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STUDIES ON DEVELOPMENT OF GEO-POLYMER CONCRETE

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ABSTRACT:

Concrete is the most abundant manmade material in the world. One of the main ingredients in a normal concrete mixture is Portland cement. However the production of cement is responsible for approximately 5% of the world's carbon dioxide emissions. In order to create a more sustainable world, engineers and scientists must develop and put into use a green building material. Geo-polymer concrete is also much more durable than ordinary concrete due to its resistance to corrosion. It is also much stronger than ordinary concrete. Geo-polymer concrete is a revolutionary sustainable building material that will pave the way for green building. In this paper experimental investigations on the development of equivalent M20 grade geo-polymer Concrete (GM20) is to be carried out. Activating solution based on sodium hydroxide and sodium silicate is prepared.Class C fly-ash is considered as the source material. Mix design is made for M20 and GM20 concrete using IS method. GPC is to be prepared by mixing fly ash, river sand, course aggregate and activating solution. Control specimens like cubes, cylinders and prisms are to be cast out of the GM20 grade GPC and M20 grade OPCC. For the GPC, ambient curing is suggested and for OPCC conventional pond curing was done. The compressive strength, tensile strength and flexural strength are to be obtained after 7days and 28days of curing. Finally comparing the GPC with conventional and suggestions to be carried out.

Keywords*: Concrete, Fly-ash, Activating solution, Mix design, Geo-polymer.*

1. INTRODUCTION:

Portland cement based mortar and concrete are the most prevalent and versatile building materials and also most effective and widely used construction materials. But, about seven percent of the total atmospheric carbon dioxide (CO_2) comes from cement industries. The demand for concrete increases day by day and also for the Portland cement. Presently about Ten billion tons of concrete is required globally and hence 15-25% of it by various types of cement.

Among the tonnage materials produced like oil, metals, ceramics, polymers and others, concrete is the highest order of annual world production and as a result, the cement industries are held responsible for some of the CO_2 emissions throughout the world. It is observed that the production of cement emits almost an equal amount of CO_2 into the atmosphere that promotes the global warming issues.

Many alternatives have been tried through the utilization of industrial waste like flyash, silica fume, rice husk ash, furnace slags and mtakoalin. These materials are also quantitatively increasing

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and causing pollution problems. The utilization of such pozzolanic waste materials by replacing cement totally or partially to the maximum possible extent for making concrete is gradually promoted after considerable research.

Geo-polymer concrete is a new material for structural concrete which is also based on an ancient technology. There are numerous publications reporting the different properties of geopolymer synthesized from different source materials and activating solutions.

In line with conventional concrete, GPC consists of geopolymer (binder), coarse and fine aggregates. The two main constituents of the binder are the source material and the alkaline liquid. The source material (Alumina-silicate) should be rich in silicon(Si) and aluminum(Al) and the choice of the source materials depends on the factors like availability, cost, application type and specific demand of end users. Conventional cement concrete and Geopolymer concrete are compared at a glance in Table

Details	Conventional	Geopolymer
Constituents	Cement +water	Flyash + activator
	Fine	Fine aggregate
	Coarse aggregate	Coarse aggregate
	Plasticizers	Plasticizers (extra water if needed)
Mixing	Hand or machine	Hand mixing or machine mixing
Curing	Water curing, steam curing (Hydration)	Steam curing, Hot oven curing, exposed curing, Ambient curing.

The scope of the thesis is confined to the development of geopolymer concrete based on the utilization of high calcium flyash as source material with sodium hydroxide/sodium silicate based activating solution. Accordingly the objectives are framed for experimentation like, making optimum proportions for conventional concrete mix and geopolymer concrete mix.Studying the possibilities by conducting tests for the determination of workability, strength and durability characteristics for three different grades of concrete and creating a theoretical model for the prediction of strength. [3] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential

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part of the system although with changing demands on physical input as the degree of mechanization is increased.

RESEARCH NEED:

The investigation on the development of geopolymer concrete becomes essential because of the problems associated with the production of cement and concrete on environmental degradation. There exists always a necessity to find some alternatives to cement. It has been found certain waste products from industries possessing cementititious properties and certain waste materials which can act as a binder when properly activated with appropriate substances. In this line, research is initiated to develop a concrete without conventional cement coined as geopolymer concrete using source materials like ash and sodium or potassium based activating solution.

