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Study on Geopolymer Concrete Block

KEYWORDS: Durability,Geopolymerbrick, UnreinforcedMasonryPrism, Stress-Strain Curve, RegressionAnalysis.

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ABSTRACT *Research on low-calcium fly-ash based geopolymer concrete, sometimes called 'concrete with no cement', has been attracting significant attention. Geopolymer concrete offers a solution for the need of 'greener' construction material in the midst of environmental concern on the production of Ordinary Portland Cement (OPC). An experimental investigation was conducted to study the durability properties of fly ash-based geopolymer concrete and also to critically assess a stress-strain model using masonry prisms constructed from different bricks.Behaviour of unreinforced geopolymer masonry prism is compared with ordinary clay brick masonry prism .Unreinforced clay brick prism and geopolymer brick prism using brick size of 225 x 105 x 70 mm were cast with 10M and12M NaOH concentration for different aspect ratio.Based on the results and observations of the comprehensive experimental study, nonlinear stress-strain curves have been obtained. Using linear regression analysis a simple relationships have been identified for obtaining the modulus of elasticity of bricks and masonry prism from their corresponding compressive strengths. It was observed from the results that geopolymer brick masonry prism possess higher load carrying capacity.*

1. INTRODUCTION

The increasing emphasis on energy conservation and environmental protection has led to investigation of alternatives to customary building material. Efforts are urgently under way all over the world to develop environment friendly construction materials which needs minimum utility of natural resources and help to reduce the green house gas emission. Geopolymer has the potential to replacethe Ordinary Portland cement concrete (OPCC) and produce fly ash based Geopolymer Cement Concrete (GPCC) with excellent physical properties, mechanical properties. The durability of concrete is a major and important requirement for the performance of the structure in aggressive environments. The present study aimed to evaluate the performance of low calcium fly ash based geopolymer concrete in aggressive environment and also to evaluatethe behaviour of Unreinforced geopolymer brick masonry under axial compression.

2. REVIEW OF LITERATURE

Hemantet al. (2007) has developed a simple analytical equation by regression analysis of the experimental data to estimate the modulus of elasticity and to plot the stress-strain curves for masonry. An improvement in ductility of masonry was noted because of the presence of lime in the mortar without any considerable reduction in its compressive strength. This reviled that lime in the mortar offered distinct structural advantages.The compressive strength of masonry was found to increase with the compressive strength of bricks and mortar.

FreedaChristy.Cet al (2013) have conducted a study on the compressive strength of brick masonry subjected to axial loading. The study focuses on the effect of the masonry components with different types of bonding on compressive strength. Mohamadet al(2005) has carried out experimental tests on masonry prisms subjected to compression. The failure mechanism of masonry depends on the difference of elastic modulus between brick unit and mortar. The mortar governed the non-linear behavior of masonry. Bakharev (2003) has investigated the durability of Alkali Activated Slag (AAS) concrete exposed to sulphate attack. AAS concrete was immersed in a solution containing 5% sodium, 5% magnesium and 5% sodium and magnesium sulphate solution. The main parameters studied were the compressive strength, products of degradation and micro structural changes. The effect of geopolymer cement on the compressive strength of concrete and resistance to sulphuric acid was studied by Hewayde et al (2006)Sreevidya et al (2012) have conducted an experimental study on the acid resistance of fly ash based geopolymer mortar specimens .

3. EXPERIMENTAL INVESTIGATION

3.1MATERIALS USED

Fly ash used for this study was low-calcium (ASTM Class F) dry fly ash from Ennore thermal power station, Chennai. The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The NaOH solids were dissolved in water to make the solution. River sand was used as fine aggregates. Ordinary granite has been used as a coarse aggregate in concrete. They posses all the essential qualities of a good building stone showing very high crushing strength, low absorption value, least porosity, interlocking textures variety of appealing colors and susceptibility to perfect polish.

3.2 DETAILS OF CONCRETE MIX

The laboratory program conducted in this investigation focused on four basic mixes and these were designated with the molarity of NaOH. The concentration of NaOH used in the experimentation was based on the review of previous researchers (Hardjito and Rangan 2005).All the concretes were designed similar to normal concrete, such that the density was approximately equal to 2400 kg/m3 (Rangan and Hardjto 2005). Accordingly the performances of geopolymer concrete block specimens made with 8M, 10M, 12M, and 14M of NaOH were evaluated. The ratio of sodium silicate solution-to-sodium hydroxide solution was fixed as 2.5. The ratio of fly ash: sand: coarse aggregate was 1:1.1:2.6 with ratio of activator solution to fly ash as 0.4. The geopolymer concrete mixes were designated as

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GP1, GP2, GP3 and GP4 respectively.

