International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 7, July-2018

AN EXPERIMENTAL STUDY ON BOND CHARACTERISTICS OF GEOPOLYMER CONCRETE

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Abstract— ***The major downside that the globe is facing these days is that the environmental pollution. Within the industry chiefly the assembly of standard Portland cement (OPC) can cause the emission of pollutants which ends in environmental pollution. The assembly of 1 ton of Portland cement emits just about 850kg of greenhouse emission into the atmosphere. A shot during this regard is that the replacement of Portland cement with materials of biological origin or by-product materials likes FLYASH, GGBFS etc. The silicon present in GGBFS associated FLYASH could be activated with a alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to make alkaline activated paste that binds alternative unapproachable materials. During this work the influence of fly ash and GGBFS on the strength of geo-polymer concrete activated by exploitation 8M base-forming solutions for different fluid to binder ratios. Within the present work, the strength characteristics of geo polymer Concrete fly ash and GGBS in Compression and further as Bond were studied. To check the BOND STRENGTH of concrete, 16mm diameter mild and HYSD steel bars were used.***

2.INTRODUCTION

The geo polymer concrete also known as alkaline activated concrete shows better promise for application in concrete industry as an alternative binder to the Portland cement in terms of global warming, the alkaline geo polymer concrete considerably cut back the carbon dioxide emission to the atmosphere caused by the cement industries. Davidovits (1988; 1994) projected that associate degree alkaline liquid can be used to react with the silicon (Si) and aluminium (Al) in a very source material of earth science origin or in by product materials like fly ash and GGBS to produce binders. As a result of the method chemical change, chemical action that takes place during this case could be a polymerization process, he coined the term alkaline Activated to represent these binders. The limitations of geo polymer concrete are more setting time and the heat curing to achieve strength. By replacing with fly ash and alkaline solution instead of OPC these limitations are removed.

The present work is aimed toward the study on the compressive strength, split tensile strength, bond strength characteristics of geo polymer using fly ash and ground granulated flast furnace slag (GGBS) that are producing at room temperature conditions while not water curing.

3.OBJECTIVES OF THE STUDY

The main objective of this work is to study the bond characteristics of geo polymer concrete using mild steel and HYSD bars of dia 16mm and comparing the results of the work. In this work we use 8M solution for preparing solution.

4.LITERATURE REVIEW

L.Krishnan, S.Karthikeyan, S.Nathiya, K. Suganya[12]In this paper they gave limitations of fly ash based geopolymer concrete are slow curing time it cured in atmosphere for stream curing and reduces the addition GGBS content to get strength and alkaline solutions are used.A 12 Molarity solution was taken to prepare the mix. They tested compressive strength for 12M solution mix. The cube specimens are taken of size 100 mm x 100 mm x 100 mm. ambient curing of concrete at room temperature was adopted. In total 36 cubes were cast for different mix and the cube specimens are tested for their compressive strength at age of 1 day, 7 days and 28 days .based on results compare normal concrete GPC get full strength in only 24hrs in normal atmosphere temperature. And also strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix.

Professor Vijaya Rangan PhD[13] is currently an Emeritus Professor of Civil Engineering in the Faculty of Science and Engineering, Curtin University, Perth, Australia, The Indian Concrete Journal April 2014.

In this paper they give merits of geo polymer concrete and which properties are plays major role in geopolymer concrete and comparison between less curing period strength and high curing period strength and different tests conducted on reinforced concrete and how it works for precast structures are briefly discuss in this paper.

Prabir sarker[10] in this paper they briefly gave the results of pullout test to carried out investigation on bond strength between fly ash based geo polymer concrete and steel reinforcing bars. In this paper they compare the bond strengths of GPC and OPC with same steel like same dia and property. In the process of testing 24 GPC specimens and 24 OPC specimens are tested by using pullout test and diameter of bars are 20mm and 24 mm for both GPC and OPC. In this investigation compared to results geopolymer concrete gives better bond strength than OPC.

5.MATERIALS

FLY ASH:

Class F fly ash is designated in ASTM C 618 and originates from anthracite and bituminous coals. It consists mainly of alumina and silica and has a higher LOI than Class C fly ash. Class F fly ash also has a lower calcium content than Class C fly ash.

GGBS:

The blast furnace scoria may be a bi-product of the iron producing industry. Iron ore, coke and limestone are fed into the furnace and also the resulting molten scoria floats above the molten iron at a temperature of about 1500°C to 1600°C. The liquid slag has a composition is near the chemical composition of Portland cement. After the molten iron is tapped off, the remaining liquid slag that consists of mainly siliceous and aluminous residue that is thought as ground granulated blast furnace slag (GGBFS). GGBFS would only bring about one-tenth of that of Portland cement in terms of environmental impact.

