Experimental Investigation of Geo-Polymer Concrete Contains Recycled Aggregate

S. Balamurugan M. E

Assistant Professor, Department of Civil Engineering, Sudharsan Engineering College, Pudukkottai, Iindia-622 501

Abstract: ***The main aim of the project is to determine the special concrete made with fly ash. Fly ash is used as cement replacement material varies from 10% to 40%. To study the effect of the replaced coarse aggregate and properties of flyash based concrete. Application of recycled materials in the building industry is essential for permanently sustainable development of each country. The use of primary sources and materials is becoming unbearable both economically and ecologically, and therefore it is necessary to seek the possibility of reuse of those materials once their durability expired. The most common use of fly ash is as a replacement for Portland cement used in producing concrete. Concrete made with fly ash is stronger and more durable than traditional concrete. Fly ash concrete is easier to pour, has lower permeability, and resists alkali-silica reaction, which results in a longer service life. Concrete mix design was prepared for the grade of M30. The trial mix was prepare with a constant water binder ratio of 0.35 on superplaticiser was added based on required degree of workability. In the present study, the Geopolymer concrete was prepared by polymerization of sodium hydroxide (NaOH) and sodium silicate (Na2Sio3) with the aid of heat. This research effectively implies the M30grade concrete with the molar concentration of sodium hydroxide and sodium silicate 5M and 6M. The properties of geopolymer concrete are studied. In the present experimental investigation of replacement of cement by fly ash and recycled aggregate has been used to study the effect on Compressive strength, split tensile strength, flexural strength of concrete. For each mix standard sizes of cubes, cylinders and prisms as per Indian standards were cast and tested for Compressive strength, split tensile strength, flexural strength at age of 7 days ,14 days and 28 days as per Indian standard. The research represents the comprehensive summary of extensive studies conducted on fly ash based geopolymer concrete and recycled aggregates. Research data are used to identify the effects of salient factors that influence the properties of geopolymer concrete in the fresh and hardened states. These results are utilized to propose sample for the design of geopolymer concrete mixtures. The most common use of fly ash is as a replacement for Portland cement used in producing concrete. Concrete made with fly ash is stronger and more durable than traditional concrete. Fly ash concrete is easier to pour, has lower permeability, and resists alkali-silica reaction, which results in a longer service life.***

1. Introduction

1.1 Influence of Aggregate in Concrete

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy.

About 75% of concrete comprises aggregates. The properties and quantities of aggregates influence the strength. These are the inert or chemically inactive materials which form the bulk of cement concrete. These aggregates are bound together by means of cement. Concrete can be considered in two phase materials. They are paper phase and aggregate phase. The analysis and study of aggregate paste is also important.

When the characters and properties of aggregates are changing the strength and the property of resulting concrete will also be changed suitably. The study of aggregates are best done as their classification, source, size, shape, texture, strength, specific gravity and bulk density, moisture content, bulking factor, cleanliness, soundness, durability, sieve analysis and grading. The aggregates are classified as fine aggregates and course aggregate.

The material which is passed through 4.75mm size sieve is termed as fine aggregate. Usually natural river sand is used as fine aggregate. The material which is retained on 4.75mm size test sieve is termed as course aggregate. Broken stone is generally used as a coarse

1.2 Necessity for the search of alternatives for the aggregates

Since the volume of construction industry is growing day by day the requirements of concrete and its constituent materials such as cement, fine aggregate and course aggregate are also increasing day by day.

Since the availability of natural resources are limited it is difficult to get more aggregates according to the increased trend of construction industry. Usually river sand is used as fine aggregate. Quantity of river sand availability is limited one. In India some specified rivers are supplying river sand as fine aggregate for the concrete. So this limited availability of fine aggregate and the increasing trend of construction industry results in the compulsory need of identifying the alternate material for fine aggregate.

If more and more sand is taken from the rivers, automatically river wealth which is known as natural wealth will be decreasing. By means of the above occurrences the water storage capacities of rivers are getting low and low.