Behavior of unreinforced geopolymer brick masonry prism is compared with clay brick masonry prism. English bond unreinforced clay brick prism (CBP) and Geopolymer brick prism GBP(M1) and GBP(M2) of brick size 225 x 105 x 70 mm were cast using 10M and12M NaOH concentration with prism dimension of 609x220x609 mm (h/t = 2.77) and 609 x220x914 mm (h/t =4.3). Table 3.1and 3.2 shows the mix proportions of brick used in masonry prismand the mix proportion for GPC for 1 m3 of Concrete

Table 3.1 Mix Proportion for Prism

Designation of prism	Type of Brick	Mix Proportion of brick	Mix proportion of binder(fly ash :binder)	Mix proportion of mortar (Cement: Sand)
CBP	Clay brick	Burnt clay brick	-	1:4
GBP(M1)	Geopolymer brick	1:3(Fly ash: quarry dust)	1:0.54	1:4
GBP(M2)	Geopolymer brick	1:1.1:2.6 (Fly ash : sand: Coarse aggregate)	1:0.54	1:4

Table 3.2 Mix Proportions for GPC for 1 m3 of Concrete

Specimen	Designation of Mix	Aggregate		Fly ash (kg)	NaOH Solution		Sodium Silicate (kg)	Curing Condition
		C.A (Kg)	Sand (Kg)		Mass (kg)	Molarity M		
GPC Solid Block(150x 150x150mm)	GP1	1274	539	490	41	8 M	103	30 °C &60°C
	GP2	1274	539	490	41	10 M	103	30 °C &60°C
	GP3	1274	539	490	41	12M	103	30 °C &60°C
	GP4	1274	539	490	41	14M	103	30°C &60°C
GPC Hollow Block(100x 100x250mm) with one hollow of size 45x75x125 mm	GP1	1274	539	490	41	8 M	103	30 °C &60°C
	GP2	1274	539	490	41	10 M	103	30 °C &60°C
	GP3	1274	539	490	41	12M	103	30 °C &60°C
	GP4	1274	539	490	41	14M	103	30°C &60°C

The experimentation consist of the tests such as compressive strength test,split tensile strength test,flexural strength test,water permeability test, Resistance of GPC blocks in 3% sulphuric acid, Change in weight,residual compressive strength,residual tensile strength, pH of solution and behavior of unreinforced geopolymer masonry prism. A detailed study was carried out on concrete as per the specifications prescribed in ASTM C 596-89 and IS (Indian Standards): 516-1959 to ascertain the above properties.

4. RESULTS AND DISCUSSION

4.1MECHANICAL PROPERTY

The 28 days compressive strength of the concrete was observed to be in the range of 29.12MPa to 36.24MPa for specimen cured at room temperature, whereas the strength varied between 32.11MPa to 37.12MPa for specimen cured at 60°C. The result shows that the compressive strength of oven cured fly ash-based geopolymer concrete achieves a good compressive strength. A maximum compressive strength of 37.12MPa was observed for GP4 mix cured at 60°C.It is clear that the range of compressive strength development compared with the 28 day strength for specimen cured at room temperature varies from 61.39% to 81.74% and for specimen cured at 60°C the variation was 65% to 85.88 %.Similarly geopolymer hollow block specimens were test and the strength varied in the range of 46.10% to 65.25%for specimen cured in room temperature and for specimen cured at 60̊C the variation was 45.70% to 89.47%.

The split tensile strength of GPC solid blocks varies between 1.05 to 4.12 MPa at 60°C and 1.2 to 3.30 MPa at 30°C respectively. The variation of split tensile strength of GPC hollow block varies between 1.75 to 3.56 MPa at 60°C and 1.76 to 3.12 MPa at 30°C. The variation of split tensile strength of GPC hollow block varies between 1.75 to 3.56 MPa at 60°C and 1.76 to 3.12 MPa at 30°C.

There was an increase in flexural strength of specimen from GP1 to GP4 can be seen. The range of flexural strength for specimen cured at room temperature is 1.25 MPa to 3.75 MPa. The flexural strength increases with increase in the concentration of NaOH.

