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CHARACTERISTIC DEVELOPMENT OF GEOPOLYMER MORTAR WITH AGRO-HYBRID FIBRES

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Abstract - *Fly ash-based Geopolymer mortar is a new material that does not need the presence of Portland cement as a binder and the role of Portland cement is replaced by low calcium fly ash. This material is being studied extensively as a greener substitute for Ordinary Portland Cement in some applications. An alternative way of replacing cement material is with alkaline activated fly ash. Fly ash as a binder needs to be added to an alkaline activator in the form of sodium silicate (Na2SiO3) or potassium silicate (K2SiO3) and sodium hydroxide (NaOH) or potassium hydroxide (KOH). The experiment uses Fly ash as binder and Foundry sand as fine aggregate in the mix, where both of the ingredients in the mix i.e. fly ash and Foundry sand are waste materials obtained from various industries, which are being used to create a useful product. We, have performed compression tests on mortar cubes primarily without agro-hybrid fibres with varying ratios of {activator solution: fly ash} and compared this result with a mortar cube cast with agro-hybrid fibres in the mix.*

Key Words: **Geopolymer mortar, Fly ash, Foundry sand, Compression tests, Agro-hybrid fibres, Alkaline activator.**

1. INTRODUCTION

The cement industry accounts for about 10% of all CO_2 emissions caused by humans. Therefore, it is necessary to find another material in order to support sustainable material. Recent investigations in the field of mortar repair materials reveal high potential of geopolymer to be used in the field of mortar which is able to transform, polymerize and harden at ambient temperature. Geopolymers are hard, stable at high temperature, cost effective, sustainable and resilient infrastructures. It is a promising alternative binder compared to ordinary Portland cement with better properties. Thus, fly ash which is an aluminosilicate source material is now becoming a valuable material due to the extensive research and development among the researchers addressed its performance concerning the mechanical strength and high durability. Further, environmentally compatible disposal of waste materials by appropriate technologies is of increasing concern and imposes interesting technical challenges. Construction industry is the one where bulk utilization of waste materials can be effectively done without any compromise on quality/ performance. Fly ash is the best known "pozzolana" in the world and one of most commonly used. Fly ash is the fine powder recovered from coal-fires electric generation power plants. On the other side, fly ash is waste material of coal based thermal power plant, available abundantly but pose disposal problem. It is usually much cheaper than cement in India and hence offers saving in product cost. In Vietnam, volumes of fly ash are generated about 600,000 tons, but 100,000 tons is used to produce concrete. In India more than 100 million tons of fly ash is produced annually, out of which 17-20% fly ash is utilized either in concrete as part replacement of cement. The recent studies on total replacement of cement to produce '*No Cement Mortar*' by alkali activation of fly ash is very encouraging from the point of development of sustainable alternative construction materials which gives fillip to booming infrastructure growth. Fly ash could be a cost-effective substitute for Portland cement in some markets. In addition, fly ash could be recognized as an environmentally friendly product, because it is a by-product and has low embodied energy. Fly ash also requires less water than Portland cement, and it is easier to use in cold weather. Geo-polymer mortar is manufactured from predominantly silica and alumina containing source material. It offers a significant opportunity to materialize 'green' concrete as it is possible to utilize an industrial by-product such as fly ash, to totally replace the use of ordinary Portland cement in mortar, and hence to reduce the emission of CO2.

Geo-polymer is new invention in the world of mortar & concrete in which cement is totally replaced by pozzolanic material that is rich in silica and alumina like fly ash and activated by alkali liquids to act as a binder in the mortar.
Geo-polymer mortar has many documented advantages over traditional concretes and its chemical composition can explain most of these advantages. It is longer lasting than standard mortar and requires little repair, thus saving huge amounts of money that would otherwise have to be spent on repairing and maintaining mortar-based infrastructure. Geo-polymer mortar is more resistant to corrosion and fire, has high compressive and tensile strengths, and it gains its full strength quickly (cures fully faster). Although the use of Portland cement is unavoidable in the foreseeable future, many efforts are being made to reduce the use of Portland cement in mortar. It is time to deploy new technology materials like geo-polymers that offer waste utilization and emissions reduction.