Hence in order to safeguard the natural wealth of rivers and to meet the increased requirements of fine aggregate construction industry people and researchers are suggesting finding the alternate material for fine aggregate for concrete.

1.3 Introduction about geopolymer concrete

The term "geo polymer" was coined by Davidovits in 1978.Geo polymer is an inorganic alumino-silicate polymer, synthesized predominately from silicon and aluminum material such as fly ash. Alkaline solutions are used, to induce the silicon and aluminum atoms; in the source materials (fly ash), to dissolve to form gel. The polymerization process may be assisted by the application of heat followed by drying. The geopolymer gel binds the loose coarse and fine aggregates to from geo polymer concrete. Geopolymer gel replaces the C-S-H gel in cement concrete. The current contribution of green house gas emission from Portland cement production is about 1.5 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere. On the other side, the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, it is necessary to replace the cement with the industrial by products such as fly ash, GGBS, metakaulin etc.., Chemical reaction period is substantially fast and the required curing period may be within 24 to 48 hours.

The production of Portland cement is increasing 9% annually. Portland cement (PC) production is under critical review due to high amount of carbon dioxide gas released to the atmosphere and Portland cement is also one among the most energy-intensive construction material. Geo polymer concrete is a 'new' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash (FA) and ground granulated blast furnace slag (GGBS) that are rich in silicon (Si) and aluminum (Al), are activated by alkaline liquids to produce the geopolymeric binder.

The major problem, the world is facing today is the environmental pollution. It has severe effect on the ecosystem. There are many reasons which cause pollution. In construction industry, cement is the main ingredient/material for the concrete production. But the production of cement means production of pollution because of the emission of CO2 during in production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of calcining limestone into lime in the cement kiln produces CO2. Ernest wore roll and Lynn Price et al., have reported that CO2 emission from the global cement industry. And also, the cement is manufactured by using the raw materials such as lime stone, clay and other minerals. Quarrying of these raw materials is also causes environmental degradation. To produce 1 tons of cement about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it.

On the other side the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, it is necessary to replace the cement with the industrial by products such as fly ash, GGBS, metakaulin etc. In this respect, the new technology geo-polymer concrete is a promising technique. A huge amount of fly ash is generated in thermal power plants, causing several disposal-related problems; the total utilization of fly ash is only about 50%. India produces 200 million tons of fly ash annually which is expected to cross 300 million tons by the year 2017. At present nearly 50% fly ash is utilized and balance is deposited in ponds. Disposal of fly ash is a growing problem as only 15% of fly ash is currently used for high value addition applications like concrete and building blocks, the remaining being used for land filling. The fly ash increases the strength in case of hardened concrete. Another alternative but promising utility of fly ash in construction industry that has emerged in recent years is in geo polymer concrete. Geo polymer technology can be appropriate process technology utilize all classes and grades of fly ash and therefore there is a great potential for reducing stock piles of waste fly ash materials. The present study considers fly ash utilization in production of geo polymer concrete since it can accommodate a major portion of the ash produced.

2. Literature Review

Davidovits et al, has done a research study on GPC, to name the three-dimensional alumino-silicates material, which is a binder produced from the reaction of a source material or feedstock rich in silicon (Si) and aluminum (Al) with a concentrated alkaline solution. The source materials may be industry waste products such as fly ash, slag, red mud, rice-husk ash and silica fume may be used as feedstock for the synthesis of geopolymers.

Raijiwala D.B et. al presented on "GEOPOLYMER CONCRETE: A CONCRETE OF NEXT DECADE" the progress of the research on making geo polymer concrete using fly ash. Potassium hydroxide and sodium hydroxide were used as alkali activators. He experimentally conducted the following tests for compressive strength, split tensile strength, flexural strength, pull out strength and durability. Finally he concluded that compressive strength of GPC increases over controlled concrete by 1.5 times. Split tensile strength of GPC increases over controlled concrete by 1.45 times. Flexural strength of GPC increases over controlled concrete by 1.6 times. In pullout test, GPC increases over controlled concrete by1.5 times. At 12% molarity of KOH, the cost per cubic meter of GPC reduces by 12% over the controlled concrete.

