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Strength of RC Beam using Geopolymer Concrete and Adopting Bubble Technology

Abhinay I. Deshmukh[1], Arpan A. Deshmukh[2]
[1]PG Student of Final year M.Tech Structural Engineering, [2]Assistant Professor at Department of Civil Engineering
G H Raisoni College of Engineering and Management, Pune (GHRCEM)

Abstract: The Bubble Deck technology developed in Europe makes use of high-density polyethylene hollow spheres to replace the ineffective concrete in the centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. Concrete is good in compression and hence is more useful in the compression region than in the tension region. The reduction in concrete can be done by replacing the tension zone concrete. Keeping the same idea in mind, an attempt has been made to find out the effectiveness of plastic bubbles by replacing concrete in the tension zone of Ordinary Portland Cement Concrete (OPCC) and Geopolymer Concrete (GPC) beam. Geopolymer Concrete does not form calcium- silicate-hydrates (CSHs) for matrix formation and strength like OPCC but utilizes the polycondensation of silica and alumina precursors to attain structural strength. In this project, M25 concrete mix is used to prepare both OPCC and GPC beams. The trial mix is tested for compressive strength. Flexure test is done is done for 28 days of curing of the beams. This paper presents the results of the experimental investigations carried out to determine and to compare the flexural behaviour of geopolymer concrete (GPC) beams with conventional concrete beams of same grade. The beams were tested under two point monotonic loading. Performance aspects such as load carrying capacity, first crack load, ultimate load, load-deflection behaviour, moment-curvature behaviour, crack width, crack spacing and the modes of failure of both types of beams were studied. The test results showed that the geopolymer concrete exhibits better performance compared to conventional concrete of same grade.

Keywords: Bubble technology, Geopolymer concrete, Ordinary Portland Cement Concrete, Sodium hydroxide, GGBS, Glass powder

I. INTRODUCTION

Geopolymer Concrete (GPC) beams can be used for sustainable and environment friendly construction work as it reduces the emission of carbon dioxide during the production of cement. However, hand mix of concrete does not provide the required compressive strength. After adopting bubble technology flexural strength of beam remains almost same. Demand for concrete as a construction material is increasing day by day. The main ingredient of conventional concrete is ordinary Portland cement. There are two major drawbacks with respect to its sustainability. About 1.5 tons of raw materials are needed for the production of every ton of Portland cement and at the same time, about one ton of carbon dioxide is released into the environment during its production. Hence the production of Portland cement is an extremely resource and energy intensive process. Recently another form of cementitious materials (Alkali activated aluminosilicates) was developed and was termed as ‘geopolymer’. The term geopolymer was introduced by Davidovits in the year 1978. The main ingredients of geopolymer were materials which are rich in alumina and silica like, fly ash, rice husk ash, metakaolin and an alkaline solution. The primary difference between Portland cement concrete (PCC) and geopolymer concrete is that in GPC, cement is completely avoided and the binder used is alkali activated aluminosilicate. In future, fly ash production will increase, especially in the countries such as China and India. Accordingly, efforts to utilize this by-product material in concrete manufacturing are important to make concrete more environment friendly instance, every million 160 tons of fly ash that replaces Portland cement helps to conserve one million ton of limestone.

II. LITERATURE REVIEW

Studies Performed on Geopolymer Concrete

Yasir Sofi and Iftekar Gull (1) intended to study the properties of fly ash based Geopolymer concrete. M20 grade GPC can be formed by adopting nominal mix of 1:1.5:3 (fly ash: fine aggregates: coarse aggregates) by varying alkaline liquid to fly ash ratio from 0.3 to 0.45. The compressive strength, tensile strength and flexural strength tests were conducted on geopolymer concrete and parameters that affect it are analysed and proved experimentally.

P. K. Jamdade and U. R. Kawade (2) studied the strength of Geopolymer concrete by using oven curing. In this study Geopolyme concrete is prepared by mixing sodium silicate and sodium hydroxide with processed fly ash. The concrete is cured at different condition and different temperatures i.e., 600 C, 900 C and 1200 C so as to increase the strength of concrete

Arya Aravind and Mathews M Paul (3) carried out research on mechanical properties of Geopolymer concrete reinforced with steel fibre. This study focuses on the compressive strength and split tensile strength of geopolymer concrete reinforced with steel fibre. Experiments were performed using the Box–Behnken experimental design. Box–Behnken experimental design is a type of response surface methodology.