4.2 WATER ABSORPTION OF GEOPOLYMER CONCRETE

Water absorption tests were performed for 7, 14 and 28 days immersion of concrete cubes of size 150 x 150 x 150 mm. Sample cured at 30°C and 60°C were tested for water absorption. The percentage of water absorption varied in the range of 2% to 4.33% and 1.33% to 3.42% for specimen cured at room temperature and at 60°C. The percentage of water absorption decreases with increase in concentration of NaOH from GP1 to GP4. The Percentage of water absorption is found to be less in case of specimen cured at the elevated temperature than the specimen cured at the room temperature. The percentage of water absorption of 28 days specimen cured at elevated temperature has low water absorption.

4.3 RESISTANCE OF FLY ASH BASED GEOPOLYMER CONCRETE TO SULPHURIC ACID

4.3.1 Change in Weight

Tests were carried out at regular intervals after 7days, 14 days and 28 days of exposure. The weight loss on exposure to sulphuric acid in GPC for specimen cured at room temperature and at 60°C was about 0.53% to 2.01 % and 0.2% to 1.02% for 28 days exposure respectively. The exposure of geopolymer in acid solution shows that the weight loss is less than 3%. Results of the weight changes for the geopolymer concrete sample cured in elevated temperature of 60°C shows a minimum weight loss of 1.02 %. From the results of the study it is also observed that oven dried specimen show less change in weight loss when immersed in sulphuric acid.

4.3.2 Residual Compressive Strength

The residual compressive strength for GPC specimen after immersion in acid solution for both curing condition was found to vary from 15.09 MPa to 20.14MPa and 20.09Mpa to 28.1MPa. The reduction in compressive strength observed for GPC specimens cured at room temperature were 7%, 14% and 22 % for 7, 14 and 28 days of exposure. The residual compressive strength for specimen cured at 60°C was 6%, 12% and 20% for 7, 14 and 28 days of exposure. The strength of geopolymer specimen gradually decreases with increase in the duration of exposure.

4.3.3 Residual Split Tensile Strength

The residual split tensile strength for GPC specimen after immersion in 3% sulphuric acid for both curing condition was found to vary from 1.81MPa to 3.36MPa and from 2.45MPa to 3.99MPa. The percentage reduction in split tensile strength observed for GPC specimens for specimen

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cured at room temperature were 4%, 11% and 19% for 7, 14 and 28 days of exposure. The residual split tensile strength for the specimen cured at 60℃ was 3%, 10% and 18% for 7, 14 and 28 days of exposure. The Split tensile strength of geopolymer specimen gradually decreases with as the day of exposure increases.

4.3.4 pH of solution

The initial value of pH for 3% sulphuric acid solution prior to immersion of specimen was 1. After 2 weeks exposure pH increased considerably in the solution containing GP1, GP2, GP3 and GP4 specimens. The increase in pH was rapid for few days and there after it was not so appreciable. The increase in pH may be attributed to migration of alkalis from specimen into the solution. Rate of migration of alkali appears to be higher within the initial days as indicated by the rapid rise in pH value. Continuous exposure beyond 9 days did not result in notable increase and this suggests that further migration of alkali from the specimen has diminished or rather stopped.

4.4 BEHAVIOUR OF UNREINFORCED GEOPOLYMER BRICK MASONRY PRISM

4.4.1 Clay Brick Prism

Stress-strain characteristics of brick masonry were examined through prism test as per IS 1905 (1987). Failure of the majority of the clay brick masonry prism specimens was due to the formation of vertical splitting cracks along their height. It is clearly known that under uniaxial compression mortar tends to expand laterally more than brick but due to the continuity between them ensured by cohesion and friction, the mortar is confined laterally by the bricks. Initial straight portion of the stress-strain curve (up to about one third of mortar strength) is followed by a nonlinear curve which extends well beyond the strain limits is shown in Figure 5.1. The mean compressive strength of the unreinforced clay brick prism varies in the range of 1.59 to 1.78 MPa.

Modulus of elasticity was calculated from stress-strain curves by measuring the slope of a secant between ordinates. The elastic modulus was found to vary from 1,520 to 2,770 MPa.