Prof.More Pratap Kishanrao investigated on **"Design of geopolymer concrete"** the behaviour of geopolymer concrete under high temperatures ranging from 100ºC to 500ºC. In this, fly ash, blast furnace slag and catalytic liquids have been used to prepare geopolymer concrete mixes. Sodium hydroxide and Sodium silicate solution are used as catalytic liquid. He experimentally conducted the test on cubes of size 150mm x 150mm x 150 mm for their residual compressive strengths after subjecting them to these high temperatures. Finally he concluded that a mixture of fly ash and ground granulated blast furnace slag in equal proportions is used as binding material in complete replacement of conventional ordinary Portland cement to prepare geopolymer concrete mixes. The parameters studied include compressive strength and weight loss after exposure to elevated temperatures.

Monita Olivia et. al presented on "**Strength and water penetrability of fly ash geo polymer concrete"** the study on the strength development, water absorption and water

permeability of low calcium fly ash geopolymer concrete. He investigated on the effectiveness of changing the following parameters: water/solids ratio; grading of aggregate; aggregate/solids ratio; fly ash content on compressive strength; water absorption; AVPV (Apparent Volume of Permeable Voids); and water permeability of the geopolymer concrete. Based on the results, this paper concluded that the influence of these parameters on the concrete properties. Ordinary Portland cement concrete with the same strength level was tested to compare the properties.
Prabir Kumar Sarker has investigated on **"Analysis of geo polymer concrete columns"** using an existing constitutive model originally proposed by Popovics for OPC concrete. He founded that the equation of Popovics can be used for geopolymer concrete with minor modification to the expression for the curve fitting factor. The modified expression provided better Correlation between the experimental and calculated stress-strain curves. A good correlation was achieved between the predicted and measured ultimate loads, load-deflection curves and deflected shapes for twelve slender test columns.

Shankar H.sanni et. al presented on the **"Performance of geopolymer concrete under severe environmental conditions"** experimental investigation on performance of geopolymer concrete subjected to severe environmental conditions. The grades were used for investigation are M-30, M-40, M-50 and M-60.Sodium silicate and sodium hydroxide are used as alkaline solution. Test specimens were 150*150*150mm cubes, 100*200mm cylinders heat-cured at 60˚C in an oven. Durability of specimens was assessed by immersing GPC specimens in 10% sulphuric acid and 10% magnesium sulphate solutions separately tested. The test results indicate that the heat cured fly ash based geo polymer concrete has an excellent resistance to acid and sulphate attack when compared to conventional concrete.

Hardjito et. al presented on **"factors influencing the compressive strength of fly ash-based geopolymer concrete"** describes the effects of several factors on the properties of fly ash based geopolymer concrete, especially the compressive strength. The test results shown that the compressive strength of geopolymer concrete does not vary with age and curing the concrete specimens at higher temperature and longer curing period will result in higher compressive strength.

Class F Fly Ash
Is a pozzolan with physical and chemical properties that improve concrete's resistance to sulfate attack. Class F fly ash also mitigates the deleterious effects of alkali-silica reactivity. Class F fly ash also decreases the permeability, increasing the long-term durability of concrete. Class F fly ash is produced from the combustion of pulverized bituminous or Texas lignite coal.

3. Materials Used in Concrete

The constituents materials used for making the concrete are as follows
1) Cement.
2) Fly ash. (F Type)
3) Fine aggregate.
4) Coarse aggregate.
5) Catalytic Liquid System (CLS)
6) Super plasticizer.
7) Water.

Materials – Brand
- Cement : PPC
- Fine Aggregate : Ordinary River Sand.
- Course Aggregate : Blue granite metal.
- Water : Potable water.

3.1 Cement

Portland Pozzolana Cement is a kind of Blended Cement which is produced by either intergrinding of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly blending them in certain proportions.Pozzolana is a natural or artificial material containing silica in a reactive form. The pozzolana materials commonly used are: Silica fumes, Fly ash, Calcined clay, volcanic ash.