ALKALINE SOLUTION:

The most common alkaline liquid used in Geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The Sodium Hydroxide (with a molecular weight of 40) will be in flakes and pellet form with about 98% purity. These pellets are mixed with distilled water to obtain the sodium hydroxide solution of required molarity. The concentration of sodium hydroxide solution can vary in the range between 8M and 16M; however, 8M solution is adequate for most applications. Addition of sodium metasilicate in water gives sodium metasilicate solution. Sodium silicate solution is available in market in the name of ‘A50’ solution. Both the solutions are mixed together to get the alkaline solution and put aside for 24hrs before the usage.

FINE AGGREGATES:

River sand confirming to ZONE-II has been used as fine aggregate.The specific gravity and water absorption of sand according to IS 2386(part-III,1963)600 microns passing fine aggregate is used in this investigation for preparing of Geo polymer concrete.

COARSE AGGREGATES:

Three different sizes of coarse aggregates are used in this investigation for preparation geo polymer concrete.

- Passing From 20mm Sieve And Retained On 16mm Sieve.
- Passing From 12mm Sieve And Retained On 10mm Sieve.
- Passing From 6mm Sieve And Retained On 2.36mm Sieve.

MATERIALS AND PROCUREMENT:

The materials used in the present study are:

1. Ground Granulated Blast Furnace Slag (GGBFS) - obtained from JSW industries, Bellary.

2. Fly ash- obtained from Nellore Thermal Power Station, Nellore.

3. Alkaline solution which is a combination of sodium hydroxide solution and sodium Meta silicate solution. The chemicals are obtained from Dutta scientific laboratories, Bangalore and the solutions are prepared by mixing with water.

4. Sand- Pennar river sand.

5. Coarse aggregate – obtained from cheemakurthi granite quarry, prakasam (dt).

6. METHODOLOGY

PREPARATION OF ALKALINE SOLUTION:

Potable water was used to prepare alkaline solution to avoid any mineral interference. The alkali solution has to be prepared 4 hours in advance before the use. The sodium hydroxide is available in small flakes and sodium silicate is available in gel form.

PREPARATION OF NaOH SOLUTION:

The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molarity(M). For instance, NaOH solution with a concentration of 8M consisted of 8x40 = 320 (in flake or pellet) per liter of the solution, where 40 is the molecular weight of NaOH. Note that the mass of NaOH solids was only a fraction of the mass of the NaOH solution, and water is the major component.

The solution is normally soapy in nature and even a drop of solution falls on the skin, it may cause skin irritation etc., hence proper care and precautions should be taken while handling the solution. The solution should be stored in closed containers with proper labelling.

PREPARATION OF SODIUM SILICATE SOLUTION:

Add 400Gms of sodium silicate in 1 litre of water. That is the total 100% of solution. That solution contains 45% of sodium silicate and 55% of water by weight is mixed. The solution is prepared in the laboratory as per the specifications it was obtained from Himalaya chemicals, Nellore. That is the total 100% of solution. That solution contains 36.47% of sodium Meta silicate and 63.53% of water by weight. Potable water was used to prepare alkaline solution to avoid any mineral interference. The alkali solution has to be prepared minimum 24 hours in advance before the use. The sodium hydroxide is available in small flakes and sodium Meta silicate is available in solution form.

MIXING:

The required quantities are weighed for a given proportion and are mixed in a drum mixer. All the dry materials are mixed for about 3 minutes in the mixer and the wet mixing after adding the solution is continued for another 4 minutes. The cubes are casted in 150mm cubes.

MIX PROPORTION:

An example of calculating the required quantities of different materials for a considered proportion is given below:

Dimension of the cube= 150mm= 150×10^{-3}m

Volume of the cube= (0.150)3= $3.375\times10^{-3}m^3$

Total amount of concrete required for 3 cubes = 28kgs.

Total (binder + fluid) = 23% of total = 6.21kg.

Only binder = 71.24% of (fluid + binder)= 4.43kg,

Fluid content = 28.66% of (fluid + binder)= 1.779kg.

Total aggregate = 77% of total = 21.79kg.

Fine aggregate = 30% of total aggregate = 6.537kg.

Total coarse aggregate=70% of total aggregate=15.253kg.(21.173% of 20mm +28.29% of 12mm+50.54% of 6mm)

The adopted fluid to binder ratios are: 0.46, 0.445, 0.43..