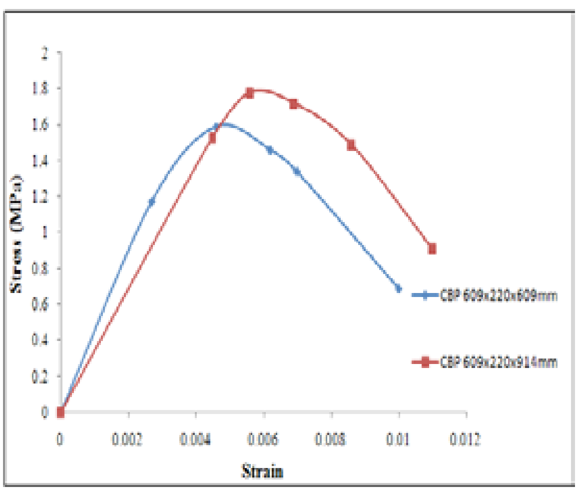

Figure 4.1 Stress- Strain Curve for Clay Brick Prism

4.4.2 Geopolymer Brick Masonry Prism GBP(M1)

The GBP (M1) masonry prisms were found damaged with visible vertical cracks (macro cracking) along the entire surface. However, the stress-strain curve of geopolymer brick masonry prism was found to be non-linear. The partial replacement of fine aggregate with fly ash and quarry dust using alkaline solution as activator increases the load carrying capacity and the strain yield more. The failure compressive strain (mm/mm length) for geopolymer brick prism GBP (M1) for 10M and 12M was noted above 0.009. The mean compressive strength of the geopolymer brick prism GBP (M1) varies in the range of 2.40 to 2.67 MPa. The compressive strength of the prism using 12M alkaline solution exhibits higher strength.

The elastic modulus was found to vary between 3,045 and 3,298 MPa. High compressive strength eliminates breakages/wastages during transport and handling. The stress strain curve is shown in Figure 5.2 and 5.3.

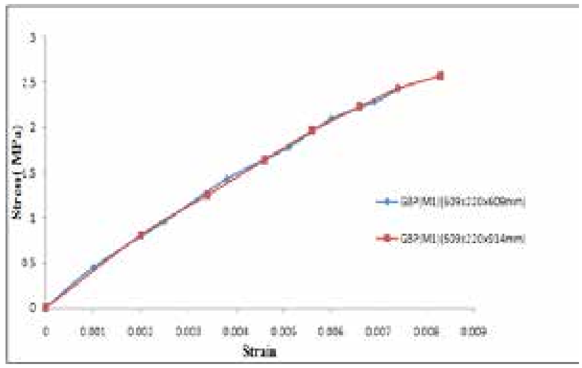

Figure 4.2 Stress- Strain Curve for GBP (M1) Prism with 10M.

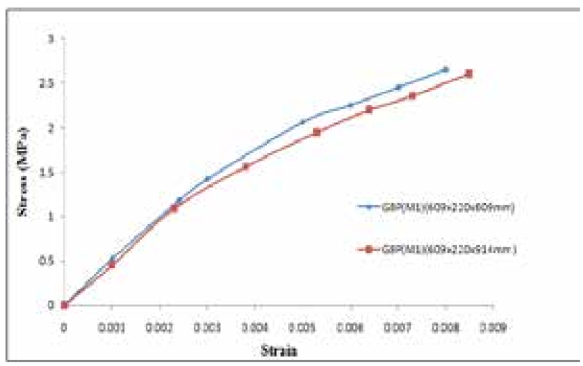

Figure 4.3 Stress- Strain Curve for GBP (M1) Prism with 12M

4.4.3 Geopolymer Brick Masonry Prism GBP (M2)

Geopolymer bricks of size 225x105x70mm were cast in the industry with molarity of activator solution as 10M and 12M.. The general form of stress strain curve of GBP and conventional concrete are almost similar and hence the equation representing these curves is same. The Modulus of elasticity of GBP (M2) is found to vary from 1967 MPa to 2358MPa and this is compared to be low than conventional concrete. The stress strain relationship is largely linear from origin to 40 % strength point on the stress strain curve.

The mean compressive strength of the unreinforced geopolymer brick prism varies in the range of 6MPa to 7.92 MPa. The compressive strength of GBP (M2) masonry prism using 12M alkaline solution exhibits higher strength. The failure compressive strain (mm/mm length) for GBP (M2) brick specimen (10M and 12M) was noted above 0.002. The stress strain curve for GBP (M2) is shown in Figure 5.4 and 5.5. Geopolymer brick masonry GPB (M2) with 12M NaOH resulted in higher load carrying capacity.