Pozzolana Portland cement is ideally suited for the following construction:
1) Hydraulic structures.
2) Marine structures.
3) Mass concreting works.
4) Masonry mortars and plastering.
5) All other applications where OPC used.
6) The compressive strength of PPC as per BIS code at present is equivalent to that of 33grade OPC.

3.2 Fly Ash

Fly ash is one of the naturally-occurring products from the coal combustion process and is a material that is nearly the same as volcanic ash. Volcanic ash concrete was used thousands of years ago to produce Roman concrete structures that exist and function today; e.g., the Pantheon, Coliseum, and ancient aqueducts. When coal is burned in today's modern electric generating plants, combustion temperatures reach approximately 2800°F. The non-combustible minerals that naturally occur from burning coal form bottom ash and fly ash. Bottom ash is a light-weight aggregate material that falls to the boiler bottom for collection. Fly ash is the material that is carried off with the flue gases, where it is collected and can be stored in silos for testing and beneficial use classification.

Fly ash concrete has increased strength and durability, which means it, can handle greater loads, is more resilient and lasts longer. Fly ash concrete can withstand harsher service environments than straight Portland cement concrete. It is less susceptible to chemical attacks (de-icing salts, soil sulfates, etc.) and mitigates the negative impact of deleterious aggregates.

Fly ash concrete costs less. Depending on what area of the country you are in, fly ash can be 20% to 60% less expensive than Portland cement. In some cases, Portland cement can be more than twice as expensive.

The use of fly ash has positive environmental impacts, as it conserves landfill space, reduces energy and water consumption, and helps reduce greenhouse gases. The use of fly ash displaces Portland cement production, which emits approximately one ton of CO_2 for every ton of cement produced; i.e. for every ton of fly ash used, CO_2 emissions are reduced by one ton.

3.3 Fine Aggregate

Aggregate which is passed through 4.75 IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Important thing to be considered is that fine aggregates should be free from coagulated lumps.

Grading of natural sand or crushed stone i.e. fine aggregates shall be such that not more than 5 percent shall exceed 5 mm in size, not more than 10% shall IS sieve No. 150 not less than 45% or more than 85% shall pass IS sieve No. 1.18 mm and not less than 25% or more than 60% shall pass IS sieve No. 600 micron.

3.4 Course Aggregate

Recycled concrete Coarse aggregate for the works should be river gravel or crushed stone .It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregates should be cubical, or rounded shaped and should have granular or crystalline or smooth (but not glossy) non-powdery surfaces. Aggregates should be properly screened and if necessary washed clean before use.

Coarse aggregates containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per specifications of IS-383.

After 24-hrs immersion in water, a previously dried sample of the coarse aggregate should not gain in weight more than 5%.

Aggregates should be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

3.6 Super Plasticizers

These are the modern type of water reducing admixtures, basically a chemical or a mixture of chemical that imparts higher workability to concrete. It consists of formaldehyde.

The use of super plasticizer in concrete particularly gives high workability to the concrete. Generally the use of super plasticizer in concrete is an important milestone in the advantage of concrete technology. It is widely used all over the world. India is catching up with the use of super plasticizer in the construction of high rise building, long span bridges and the recently become popular ready mixed concrete technology.

3.7 Water

Water is an essential ingredient of concrete since it takes part in chemical reaction with cement to form a binding paste that fills the innumerable minute surface irregularities o fine aggregate and coarse aggregate, and thus bring them into closer adhesion. Water is needed not only to bring about hydration but also to render its easy placing inside the form and around reinforcement. Such additional water should of course be present to the minimum requirement.

Excessive water is found to produce other defects in concrete. As the water evaporates it will leave blank space or voids. This will bring down the density, strength and durability. Water if provided excessively is liable to leak out of shuttering and leaking water may carry away some of the cement resulting in honey comb formation in concrete. The water which is fit for drinking should be used for making concrete.