WORKABILITY TEST:

Slump test gives a measure of consistency, but is very useful in detecting variations in uniformity of mix of given nominal proportions. IS 1199-1959 describes the slump test. Slump cone test mould is filled in fresh concrete in four layers, each layer of approximately one quarter of the height of the mould and tamped with 25 strokes of the rounded end of the tamping rod. Strokes are distributed in a uniform manner over the cross section and for the second and subsequent layers should penetrate into the underlaying layer. After the top layer has been rodded, the concrete is struck of level with a trowel, such that the mould is exactly filled. Mould is removed immediately by raising slowly and carefully in a vertical direction. It allows the concrete to subside and the slump is measured immediately by determining the difference between the height of the mould and that of the highest point of the specimen being tested. Slump measured is recorded in terms of millimetres of subsidence of the specimen.

COMPRESSIVE STRENGTH TEST:

The compressive strength test of concrete is done as per the IS516-1959. Now we discuss the procedure for compressive strength test. The test specimen is placed between the plates of the compression testing machine with the care that the axis of the specimen is aligned with the centre of thrust of the seated plate. According to the codal provisions apply a gradual load of 14 N/mm2 until the specimen is crushed. Average of the three specimens is taken as the compressive strength of concrete, provided that the individual viriation is not more than ± 15% of the average. The important precaution taken while testing is the smooth face of the cube is facing the plates of the compressive testing machine to provide uni axial loading.

SPLIT TENSILE STRENGTH TEST:

In Split Tensile Strength Test we prepare the geo polymer concrete as we done before. Prepare the cylindrical moulds and apply the grease on it. Place the concrete in the moulds and vibrate it. After vibration we place the cylinders for 24 Hours in room temperature. Then stripping the cylinders after 24 hours. Place the cylinders for ambient curing after stripping. Then the cylinders were tested.

BOND STRENGTH TEST:

The bond strength of concrete is done by pull out test according to the codal provisions provided in IS 2770 part1. The mechanics of bond stresses ensure the reinforcement is solidly anchored to the surrounding concrete. Analysis and design of the reinforced concrete composite members are based on the assumption that no slippage will occur in the interface of steel and concrete. Bond stress is the shear stress at the reinforcing bar – concrete interface which by transferring load between the reinforcing bar and the surrounding concrete, modifies the steel stresses. This bond stress enables the two materials to form a composite member. The efficiency of a reinforced concrete structural member is based on the adequate composite action between the steel and concrete.

Fig:stirrups arrangement

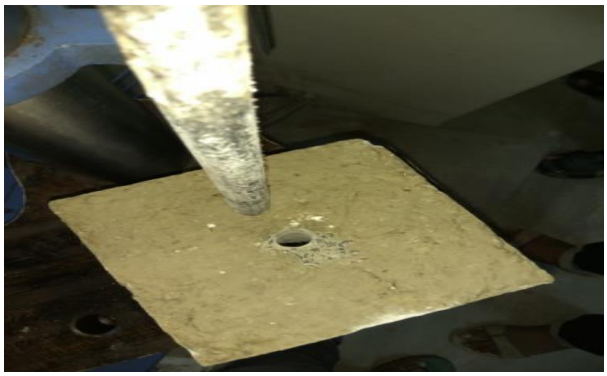
Fig: cube casting for pull out test

During bond strength test i.e pull out test, one of the following three failures may occur

1. Slip of Bars
2. Yielding of bars
3. Cracking/crushing of concrete

SLIP OF BARS:

During slip the bar comes out of the cube as shown in figure. which will occur in case of MILD steel bars



YIELDING OF BARS:

In yielding of bars the may broken during testing without slipping as shown In figure. which will occur in case of HYSD bars.

CRACKS/CRUSHING OF CONCRETE:

The cracks were also may develop in cubes during testing in UTM as shown in figure. which will occur in case of HYSD bars.

7. RESULTS

WORKABILITY:

Slump cone test:

Workability tests were conducted on geo polymer concrete using 8M alkaline solutions with different f/b ratios. The concrete contains flow nature, and then the concrete has good workability.