Kamlesh. C. Shah (4) conducted research on strength parameters and durability of fly ash based Geopolymer concrete. In this study, two concrete mixes are to be worked out; GPC Mix-1 fly ash concrete and OPC Mix-2 Concrete mix having OPC equivalent to amount of cementitious material used in GPC Mix-1.

S. Jaydeep and B. J. Chakravarthy (5) prepared an optimum mix for Geopolymer concrete using admixtures. Concrete cubes of size 150×150×150mm were prepared to find out compressive strength at 7 and 28 days. Results showed that the addition of sodium silicate solution to the sodium hydroxide solution as an alkaline activator enhanced the reaction between the source material and solution.

Shankar H. Sanni and R. B. Khadiranaikar (6) carried out investigation on the variation of alkaline solution on mechanical properties of geopolymer concrete. The grades preferred for the investigation were M30, M40, M50 and M60; the mixes were designed for 8 molar. The alkaline solution used was the combination of sodium silicate and sodium hydroxide solution with the varying ratio of 2, 2.5, 3 and 3.5.

Benny Joseph and George Mathew (7) carried out the influence of aggregate content on the engineering properties of Geopolymer concrete. Influence of other parameters such as curing temperature, period of curing, ratio of sodium silicate to sodium hydroxide, ratio of alkali to fly ash and molarities of sodium hydroxide were also discussed.

Aminul Islam Laskar and Rajan Bhattacharjee (8) investigated the variation of workability of fly ash based Geopolymer concrete with the variation of lignin-based plasticizer and poly-carboxylic ether-based superplasticizer. It has been observed that there exists a critical value of molar strength of sodium hydroxide beyond which superplasticizer and plasticizer have adverse effect on workability of fly ash based geopolymer concrete.

Monita and Hamid R. Nikraz studied (9) the strength characteristics, water absorption and water permeability of low calcium fly ash based geopolymer concrete. Mixtures with variations of water/ binder ratio, aggregate/binder ratio, aggregate grading, and alkaline/fly ash ratio were investigated.

Steenie Edward Wallah (10) used low-calcium fly ash as its source material, alkaline activators and aggregates normally used for Ordinary Portland cement concrete. Four series of test specimens with different compressive strength were prepared to study the drying shrinkage of this concrete.

J. K. Dattatreya and N. P. Rajamane (11) studies that the context of this topic, a 'geopolymer' is in general defined as a solid and stable aluminosilicate material formed by alkali hydroxide or alkali silicate activation of a precursor that is usually (but not alwar354ys) supplied as a solid powder.

B. Sarath Chandra Kumar, and K. Ramesh (12) this Paper states that the Given large part of the purpose of this book is to provide an overview of the state of the art in various aspects of geopolymer concrete, it would be superfluous to provide a detailed description in this Introduction.

B. Vijaya Rangan (13) in this the author states that From this basis, the structural analysis presented in various chapters of this book represents the results of detailed investigations by various research groups over a number of years. Very little about the structural analysis of geopolymers is straightforward, as they comprise a mixture of various X-ray amorphous phases (reaction product as well as unreacted precursor material).

J. Davidovits (14) this paper deals with reinforced geopolymer concrete beams made with 100% of GGBS(Ground Granulated Blast Furnace Slag) under ambient curing. The reinforced geopolymer concrete beams were compared with reinforced beams made with OPC.

Duxson, G. C. Lukey (15) in this the author states that this test is performed on the beams that were cast with different molarity and M40 grade concrete beam. The load is applied on the beam and the deflection is noted at the centre of the beam. The beam specimens before test and after test were show From the test results the load carrying capacity of the geopolymer concrete beams are higher than the normal concrete beam, as the molarity concentration in the geopolymer increases the load carrying capacity was also increasing.

B. Sarath Chandra Kumar, K. Ramesh and P. Poluraju (16) in this the author states that the flexural cracks were standard after the peak load at the mid span of the beam. At failure load, all the beams deflected significantly. In both mixes i.e. control mix and geopolymer mix the crack patterns were similar. The failure that occurred in all the beams made with OPC and GPC was started by yielding of the tensile steel and continued by crushing of concrete in compression zone [1]. And it was clear that, no major difference in failure of the OPC and GPC beams. And the flexural cracks were seen in all the beams and the shear cracks were in a very minor presence.