4. Properties of Materials

4.1 Fineness Test on Cement

The test has been carried out to find the fineness of cement sieving. Average fineness of cement = 2.56%

4.2 Specific Gravity of Cement

This test has been carried out to find the specific gravity of cement using Le Chatelier flask.

The Specific gravity of cement=3.16.

4.3 Specific Gravity of Fine Aggregate

This test has been carried out to find the specific gravity of fine aggregate by using pycnometer.

Specific gravity of fine aggregate = 2.6

4.4 Specific Gravity of Coarse Aggregate

This test has been carried out to find the specific gravity of coarse aggregate by perforated basket.
The specific gravity of course aggregate = 2.7

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4.5 Sieve Analysis for Fine Aggregate

River sand is used as fine aggregates. They were tested as per IS 2386 standards. The physical properties of Sand are shown on Table 3. The fineness modulus of fine aggregate = 1.93

4.6 Sieve Analysis for Coarse Aggregate

In this investigation locally available blue granite crushed stone aggregates of maximum size 20mm were used and characterization tests were carried out as per IS 2386. The physical properties of coarse aggregate are shown in table 4

The fineness modulus of coarse aggregate = 4.5

5. Mix Design

5.1 Definition

Mix design is the process of selecting suitable ingredient of concrete and determines their relative proportions with the object of certain minimum strength and durability as economically as possible.

5.2 Objective

The objective of concrete mix design as follows.
1) The first objective is to achieve the stipulated minimum strength.
2) The second objective is to make the concrete in the most economical Manner. Cost wise all concretes depends primarily on two factors, namely cost of material and cost of labor. Labor cost, by way of formwork, batching, mixing, transporting and curing is namely same for good concrete.
3) There are attention is mainly directed to the cost of materials. Since the cost of cement is many times more than the cost of their ingredients, optimum usage of cement is sought for by designing the mix.

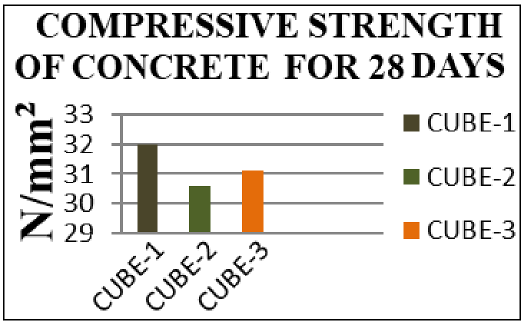
Procedure followed Mix Design As Per Is: 10262-2009

6.1 Compressive Strength Test Results for 28 Days Conventional Concrete Cube Specimens

Tabulation

S.No	Mix Design	Load in KN	Average Load in KN	28 Days Strength (N/mm²)
1	M 30	720	703.33	32
2	M 30	690		30.6
3	M 30	700		31.1

Hence the average result obtained for compressive strength of concrete is 31.23N/mm² and target mean strength of concrete for M30 grade of concrete is 38.25N/mm². 31.23>38.25 N/mm². Hence ok.

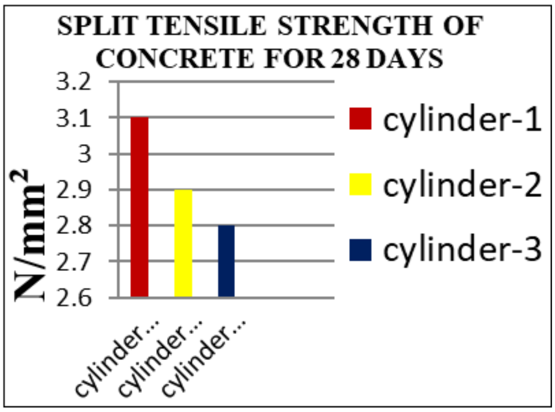


6.2 Split Tensile Strength Test for Conventional Concrete

Split Tensile Strength Test Results For 28 Days Conventional Concrete Cylindrical Specimens

Tabulation

S.No	Mix Design	Load in KN	Average Load in KN	28 Days Strength (N/mm²)
1	M 30	205	208.33	3.1
2	M 30	200		2.9
3	M 30	200		2.8

