Fine aggregate (SSD) , kg/m^3	934	931.10	929.02	926.94
Coarse aggregate (SSD) , kg/m^3	995	973.92	971.75	969.57
Chemical admixture, kg/m^3	2.6025	2.43	2.082	1.735
Free water-cement ratio	0.45	0.45	0.45	0.45

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V. RESULTS AND DISCUSSIONS

A. *Marsh Cone Analysis*

Marsh Cone analysis has been done to check the compatibility of the various blended mixes with the chemical admixture and to fix the dosage of chemical admixtures.

Table 5.1 Marsh Cone Results

Mix	Optimum Dosage of super plasticizer, %
C100	0.75
C80G20	0.70
C60G40	0.60
C40G60	0.50

A reduction in superplasticizer dosage reuirement was observed with increase in GGBS content in concrete.

B. *Water Absorption ($W_{percent}$)*

Table 5.2 Water absorption of paver blocks

Mix	$W_{Percent}$
C100	5.5
C80G20	5.1
C60G40	5.2
C40G60	6.0

Decrease in water absorption was observed with mix C80G20 due to reduction in microcracks in concrete as a result of relatively finer GGBS particles in comparison with OPC. However the mix C40G60 showed higher water absorption as a result of unhydrated slag grains in the concrete.

C. *Compressive Strength Results (M35 Concrete)*

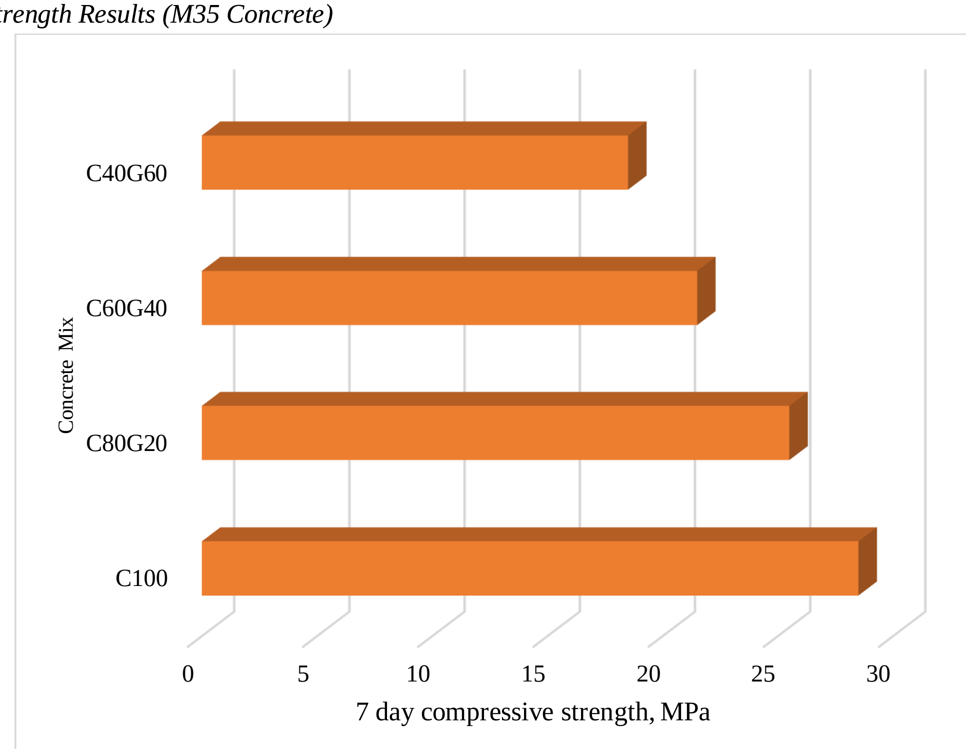

Fig 5.1 Variation in 7-day Compressive strength of paver blocks

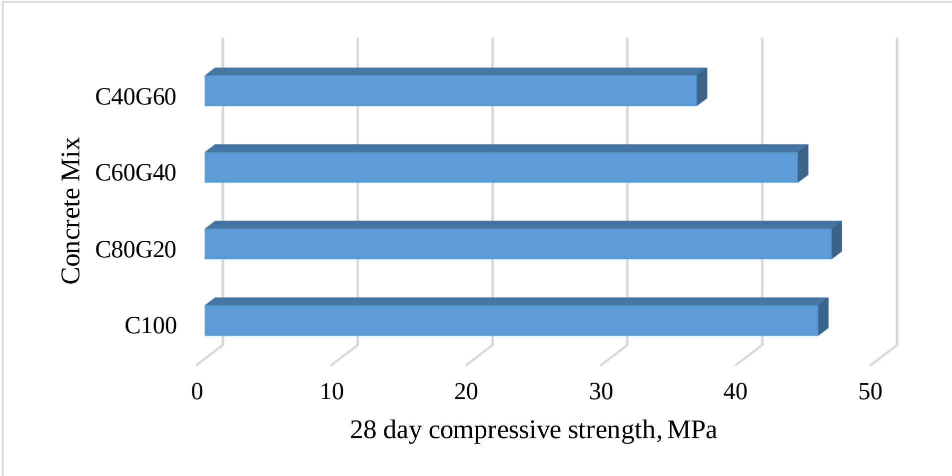

Fig 5.2 Variation in 28-day Compressive strength of paver blocks

D. Tensile Splitting Strength

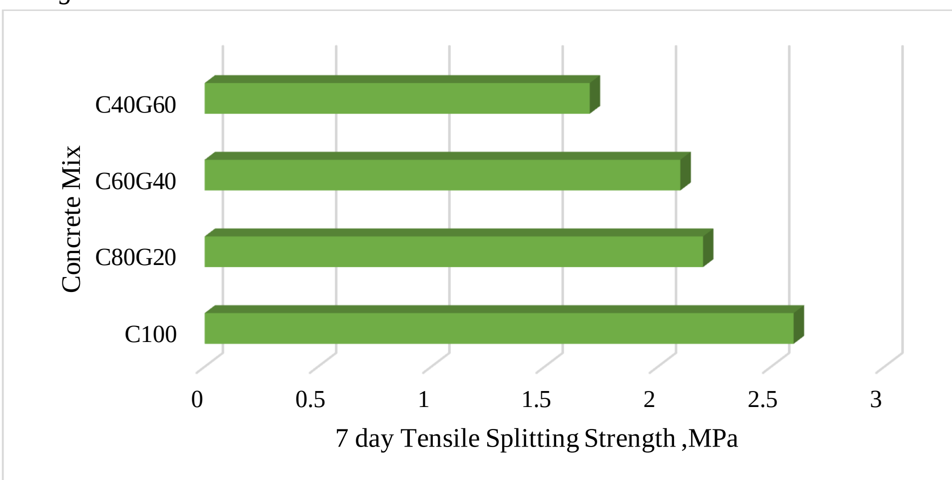

Fig 5.3 Variation in 7-day tensile splitting strength of paver blocks

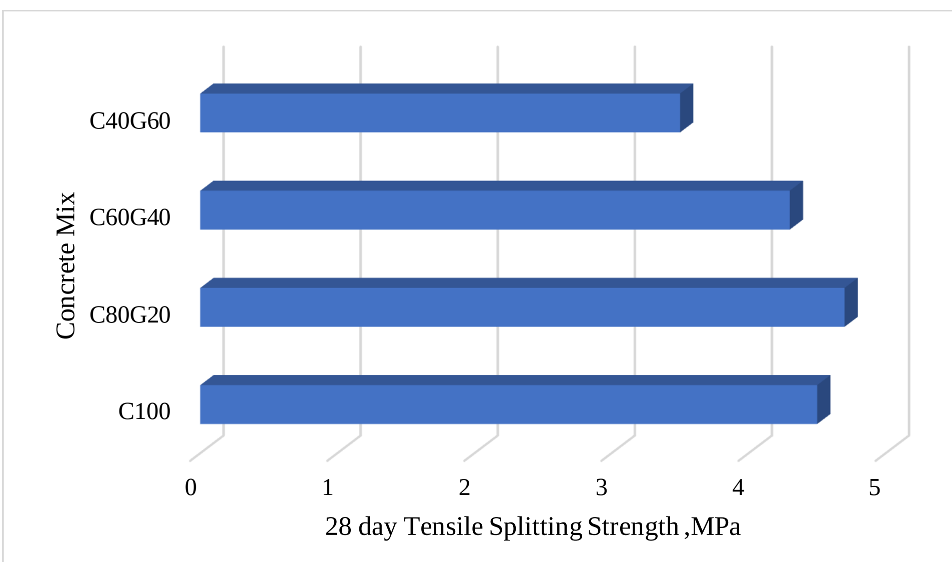

Fig 5.4 Variation in 28-day tensile splitting strength of paver blocks

E. Flexural Strength of Concrete Paver Block

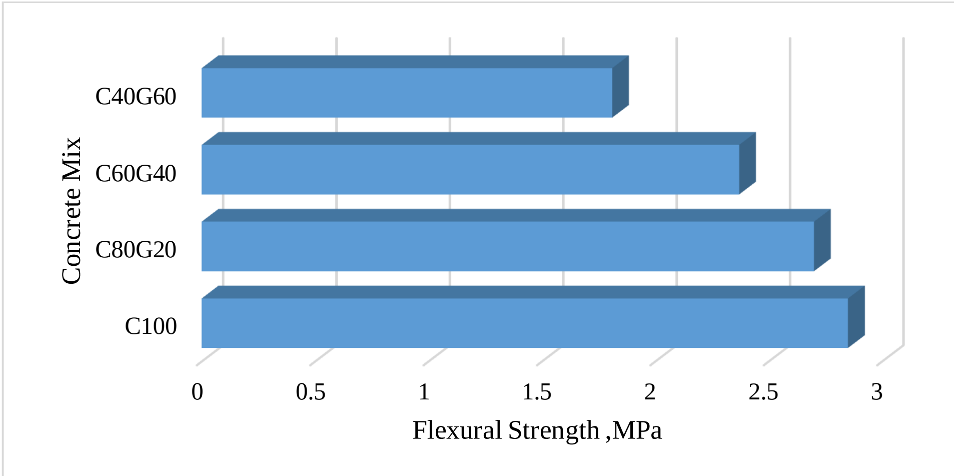