2. EXPERIMENTAL INVESTIGATION:

Cement and Flyash

Ordinary Portland cement of Grade 43 is used for the conventional concrete and high calcium class C flyash (ASTM) obtained from lignite based thermal Power station (Neyveli Lignite Corporation, Neyveli, Tamil Nadu, India) is used as the source material for the GPC respectively. The entire quantity of flyash required for the thesis work is collected at one time and preserved for the entire stretch of its use for making GPC. The chemical composition of cement and flyash used are determined as per the Indian specifications and are presented in Table for comparison. The fundamental physical properties of cement and flyash are also determined as per relevant Indian standards and presented in Table

Chemical composition of Cement and Flyash

No	Compounds	Composition of Cement Flyash OPC 43	
1	Silica (SiO_2)%	18.30	52.0
2	Alumina	5.50	33.9
3	Iron Oxide	5.70	4.0
4	Calcium oxide	61.20	1.2
5	Magnesium Oxide(MgO_3)%	1.20	0.81
6	Sulphur trioxide	1.40	0.28
7	Sodium Oxide %	-	0.27
8	Potassium oxide	-	0.83
9	Loss on Ignition	2.31	6.23

Physical properties of Cement and Flyash

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No	Description of Test	Cement OPC 43	Flyash
1	Specific gravity	3.15	2.12
2	Consistency %	28%	30%
3	Initial setting time (minutes)	40	50
4	Final setting time (minutes)	445	480
6	Retained on 75 micron sieve (%)	7.99	5.77

Fine and coarse aggregates

Locally available clean river sand was used as fine aggregate in the study conforming to Zone-II as per IS: 383-1970. The locally available crushed granite course of size 12.5 mm was used for the preliminary study and maximum size of 20mm size used for the main study as the coarse aggregate. To facilitate the mix design for concrete, the following physical properties appropriate for fine and coarse aggregates are determined as per relevant Indian standards

No	Properties	Fine aggregate	Coarse aggregate Max. size 20mm
1	Fineness modulus	2.89	2.51
2	Grading	II	-
3	Specific gravity	2.85	2.6
4	Bulking	23.39	-
5	Water	0.5%	0.5%
6	Impact	-	20.39%

3. TRIAL MIX:

Based on the literature survey, the molar concentrations of NaOH as 8M the activator/fly ash ratio by masses as 0.35 and the liquid ratio of Sodium silicate and sodium hydroxide based activating solution as 2.5 are considered. Trial mixes of conventional concrete of M20 grade using IS 10262: 2009 and equivalent grade of geopolymer concrete designated as GM20 are designed (Rangan, 2008) and prepared. The mix proportions for the trial mix and the quantities required for one meter cube of concrete are to be test.

The Sodium hydroxide solution is prepared 24 hours prior to use, because after dissolving flakes of NaOH in water, the temperature of solution can go up to 80^{o}C, hence it is necessary to cool it at room temperature before use. The solids dissolved in water making a solution with the required

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concentration is allowed to cool to reduce the generated heat for 4 to 6 hours. Then it is mixed with sodium silicate solution. The Sodium hydroxide solution thus prepared is mixed together with Sodium silicate solution one day before adding the liquid to the solid dry constituents to get desired alkaline solution.

No	Conventional concrete Mix (M20)		
1	Constituents	Ratio	Wt(kg/m^3)
2	Cement	1	383.16
3	Sand	1.24	598.6
4	Jelly 20mm	2.26	1181.6
5	Water	0.40	197.52
6	Admixture	No	
7	Slump	34mm	

No	Geopolymer concrete (GM20)		
1	Constituents	Ratio	Wt (kg/m^3)
2	Fly ash	1	320
3	Sand	1.09	576
4	Jelly	1.53	1344
5	Activator	2.5	114.28
6	Activator/FA	0.68	45.72
7	Admixture	1.5%	
8	Extra water	Vary w.r.to molarity	
9	Made to 40mm by adding water		

4. CASTING AND TESTING:

FRESH CONCRETE PROPERTIES

For determining the fresh concreteproperties the following test are conducted.