Mix (%)	Change in fluid content (%)	Workability (cm)
100% Flyash	40	13
25% GGBS + 75% Flyash	41.5	12
50% GGBS + 50% Flyash	43	13
75% GGBS + 25% Flyash	44.5	13
100% GGBS	46	12.5

COMPRESSIVE STRENGTH:

S. No.	Mix	3 days	7 days	14 days	28 days
		Average compressive strength (Mpa)			
1	100% Fly ash + 0% GGBS	22.8	39.55	42.60	43.00
2	75% Fly ash + 25%GGBS	34.8	40.15	43.20	43.76
3	50% Fly ash +50% GGBS	40.59	43.4	48.50	49.14
4	25% Fly ash +75% GGBS	45.23	47.3	49.64	52.10
5	0% Fly ash + 100% GGBS	50.68	52.61	54.10	54.34

SPLIT TENSILE STRENGTH TEST:

Table:Split Tensile Strength of GPC

S. No.	Mix	Average split tensile strength (Mpa)			
		3days	7days	14days	28days
1	100% Fly ash + 0% GGBS	4.19	5.31	6.57	7.68
2	75% Fly ash + 25%GGBS	5.309	6.571	7.47	8.53
3	50% Fly ash +50% GGBS	6.57	7.64	8.53	9.55
4	25% Fly ash +75% GGBS	7.49	8.70	9.55	10.47
5	0% Fly ash + 100% GGBS	8.55	9.55	10.47	11.10

BOND STRENGTH OF CONCRETE:

FOR MILD STEEL:

TABLE: Bond Strength of GPC

S. No.	Mix	Ultimate bond Strength(Mpa) (Avg values)			
		3 days	7 days	14 days	28 days
1	100% Fly ash + 0%GGBS	6.89	9.3	11.01	12.202
2	75% Fly ash + 25%GGBS	7.82	10.01	11.936	13.50
3	50% Fly ash + 50% GGBS	7.95	10.61	12.334	13.90
4	25% Fly ash + 75% GGBS	8.5	10.87	12.59	14.45
5	0% Fly ash + 100% GGBS	8.88	11.27	12.99	14.70

BOND STRENGTH OF CONCRETE FOR HYSD STEEL:

TABLE: Bond Strength of GPC for HYSD

S. No.	Mix	Ultimate bond Strength(Mpa) (Avg values)			
		3 days	7 days	14 days	28 days
1	100% Fly ash + 0% GGBS	6.89	9.3	11.01	12.202
2	75% Fly ash + 25% GGBS	7.82	10.01	11.936	13.50
3	50% Fly ash + 50% GGBS	7.95	10.61	12.334	13.90
4	25% Fly ash +75% GGBS	8.5	10.87	12.59	14.45
5	0% Fly ash + 100% GGBS	8.88	11.27	12.99	14.70

7. DISCUSSIONS

WORKABILITY:

The following sections mentioned about variations in workability of geo polymer concrete.

In this investigation mainly 5 different proportions are use 100% flyash,75% flyash+25% GGBS, 50% fly ash +50% GGBS, 25%fly ash+75%GGBS, 100% GGBS. Geopolymers concrete (GPC) with fly ash and GGBFS in different proportions and variation of these two changes in workability of geo polymer concrete. In the mix proportions increase in the percentage of GGBFS workability is increase compared to previous proportions. For same f/b ratio the workability of (50% GGBFS+ 50% FLY ASH) concrete is found to be better than other two. Hence f/b ratio shall be increased with increase in the GGBFS content.

COMPRESSIVE STRENGTH:

1**. 3Days:** In the mix proportions when 100% fly ash +0% GGBS in that time compared to all proportions this proportion having low compressive strength in 3days.In 3days 100% GGBS +0% fly ash having more compressive strength. Here almost 75% strength difference between these two proportions. In remaining proportions having variations in compressive strength when GGBS content increases compressive strength is also increases.

2. **7Days:** Like 3 days compressive strength is increases when percentage of GGBS content increases same 7 days also compressive strength is increases but in only 23%.Geoplymer concrete is get almost better strength in 3days.

3. **14Days:** In 14 days only 10% is increases to 100% fly ash proportion and 100% GGBS proportion. Increasing GGBS content compressive strength increases and increasing curing period there is no much difference in variation of compressive strength.

4. **28Days:** In 28days also only 10% is increases to 100% flyash proportion and 100% GGBS proportion.

SPLIT TENSILE STRENGTH:

1.**3Days:** In split tensile strength also increasing in GGBS increasing the strength. Compare to both 100% fly ash(4.19 Mpa) proportion and 100% GGBS(8.55Mpa) proportion strength may increases near to 69%.

2.**7Days:** In 7 days also split tensile strength is gradually varies in lesser amount. In this period also 100% GGBS get more strength compared to all proportions. The increasing in split tensile strength is 10%.

3. **14Days:** In 14 days also strength is gradually varies with different proportions same 10-11% of strength is increases by proportion. And 100% GGBS get more strength compare to all.