Need for present study

It is evident from the present scenario that ordinary Portland cement is causing much of the environmental hazardous such as:

- Increasing greenhouse gases.
- Enormous consumption of power for manufacture of cement.
- Economic point of view.
- Restricted use of natural resources.
- There is a need to find some alternative materials, the material which contains silicon and aluminium in amorphous state can be a source of binding material. Hence fly ash, a waste product containing these elements can be utilized effectively to overcome the effects caused by ordinary Portland cement.

Terminology and Chemistry

The term 'geo-polymer' was first introduced by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolite but with an amorphous microstructure. He also suggested the use of the term 'Poly (sialate)' for the chemical designation of geo-polymers based on silico-aluminate; Sialate is an abbreviation for silicon-oxo-aluminate. Poly(sialates) are chain and ring polymers with Si4+ and AL3+ in IV-fold coordination with oxygen and range from amorphous to semi-crystalline.

A geo-polymer can take one of the three basic forms:

- Poly (sialate), which has [-Si-O-Al-O] as the repeating unit.
- Poly (sialate-siloxo), which has [-Si-O-Al-O-Si-O-] as the repeating unit.
- Poly (sialate-disiloxo), which has [-Si-O-Al-O-Si-O-Si-O-] as the repeating unit.

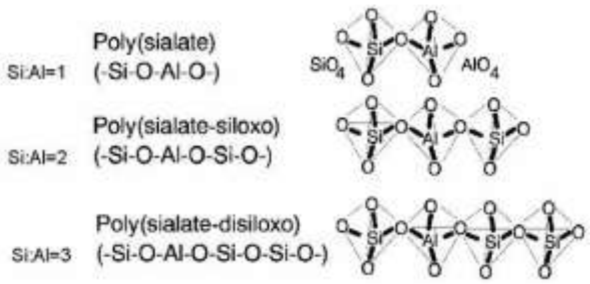

Fig 1: Three basic forms of geo-polymer

Constituents of geo-polymer

1) Source material

There are two main constituents of geo-polymers, namely the source materials and the alkaline liquids. The source materials for geo-polymers based on alumino-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, micas, andalousite, spinel, etc. whose empirical formula contains Si, Al and oxygen (O).

2) Fly ash

Fly ash, generated during the combustion of coal for energy production, is an industrial by-product which is recognized as an environmental pollutant. Because of the environmental problems presented by the fly ash, considerable research has been undertaken on the subject worldwide. The chemical composition is mainly composed of the oxides of silicon (SiO_2), aluminium (Al_2O_3), iron (Fe_2O_3), and calcium (CaO), whereas magnesium, potassium, sodium, titanium, and Sulphur are also present in a lesser amount. The particle size, calcium content, alkali metal content, amorphous content, and morphology and origin of the fly ash affected the properties of geo-polymers

3) Alkaline liquids (Alkali activators)

The most common alkaline liquid used in geo-polymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. The type of alkaline liquid plays an important role in the polymerization process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. The addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution

Properties of geo-polymer mortar

1. ***Fire-proof geo-polymeric cements*** - Geo-polymers are generally believed to provide good fire resistance due to their ceramic-like properties.
2. ***Low shrinkage*** - It has also been shown that compared to OPC, geo-polymeric cement has extremely low shrinkage.
3. ***Alkali-Aggregate-Reaction*** - the geo-polymeric system is safe from that phenomenon even with higher alkali content. As demonstrated by Davidovits, based on ASTM C227 bar expansion test, geo-polymer cements with much higher alkali content compared to OPC did not generate any dangerous alkali-aggregate reaction where the OPC did.
4. ***Acid resistance*** - Geo-polymer cement is also acid-resistant, because unlike the OPC, geo-polymer cements do not rely on lime and are not dissolved by acidic solutions
5. ***Compressive strength*** - It depends on curing time and curing temperature. As the curing time and curing temperature increases, the compressive strength increases.
6. ***Resistance to corrosion*** - Since no limestone is used as a material, geo-polymer cement has excellent properties within both acid and salt environments. It is especially suitable for tough environmental conditions.

7. ***Toxic waste management*** - Geo-polymers have been shown to possess great potential to immobilize toxic waste as well as to convert the semi solid wastes to adhesive solid materials.