G. Varga (17) in the following paper the author states that the strength parameter compressive tests were performed on different mix i.e. on M40 grade control mix, geopolymer concrete specimens with 8 M, 10 M, 12 M, 14 M and 16 M. The tests were carried out after 7 and 28 days of curing. The results obtained were clear and shows that the compressive strength of the geopolymer concrete mix is very much high than the control mix. The test specimen for flexural behave iour. The test beams were placed on a loading frame of capacity 2000kN. The support conditions were simply supported and the load is applied on two points.

III. METHODOLOGY

Study of Mix Design of M25 concrete and selection of ingredients of concrete mix as per the Mix Design (both OPCC and GPC). Ingredients selected are cement, sand and coarse aggregate for OPCC and for GPC cement is completely replaced with 70% fly ash, 15% GGBS and 15% glass powder. NaOH solution of 12M is added in place of water for GPC. Preparation of beam samples with conventional concrete and geopolymer concrete. Testing of RC beam (750mm x 150mm x 150mm) for bending and deflection. Preparation of test samples of Ordinary Portland cement and geopolymer cement concrete beam with plastic balls as partial tension zone replacement. Testing of samples for bending and deflection. Preparation of sample beams with replacement of tension zone concrete with bubble mesh and provision of shear reinforcement. Comparing the results of OPCC and GPC beams to draw conclusions.

Materials	**GPC (Kg/m^3)**	**PCC (Kg/m^3)**
Coarse Aggregate	1294	1266
Fine Aggregate	554	598
Fly Ash	408	Nil
Cement	Nil	426
Sodium Silicate Solution	103	Nil
Sodium Hydroxide Solution	41	Nil
Superplasticizer	10.2	Nil
Water	14.5	192

Tab 1: Mix Design

Sources: Ruby Abraham et al. (2013)

IV. RESULTS AND DISCUSSION

Concrete beam of size 750mm x 150mm x 150mm with replacement of concrete below neutral axis with bubble mesh and shear reinforcement were tested for OPCC and GPC beams. Based on the test results, the following conclusions are made. The replacement of tension zone concrete with bubble mesh has caused a decrease in flexural strength for both OPCC and GPC beams. However, the strength has been maintained for beams with bubble mesh replacement with shear reinforcement. It is observed that the placement of bubble mesh in concrete beam does not require any additional time. However, accurate placement of the mesh without displacement while pouring the concrete is a challenge. Another challenge is allowing for sufficient concrete to be present between lower portion of bubble mesh and tension zone reinforcement to enable maximum transfer of tensile forces from concrete to reinforcement. Economy and reduction of weight is upto 15% in OPCC and 13% in GPC beams. GPC beams can be used for sustainable and environment friendly construction work as it reduces the emission of carbon dioxide during the production of cement. However, hand mix of concrete does not provide the required compressive strength.

- 28 days compressive strength for conventional concrete obtained was about 54.44MPa and for GPC 12MPa.
- After adopting bubble technology flexural strength of beam remains almost same.

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Beam	Ultimate Load (kN)	Deflection (mm)
GCB_1	59.25	6.814
RCB_1	58.25	3.273
GCB_2	69.75	4.397
RCB_2	60.25	3.92
GCB_3	82	6.762
RCB_3	76	5.071
GCB_4	88	7.98
RCB_4	88	5.016

Tab 2: Ultimate Load- Deflection

Sources: Ruby Abraham et al. (2013)

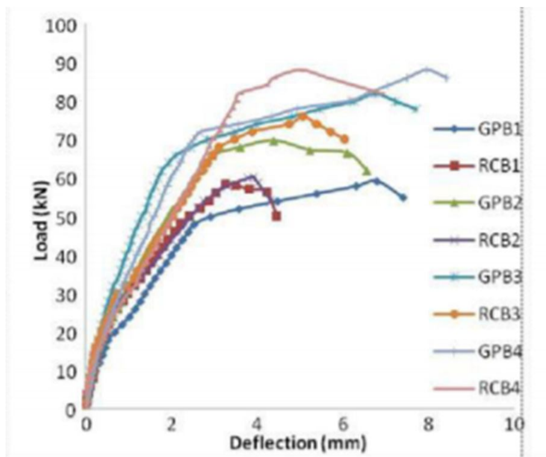

Fig 1: Load-Deflection Curves

V. SCOPE FOR FUTURE WORK

A. Analysis may be carried out considering cracking load instead at breaking load to get the exact behaviour of concrete.
B. Optimum mix proportions for geopolymer concrete can be developed to achieve higher strength.
C. Geopolymer concrete beams with optimum molarity may give better results.
D. Durability test may help in long term effect on strength.
E. Economy and reduction of weight is upto 15% in OPCC and 13% in GPC beams.
F. GPC beams can be used for sustainable and environment friendly construction work as it reduces the emission of carbon dioxide during the production of cement. However, hand mix of concrete does not provide the required compressive strength.
G. 28 days compressive strength for conventional concrete obtained was about 54.44 MPa and for GPC 12MPa.
H. After adopting bubble technology flexural strength of beam remains almost same.
I. Saving in concrete is about 15% by weight.