4. **28Days**: increasing GGBS increasing the split tensile strength. The split tensile strength is increase in 10%, 11.28%, 9.19%, 5.84%

BOND STRENGTH:

BOND STRENGTH OF GPC FOR MILDSTEEL:

7days strength is increasing with increasing curing period and addition of GGBS content. That increasing percentage is slightly increases with less difference. In 7 days percentage of increasing strength is 7.35%, 5.81%, 2.42%, 3.61% And for 14 Days it varies like 8.07%, 3.27%, 2.05%, 3.12% and 28 days also it varies like 10.1%, 2.91%, 3.88%, 1.71% percentage of increase in strength is increasing by proportion to proportion and coming to same proportion in different curing periods almost all proportions are increases their strength in increasing curing period. In GPC almost it gets full strength in 3Days, but in increasing curing period strength also increases in slight variation. In finding bond strength of GPC for mild steel almost all bars slipping occurred.

BOND STRENGTH OF GPC FOR HYSD:

In 7Days also strength is gradually increases with slight variation in strength. But in like 3 days strength in 7 days also strength for 1st to second proportion strength is decreased in 10%. There is no problem in mixing and curing process that decreasing strength came from instrumental error.Normally, when GGBS content increases strength also increases. And for next proportion strength increases for 16.6%, 0.045%, 0.041%.In 14, 28 days also strength is increases in very less percentage. The variation of strength in percentages is 0.61%,4.49%,0.05%,0.05%.In 28 days also it varies 2.28%,0.02%,0.06%,0.16%.For same proportion strength is increases more changing of curing period. Compare OPC, GPC having more compressive strength and split tensile strength and bond strength between concrete and mild steel and HYSD bars also more compare OPC.

8.CONCLUSIONS

1.High early age strength can be achieved with GPC made with GGBFS. From the test based on investigations, 60% to 90% of the target strength is achieved in 3 days.

2. As no cement is used, the GPC can be recognized as eco-friendly because, cement production leads to emission of CO2.

3. The workability of GPC is poor when compared to ordinary cement concrete. However, increase in workability can be achieved by using super plasticizer.

4. Hence f/b ratio shall be increased with increase in the GGBFS content.

5. For 100% GGBS the compressive is 50.68 Mpa and in 7Days it increases by 3.73%, 14 Days it increases by 6.52%, 28Days is 6.97% compared to 3days strength.

6. For (75% GGBS+25% FLY ASH) concrete the compressive strength increases by 4.47 at 7 days and 9.29 at 14 days and 14.11 at 28days When compared to 3 days strength

7. For (50% GGBS+50% FLY ASH) concrete the compressive strength increases by 6.89% at 7days and 17.75% at 14 days and 19.05% at 28days when compared to 3 days strength

8. For(75% FLYASH + 25% GGBS) concrete the compressive strength increases by 14.27% at 7days and 21.53% at 14 days and 22.81% at 28days when compared to 3 days strength.

9. For(100% FLYASH) concrete the compressive strength increases by 53.72 at 7days and 60.55% at 14 days and 61.39% at 28days when compared to 3 days strength.

10. Compressive strength decreases with increase in Fly Ash content.

11. For 100% GGBFS the three days compressive strength is found to be much higher than remaining proportions.

12. For 100% GGBS the split tensile strength increases by 11.69% at 7 days and 20.18% at 14 days and 25.95% at 28 days when compared to 3 days strength

13. For (75% GGBS+25% FLY ASH) concrete the split tensile strength increases by 14.94% at 7 days and 24.17% at 14 days and 33.18% at 28 days when compared to 3 days strength

14. For (50% GGBS+50% FLY ASH) concrete the split tensile strength by 15.05% at 7 days and 25.96 at 14 days and 36.97% at 28 days when compared to 3 days strength

15. For (25% GGBS+75% FLY ASH) concrete the split tensile strength by 31.24% at 7 days and 33.82% at 14 days and 46.54% at 28 days when compared to 3 days strength

16. For (100% FLYASH) concrete the split tensile strength by 23.57% at 7 days and 44.23% at 14 days and 58.80% at 28 days when compared to 3 days strength

17. Split tensile strength decrees with increase in Fly Ash content.

18. Pull out of bars is possible in case of mild steel used for bond strength test.

19. Yielding of bars takes place in case of HYSD steel used for bond strength test.

20. The ultimate bond strength between GPC and MILD STEEL decreases with increase in Fly Ash content.

21. The bond strength between GPC and MILD STEEL decreases with increase in Fly Ash content.

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