Factors affecting geo-polymer mortar

Using the amorphous composition improves the development of fly ash geo-polymer mixture formulation and its adoption will ensure manufacture of improved geo-polymer products. The curing temperature was a reaction accelerator in fly ash-based geo-polymers, and significantly affected the mechanical strength, together with the curing time and the type of alkaline liquid. Higher curing temperature and longer curing time were proved to result in higher compressive strength. Alkaline liquid that contained soluble silicates was proved to increase the rate of reaction compared to alkaline solutions that contained only hydroxide. The water content and the curing affected the properties of geo-polymer mortar. However, curing at too high temperature caused cracking and a negative effect on the properties of the material. Finally, the use of mild curing to improve the physical properties of the material is suggested. The source materials determine the properties of geo-polymer mortar, especially the CaO content, and the water-to-fly ash ratio.

OBJECTIVES

The objectives of this project are to study the following properties of Agro hybrid based geo-polymer mortar.

1) To develop a mixture proportion to manufacture low calcium fly ash based geo-polymer mortar.
2) To study the influence of compressive strength of fly ash based geo-polymer mortar by varying the ratio of alkali activator solution to fly ash for different mix proportions.
3) To study the influence of compressive strength of fly ash based geo-polymer mortar by keeping the fixed molarity of sodium hydroxide solution.
4) To study the influence of compressive strength of fly ash based geo-polymer mortar with Agro-hybrid fibres.
5) To compare the compressive strength values of mortar specimens with and without Agro hybrid fibres.
6) To compare the compressive strength values of mortar specimens having different fly ash to activator ratios.
7) To study the propagation of cracks through the specimen during the presence and absence of fibres.

Preparation of solution

Sodium hydroxide pellets were mixed with distilled water to get the sodium hydroxide solution with the required molarity. This was mixed with the sodium silicate solution to prepare the alkaline solution. As the NaOH hand mixed from a combination of pellets and water, it was mixed a minimum of 24 hours prior to its intended time of usage in a mix. This waiting time period allowed the solids to fully dissolve throughout the solution. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 12M consisted of 12X40=480 grams of NaOH solids per litre of solution, where 40 is the molecular weight of NaOH.

Sodium silicate solution (Na_2SiO_3) and sodium hydroxide (NaOH) solids were obtained from Amar Chemical Agency, Bangalore. Commercially available sodium silicate was used for this experimental work with specific gravity of 1.53. Sodium-based solutions were selected since they are cheaper than Potassium-based solutions. Sodium silicate and sodium hydroxide were used to prepare alkaline solution to react with the aluminium and silica in the fly ash.

Fig 2: Mixing of Na_2SiO_3 with NaOH

Mould preparation- For compressive strength aspects, the standard cube moulds of size 70mmX70mmX70mm were used to prepare specimen on geo-polymer mortar. Grease and oils were applied to the moulds to avoid stickiness of mortar, before pouring the mortar to the specimen.

Mixing- Preparation of geo-polymer mortar is similar to that of cement mortar. Foundry sand and fly ash were mixed in dry state. Then add prepared mixture solution of sodium hydroxide and sodium silicate and mix thoroughly so as to give homogeneous mix.

Casting- the fresh mortar was cast into the moulds immediately after mixing, in three layers. Each layer was well compacted with manual gentle strokes using tamping rod of diameter 20mm. The top surface was finished using trowel. Mixing all samples immediately with its mixture proportions, enables easier tracking and handling.

Fig 3: Materials ready to make a batch of fly ash based geo-polymer mortar

Curing of test specimens-After 24 hours of casting, all specimens were de-moulded and then placed in natural sunlight for thermal curing (heating). Heat curing substantially assists the chemical reaction that occurs in the geo-polymer paste. The rate of increase in strength was rapid up to 24 hours of the curing time; beyond 24 hours, the gain in strength is only moderate. Heat curing can be achieved by either steam curing or dry curing. Compressive strength of dry cured geo-polymer mortar is approximately 15% larger than that of steam cured geo-polymer mortar. In this project work, dry curing (sunlight curing) was adopted.