Slump cone test

The concrete slump test is an empirical test that measures the workability of fresh concrete. It measures the consistency of the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete. Testing and results are shown in fig and table. The slump indicates true slump characteristics.

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Trail	Control concrete		Geo polymer concrete	
	Unsupported ht. of concrete	Slump value	Unsupported ht. of concrete	Slump value
1	28.5	1.5	27	3
2	27.8	2.2	27.5	2.5
3	28.1	1.9	26.5	3.5
AVG	1.87		3	

Flow table test

The flow table test measures the horizontal spread of a concrete cone specimen after being subjected to jolting. Resistance to segregation can be assessed qualitatively in concrete mixes that are susceptible to segregation, the paste will tend separate from the coarse aggregate around the perimeter of concrete mass. Testing and results are shown in figand table

Trail	Control concrete		Geo polymer concrete	
	Spread dia.in cm	Flow %	Spread dia.in cm	Flow %
1	31.2	24.8	33	32
2	31.6	26.4	32.7	30.8
3	32	28	32.9	31.6
AVG	26.4%		31.5%	

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HARDENED CONCRETE PROPERTIES

The hardened properties of concrete such as concrete cube compressive strength, split tension strength and Flexural Strength tests are conducted as per Indian standard. The 12 controls and Geo polymer concrete cube, cylinder and Prisms specimens are casted for tests conducted at 7 and 28 days. The concrete after workability tests was used for casting test specimens. For casting cube specimen cube moulds of size 150x150x150 and for cylinder 15mm dia. and 30mm high cylindrical mouldsand for prism 100x100x500mm are used. The inner surface was thoroughly cleaned and a thin layer of grease was coated. The concrete was filled and compacted in three layers with standard tamping bar. After the top layer was compacted, the surface of the concrete was finished in level with top of the mould using a trowel. The hardened casted cubes are remolded and subjected to curing in water until one hour before testing. Casting of cube and cylinder specimens are shown in fig

Compressive strength test

Compressive Strength of Concrete cube Specimens is tested after 7thand 28thdays. The test is done using Compression Testing Machine. As per IS 456:2000 and IS516:1959 the compressive strength value of cube specimen should not less than 20 N/mm^2.

Results of M20 grade concrete

Specimens	Weight(kg)	Load(kN)	StrengthN/mm^2	Average N/mm^2
Cube 1	8.388	385	17.11	17.33 (7days)
Cube 2	8.471	400	17.78	
Cube 3	8.549	385	17.11	
Cube 4	8.610	650	28.88	28.39 (28days)
Cube 5	8.400	622	27.64	
Cube 6	8.560	645	28.66	
Cylinder 1	13.28	258	3.65	3.40 (28days)
Cylinder 2	12.10	245	3.46	
Cylinder 3	13.16	218	3.08	
Prism 1	13.50	9.10	4.55	4.51 (28days)
Prism 2	14.00	8.75	4.38	

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Prism 3	3.232	9.20	4.60	

Cylinder split tensile strength test

Split tensile Strength of concrete cylinder specimens are tested at 28th days on universal Testing Machine as per IS456:2000 and IS 5816:1999 the split tensile strength of concrete should not less than 1/10 of fck. The testing, results and tested specimens are shown in fig and table

Prism Flexural strength test

Flexural Strength of concrete Prismspecimens are tested at 28th days on universal Testing Machine as per IS456:2000 and IS 5816:1999 the Flexural strength of concrete should not less than 0.66 of split tensile strength. The testing, results and tested specimens are shown in fig and table

Results of GM20 grade concrete

Specimens	Weight (kg)	Load(kN)	Strength N/mm^2	Average N/mm^2
Cube 1	6.921	345	15.33	16.01 (7days)
Cube 2	6.999	370	16.44	
Cube 3	7.001	366	16.26	
Cube 4	6.825	625	27.77	27.74 (28days)
Cube 5	6.925	630	28.00	
Cube 6	7.102	618	27.46	
Cylinder 1	13.10	224	3.16	3.15 (28days)
Cylinder 2	12.96	230	3.25	
Cylinder 3	13.55	215	3.04	
Prism 1	12.88	8.20	4.10	4.165 (28days)
Prism 2	11.98	8.15	4.075	
Prism 3	11.45	8.65	4.32	