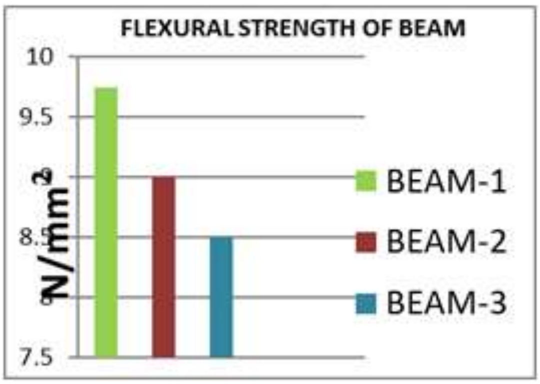


6.3 Flexural Strength Test on Conventional Concrete

Flexural Strength Test Results For 28 Days Conventional Concrete Beam Specimens

Tabulation

S.No	Mix Design	Load in KN	Average Load in KN	28 Days Strength (N/mm²)
1	M 30	19.5	18.16	9.77
2	M 30	18		9.00
3	M 30	17		8.56



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6. Conclusion

The following conclusions are drawn from the observations of Compressive strength, Split tensile strength and Flexural strength of concrete made by using conventional concrete.

1) The mix proportion for M30 grade is 1:1.55:2.56 with water cement ratio as 0.45 was casted.
2) The cubes, cylinder and beams were tested for compressive strength, split tensile strength and flexural strength. These tests are carried out at the age of 28 days.
3) The average test results were obtained for compressive strength of concrete at 28 days is 31.23 N/mm².
4) The average test results were obtained for split tensile strength of concrete at 28 days is 2.93 N/mm².
5) The average test results were obtained for flexural strength of concrete at 28 days is 9.08 N/mm².

References

[1] Davidovits.J. 1991, Geopolymers: inorganic polymeric new materials, Journal Thermal Analysis, 37, pp 1633–1656.
[2] "Low-calcium fly ash-based Geopolymer concrete: long-term Properties By S. E. Wallah and B.V. Rangan Research report GC 2 Faculty of engineering Curtin university of technology Perth, Australia 2006.
[3] "Introducing Fly ash-based Geopolymer Concrete: Manufacture and engineering properties" D Hardjito,S E Wallah, D M J Sumajouw, B.V. Rangan, 30th Conference on Our World In Concrete & Structures: 23 - 24 August 2005,Singapore.
[4] Hardjito, D., S. Wallah, D. M. J. Sumajouw, and B. V. Rangan. 2004. "On the Development of Fly Ash– Based Geopolymer Concrete." ACI Materials Journal, vol. 101, no. 6.
[5] Rangan, B. V.. "Low-Calcium, Fly-Ash-Based Geopolymer Concrete." Concrete Construction Engineering Handbook. Taylor and Francis Group, Boca Raton, FL, 2008.
[6] Steenie Edward Wallah, Drying Shrinkage of Heat-Cured Fly Ash-Based Geopolymer Concrete, Modern Applied Science, Vol-3, No-12, December-2009.
[7] Thokchom S., Ghosh P. and Ghosh S., Performance of Fly ash Based Geopolymer Mortars in Sulphate Solution, Journal of Engineering Science and Technology Review 3 (1) (2010) 36-40, 24 February 2010.
[8] Rangan Vijaya B., Studies on Fly Ash-Based Geopolymer Concrete, Malaysian Construction Research Journal, Vol-3, No.-2, 2008.

Author Profile

S. Balamurugan M.E., (struct.) received the B.E. (Civil) and M.E. (Struct.) degrees in Civil Engineering from Various reputed affiliated college of Anna University in 2013 and 2015, respectively. Pursuing Ph.D. in Anna University of Technology, Chennai-600 025. He was working as Assistant Professor in the Department of Civil Engineering. He is executing various consultancy works to government and private construction sectors.

Photo Gallery

Casting of Concrete Specimen

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