Fig4: Curing of Specimen

Mix design of Fly ash based geo-polymer mortar using Agro hybrid fibres

The following specific procedure was derived and adopted for this study. This example gives the details of mix design for 1 cube of 12M NaoH and ratio of Na_2SiO_3: NaOH=2.5. Generally, the fly ash to activator ratio is between 0.5 – 0.7. Following are the mix design tables of various fly ash to activator ratios without and with Agro-hybrid fibres:

SL NO.	FLYASH = $\frac{ACTIVATOR}{0.5}$ (g)	ACTIVATOR (ml)	SAND=FLYASH × 2.5 (g)
1	700	350	1750
2	700	350	1750
3	700	350	1750

Table 1: Mix design for 0.5 ratio for activator: flyash {without Agro-hybrid fibres}

SL NO.	FLYASH= $\frac{ACTIVATOR}{0.5}$ (g)	ACTIVATOR (ml)	SAND=FLYASH × 2.5 (g)	COIR FIBRE (g) (0.25% by wt.)	CELLULOSE ACETATE (g) (0.1% by wt.)
1	700	350	1750	6	2.45
2	700	350	1750	6	2.45
3	700	350	1750	6	2.45

Table 2: Mix design for 0.5 ratio for activator: flyash {with Agro-hybrid fibres}

Compressive strength

The compressive strength of mortar is one of the most important and useful properties of mortar. In most structural application mortar is implied primarily to resist compressive stress. To determine the compressive strength of mortar, 70mm X 70mm X 70mm cubes are casted and cured for 1, 3 and 7 days. At the end of above curing period, the specimen is placed on the lower bearing block of the compressive testing machine of under a uniform rate of loading at. The load at which the specimen ultimately fail is noted, compressive strength is calculated by dividing load by area of the specimen as per IS: 516-1989.

$$\mathbf{fc} = \frac{\mathbf{P}}{\mathbf{a}}$$

Where, f_c = cube compressive strength in N/mm^2
P = cube compressive load causing failure in N
a = cross-sectional area of cube in mm^2

RESULTS

Table 3: Compression test results for 0.5 ratio for activator: flyash {without Agro-hybrid fibres}.

DAYS	WEIGHT OF BRICK (g)	LOAD (kN)	COMPRESSIVE STRENGTH (N/mm^2)
1	700	60	12.20
5	700	110	22.47
7	710	112	22.56

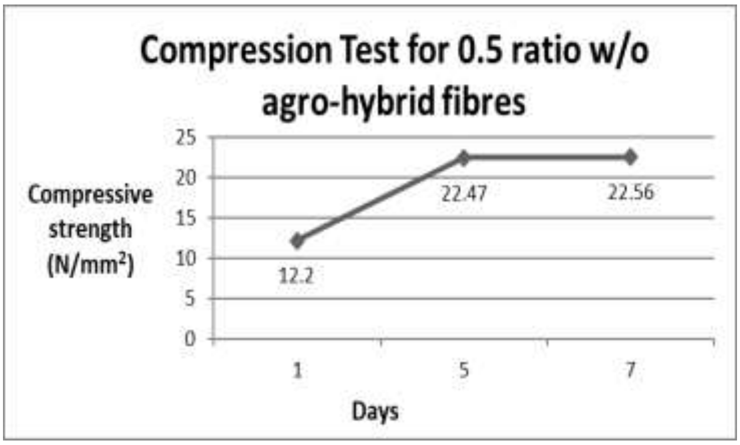

Fig 5: Compression test result for 0.5 ratio.

Table 4: Compression test results for 0.5 ratio for activator: flyash {with Agro-hybrid fibres}.

DAYS	WEIGHT OF BRICK (g)	LOAD (kN)	COMPRESSIVE STRENGTH (N/mm²)
1	713	48	9.79
5	734	80	16.30
7	750	110	22.47

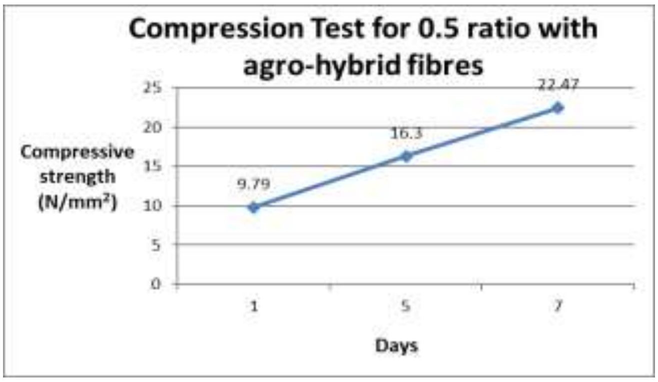

Fig 6: Compression test results for 0.5 ratio (with Agro hybrid fibres)

SL. No.	ACTIVATOR /FLY ASH RATIO	COMPRESSIVE STRENGTH(N/mm²)
1	0.5	22.56
2	0.55	17.95
3	0.6	12.20
4	0.7	8.16

Table 5: Compressive strength values of 7 days cured specimens of all ratios.