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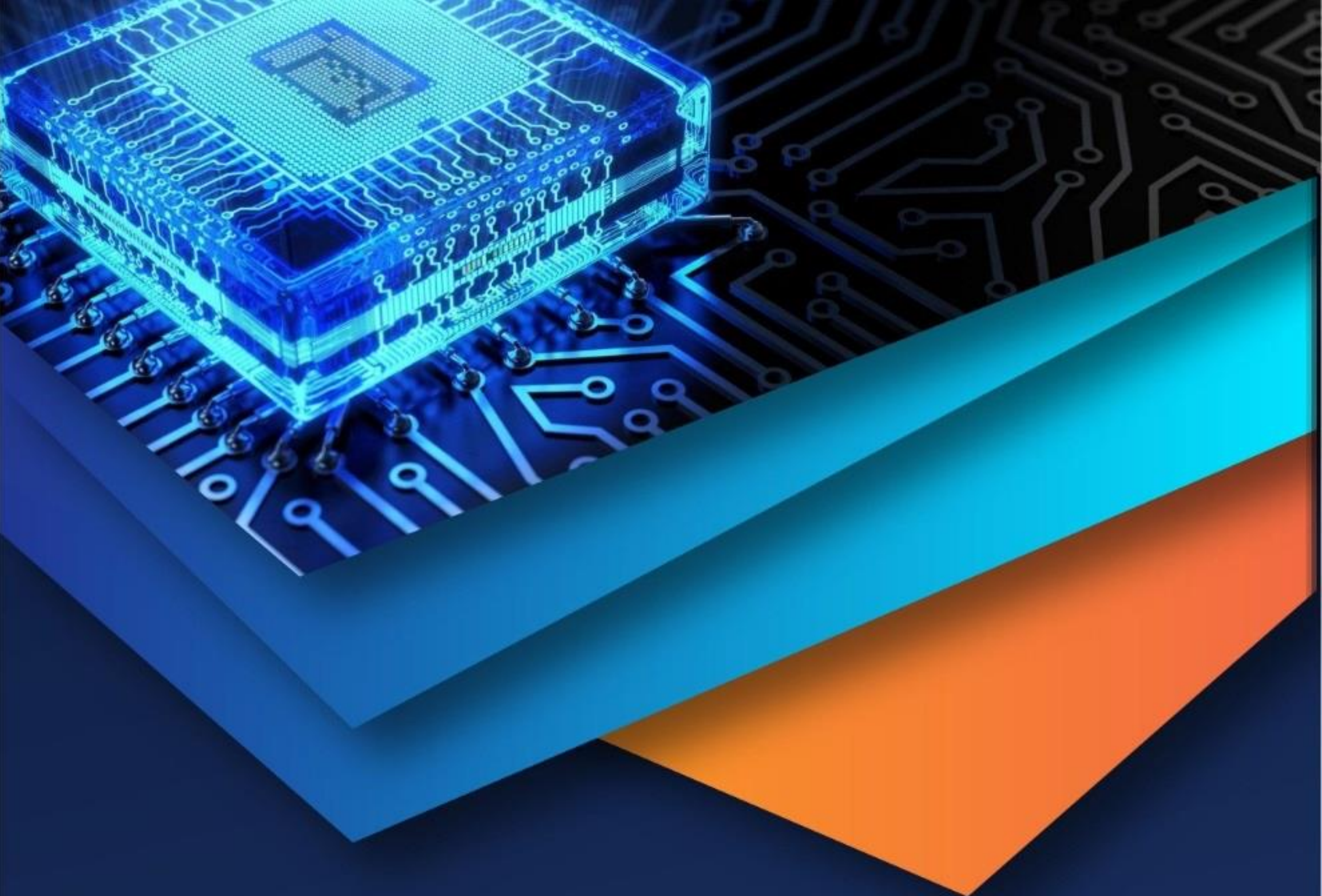

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