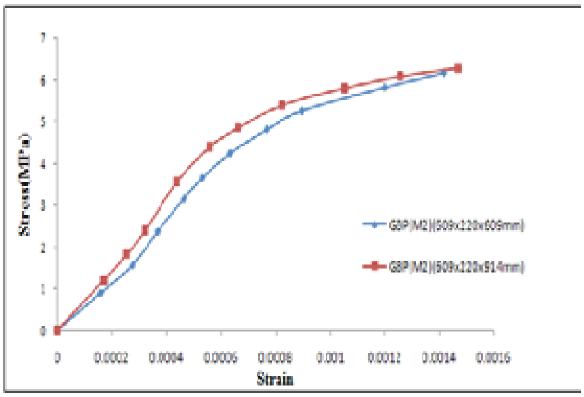

Figure 4.4 Stress- Strain Curve for GBP (M2) Prism with 10M

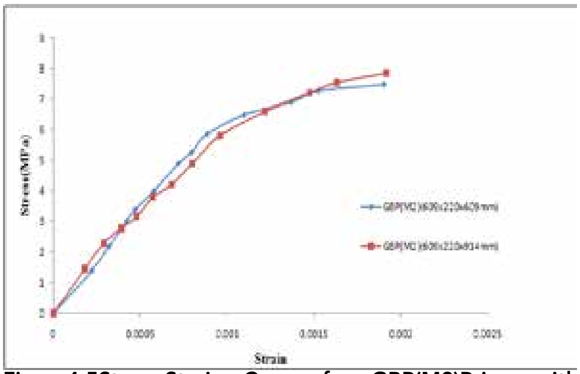

Figure4.5Stress-Strain Curve for GBP(M2)Prism with 12M

5 VALIDATION OF EXPERIMENTAL RESULT BY REGRESSION ANALYSIS

The modulus of elasticity has been predicted for brick masonry prism using regression equation. Data used for regression analysis was modulus of elasticity and prism strength.The predicted value obtained from linear regression analysis is tested using chi square test

The deviation of experimental results for modulus of elasticity of clay brick masonry prism was about 0.68% to 1.68 %.The deviation of the experimental results for GBP (M1) with 10M NaOH was found to be 0.09% to 0.68% and for GBP (M1) with 12M NaOH.The deviation of the experimental results of GBP (M2) with 10M NaOH was found to be 0.19% to 0.92% and for 12M NaOH it was found to be 0.04% to 0.46% .The experimental results are consistent with the equations developed by regression analysis. The calculated value of chi square for a level of significance of 0.05 is 2.83 which when compared to the chi square distribution table value is lesser and not significant, hence the hypothesis can be accepted and the experimental result fits well with the predicted value.

6 CONCLUSION

The following conclusions are drawn based on the experimental work reported on this research

1. Compressive strength and split tensile strength increases with increase in concentration of NaOH from 8M to 14M. Increase in compressive strength was also observed with increase in curing time for both GPC solid and hollow block.

2. Water absorption decreases with increase in concentration and curing time. The percentage of water absorption was found to decreases with increase in concentration of NaOH from GP1 to GP4. The percentage of water absorption varied in the range from 2% to 4.33% and 1.33% to 3.42% for specimen cured at room temperature and at 60℃. The percentage of water absorption is found to be less in specimens cured at elevated temperature than specimen cured at room temperature.

3. Geopolymer concrete has a very good resistance in acid media in terms of weight loss. The weight loss on exposure to sulphuric acid in GPC for specimen cured at room temperature and at 60℃ was about 0.53% to 2.01 % and 0.2% to 1.02% for 28 days exposure respectively.

4. The reduction in compressive strength observed for GPC specimens for specimen cured at 30℃ and 60℃ were 7%, 14%, 22 % and 6%,12%,20% for 7, 14 and 28 days of exposure.

5. The residual tensile strength for specimen after immersion in 3% sulphuric acid for curing at 30℃ and 60℃ was found to vary between 1.81 MPa to 3.36MPa and 2.45Mpa to 3.99 MPa

6. Exposure solutions recorded considerable increase in pH value which can be attributed to migration of alkalis from specimen to solution.

7. The successful production of GPC block with the existing concrete production facilities in plant indicates that conventional concrete tools and equipment can be utilized. Geopolymer concrete has excellent compressive strength and is a best fit for structural applications.

8. The stress strain behavior of GPC brick when compared to clay brick prism was found to be better and the analytical values obtained using regression analysis and chi square test is substantially conservative when compared to the test values.

GPC utilises the industrial waste for producing the binding material in concrete and it can be considered as eco-friendly material.

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