5. RESULT AND DISCUSSION:

- Compressive strength of M20 grade concrete 28.40 N/mm2 and for GM20 grade concrete 27.74 N/mm2
- Split tensile strength of M20 grade concrete 3.40 N/mm2 and for GM20 grade concrete 3.15 N/mm2
- Flexural strength of M20 grade concrete 4.51 N/mm2 and for GM20 grade concrete 4.165 N/mm2
- Minimum setting period for GM concrete gets 48 hrs
- Basically, Fly ash is weight less. So the concrete made by fly ash is less weight
- Sunlight curing adopted for GM grade concrete. To get more strength steam curing required
- Solution should be prepared 24hrs before of casting for GMC.
- Required workability achieved and compared with conventional concrete

- Little tough to get workability compared with conventional grade concrete
- Less emission of carbon-di-oxide for Fly ash not much as cement

6. CONCLUSION:

- Produces a substance that is comparable to or better than traditional cements with respect to most properties.
- Geo-polymer concrete can be produced with less cost compared to OPC concrete with similar properties
- Use of Higher concentration of NaOH solution provide higher strength.
- The 28 day Compressive strength of GPC is only 2.33% less than the conventional concrete which by adding Superplasticizer or increasing the molarity of NaOH could be easily obtained.

REFERENCES:

[1] Antony Jeyasehar, C., Saravanan, G., Salahuddin, M and Thirugnanasambandam, S (2013). Development of flyash based geopolymer precast concrete elements, Asian Journal of Civil Engineering, 14(4): 605-615

[2] Davidovits, J and M. Morris (1988). The Pyramids: An Enigma Solved, Chapter I, Hippocrene Books, New York, ISBN 0-87052-559

[3] Christo Ananth, M.A.Fathima, M.Gnana Soundarya, M.L.Jothi Alphonsa Sundari, B.Gayathri, Praghash.K, "Fully Automatic Vehicle for Multipurpose Applications", International Journal Of Advanced Research in Biology, Engineering, Science and Technology (IJARBEST), Volume 1,Special Issue 2 - November 2015, pp.8-12.

[4] Joseph Davidovits (2011). Geopolymer Chemistry and Applications, 3rd edition, Institut Geo polymer, 16-Rue Galilée, F-02100 Saint-Quentin, France, www.geopolymer.org, ISBN: 9782951482050

[5] Joshi, R. K (2014). Flyash scenario in India, Scientist Report, Department of Science and Technology, India, pp. 1-18..

[6] More PratapKishanrao (2013). Design of Geopolymer Concrete, International Journal of Innovative Research in Science, Engineering and Technology, 2(5):1841-1844.

[7] Parthiban. K and Saravana Raja Mohan.K(2014). Effect of sodium hydroxide concentration and alkaline ratio on the compressive strength of slag based Geopolymer concrete, International Journal of ChemTech Research, CODEN (USA): IJCRGG ISSN: 0974-4290, 6(4): 2446-2450.

[8] PrinyaChindaprasirt, UbollukRattanasakand SompopTaebuanhuad (2013). Resistance to acid and sulfate solutions of microwave-assisted high calcium fly ash geopolymer,Materials and Structures, 46 (3):375-381.

[9] Rajamane, N. P., Nataraja, M. C., Lakshmanan, N andAmbily, P.S (2012). Literature survey on geopolymer concretes and a research plan in Indian context, The Master builder - May 2012, www.masterbuilder.co.in, pp. 50-56.

[10] Rangan, B.V(2008). Flyash based geopolymer concrete, Research Report GC 4, Engineering Faculty, Curtin University of Technology,Perth, Australia.

[11] Indian standard code for recommended guide lines for concrete mix design, Bureau of Indian Standards, New Delhi..

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Available online at www.ijartet.com
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[12] IS: 516-1959. Methods of test for strength of concrete, Bureau of Indian Standards, New Delhi.44.IS: 5816-1999.Splitting tensile strength of concrete - Method of test, Bureau of Indian Standards, New Delhi.