Fig 5.5 7-day Flexural Strength of paver blocks

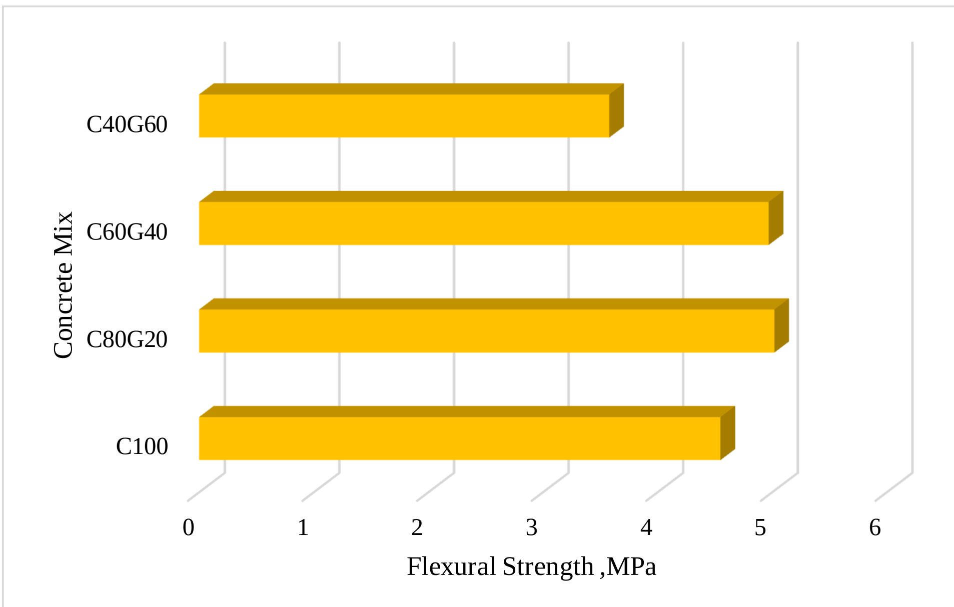

Table 5.6 28-day Flexural Strength of paver blocks

VI. CONCLUSION

A. Usage of GGBS as a replacement to OPC reduces cost of binder by 75%.

B. Compressive strength of concrete decreases with increase in GGBS content at the age of 7 days. This is due to incomplete hydration of GGBS during initial period. Concrete with 20% GGBS possess higher compressive strength in comparison with other mixes and controlled concrete at the age of 28 days.

C. Flexural strength of concrete paver blocks with 20% GGBS increased by 10% in comparison with controlled concrete at 28 days testing.

D. 28-day Tensile Splitting Strength results showed an increase of 4% for concrete paver blocks with 20% GGBS in comparison with controlled concrete.

VII. ACKNOWLEDGMENT

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