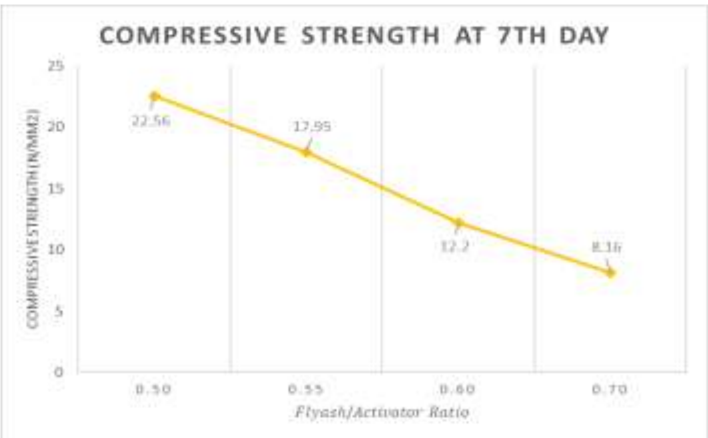

Fig 7: Compressive strength values of 7 days cured specimens of all ratios

- According to results obtained, it can be seen that the compressive strength of the specimen cured for 7 days was 45% more than that of the specimen cured for 1 day.
- Compressive strength of the geo-polymer mortar increases with increase in the curing period.
- Compressive strength of mortar specimens with and without Agro-hybrid fibres are almost same at 7 days curing period.
- In mortar specimen with Agro hybrid fibres, compressive strength is seen to increase at a uniform rate along the curing period.

CONCLUSIONS

Based on the obtained results, the following conclusions can be drawn:

- Conventional methods of mixing, compaction, moulding and de-moulding can be adopted for fly ash based geo-polymer mortar. The only precaution needed is in handling of liquid system which is highly alkaline in nature.
- Compressive strength of fly ash based geo-polymer mortar is maximum when the ratio of sodium silicate to sodium hydroxide solution is 2.5.
- It is seen that the compressive strength values decrease with the increase in fly ash to activator ratios.
- Geo-polymeric materials are likely to be effective alternative construction materials for cement-based materials in future. However, the elevated temperature curing and the use of expensive alkaline solutions and lack of enough experience on the part of its long-term durability are yet to be tackled before its wider acceptance.
- The heat generation process is more while mixing sodium hydroxide pellets to water and then adding that solution to sodium silicate solution rather than adding sodium hydroxide pellets to the mixture of sodium silicate and water.
- As the fly ash based geo-polymer mortar doesn't have any Portland cement they can be considered as less energy interactive. The fly ash based geo-polymer mortar utilizes the industrial waste such as fly ash for producing the binding system therefore, it should be considered as eco-friendly material.

REFERENCES

1) Joseph Davidovits "Ancient and modern concrete: what is the real difference?" Indian Concrete Journal, December 1987.

2) Xu H., Van Deventer J.S.J., (2000) "The geo-polymerization of alumino-silicate mineral",

International Journal of Mineral Processing. 59: 247-200.

3) Bakhareve T "Geo-polymeric materials prepared using class F fly ash and elevated temperature curing" Cement Concrete Research 2005. pp. 1224-1232.

4) Anurag Mishra, Deepika Choudhary, Namrata Jain, Manish Kumar, Nidhi Shard and Durga Dutt (2008) "Effect of Concentration of Alkaline Liquid and Curing Time on Strength and Water Absorption of Geopolymer", ARPN Journal of Engineering and Applied Sciences; Vol. 3, No. 1.

5) Mandal S and Majumdar D "Study on the alkali activated fly ash mortar", The Open Civil Engineering Journal, 2009, pp. 98-101.

6) Shweta Mane, H.S. Jadhav "Investigation of Geopolymer mortar and concrete under high temperature", December 2012.

7) Xueying Li, Xinwei ma, Shoujie Zhang and Enzu Zheng "Mechanical properties and Microstructure of Class C Fly ash-based Geopolymer paste and mortar, April 2013.

8) Saloma, Anis Saggaff, Hanafiah, and Annisa Mawarni, "Geopolymer Mortar with Fly Ash", MATEC Web of Conferences (2016).

9) IS 3812-1981, Indian standard code of practice for fly ash use as a pozzolana and admixture, Bureau of Indian standards, New Delhi.