Strength Assessment of Lightweight Geopolymer Wall Panels infilled with Expanded Polystyrene

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Abstract **- This paper briefly reviews the strength characteristics of Precast Geopolymer Concrete wall panels infilled with Expanded Polystyrene or Geofoam. Geopolymer concrete is an innovative construction material manufactured by the polymerization of inorganic molecules. It can be produced without using any amount of Portland cement. The geopolymer depend on thermally activated natural materials like metakaolinite or industrial byproducts like fly ash or slag to provide a source of silicon (Si) and aluminum (Al). As Fly ash is rich in silica and alumina, it reacts with alkaline solution producing aluminosilicate gel that act as a binding material for concrete. While fabricating wall panels, Expanded Polystyrene Foam (EPS) is sandwiched between two layers of geopolymer concrete. These types of walls will carry load more effectively than conventional walls with reduced thickness. Also, it has the combined advantage of both ferrocement technology and light weight panels.**

Index Terms **- Geopolymer Concrete, Fly Ash, Wall panels, Expanded Polystyrene Foam, Compressive strength**

I.INTRODUCTION

The global warming is caused by the emission of greenhouse gases, such as carbon dioxide and other air pollutants to the atmosphere by various human activities. Among the harmful greenhouse gases, carbon dioxide contributes about 65% of global warming. The cement manufacturing process is highly responsible for the carbon dioxide emissions because the production of one ton of Portland cement release approximately one ton of carbon dioxide into the atmosphere. Several remedial measures are in progress to protect the environment from greenhouse gases. These include the utilization of innovative concrete materials such as fly ash, ground granulated blast furnace slag and silica fume and also the development of alternative binders to Portland cement. In this aspect, the Geopolymer concrete with much lower environmental effects are being implemented in construction industry. It is an excellent alternative construction material to the existing Portland cement concrete.

Geopolymer concrete shall be produced without using any amount of ordinary Portland cement. Further adding this concrete to wall panels infilled with expanded polystyrene foam helps to achieve a lightweight panel which can be used as load bearing walls with reduced thickness. Expanded Polystyrene insulation is light weight, rigid, and closed cell insulation. The behaviour of geopolymer sandwich panel is much easier to predict than the wall panels constituting other building walls. Geopolymer wall panel has the combined advantage of both precast technology and light weight structure. If the panels act fully composite, then the panel behaves homogeneously and thus ultimate load carrying capacity increases. These panels can be also used as load bearing walls. These types of walls will carry load more effectively than conventional walls with reduced thickness, thus the dead load acting on a structure gets reduced, which results in reduced cross section of columns and beams.

II. PROJECT SCOPE

Lightweight geopolymer concrete helps in faster construction process, since installing these wall panels are easier. Since GPC wall panels are infilled with expanded polystyrene, it shows excellent thermal efficiency, and it is used for fire related applications. These panels do not get affected by extreme climatic conditions. Geopolymer panels can be used as both load bearing and non-load bearing walls with reduced thickness.

III. OBJECTIVES

To assess the strength characteristics of Geopolymer concrete wall panels infilled with expanded polystyrene foam. In this geopolymer composition, the mixture contains Fly ash, Copper slag, Ground granulated blast furnace slag along with alkaline solutions. There will be zero percentage use of ordinary Portland cement in producing this geopolymer mortar. GGBS replaced in various percentages with respect to Fly ash. Making workable, high strength and durable Geopolymer concrete containing G.G.B.S (Slag) without usage of ordinary Portland cement. Further carry out a detailed study on the usage of Geopolymer concrete in recent construction activities and its advantages.

IV. MATERIALS

A. *Welded Steel Mesh*

1½ inch square wire mesh is one of reinforcing material used in fabrication. It is generally used in ferrocement technology. This project also includes the same technology.

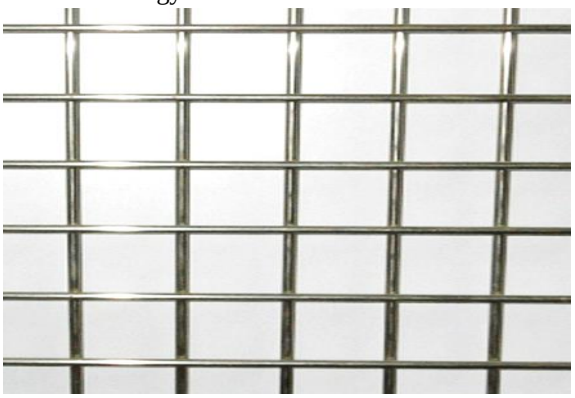

Figure 1-Welded Mesh

B. *Fly ash*

Fly ash is the inorganic mineral residue obtained after burning of coal/lignite in the boilers. Fly ash is a portion of ash which can be collected from the bottom portion of the boilers. The characteristics of fly ash depend upon the quality of lignite/coal and the efficiency of boilers. India depends upon primarily on coal for the requirement of power and the power generation is likely to go up from 60,000Mw in the year 2010. The generation of fly ash is also likely to increase. The fly ash generation in India Thermal Stations is likely to shoot up to 170 million tonnes in 2010 from the present level of 100 million tonnes. The disposal of fly ash in the present method will be a big challenge to environment, especially when the quantum increases from the present level.

C. *Copper Slag*

Copper slag is also mixed in concrete, which is considered as a waste material, but it has a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material.

D. *Ground Granulated Blast Furnace Slag*

Ground granulated blast furnace slag (GGBS) is a hydraulic binder, i.e., a cement, which has been known and utilized for 150 years. It improves the quality and lifetime of cement, and its generation is basically CO_2 free.

To ensure its activation, GGBS is most often used with normal cement. It will typically replace 30 - 70% of cement on an equal weight basis. The manufacture of normal cement results in the emission of 930kg of CO_2/t of cement approximately 50% from decarbonation of the limestone raw material (process emissions), 40% from fossil fuel consumption, and 10% from generating the electricity used in the process. GGBS manufacture typically releases 35 kg of CO_2/t of GGBS: less than 4% of the carbon of normal cement.

Figure 2-Ground Granulated Blast Furnace Slag

E. *M-Sand*

It does not contain organic and soluble compound that affects the setting time and properties of geopolymer mortar, thus the required strength of concrete can be maintained. Usage of manufactured sand prevents

dredging of riverbeds to get river sand which may lead to environmental disaster like ground water depletion, water scarcity, threat to the safety of bridges, dams etc. to make M-Sands more eco-friendly than river sand.

F. *Sodium Silicate*

Sodium silicate is colorless glassy compound known as water glass or liquid glass, available in liquid form or gel. In this project, sodium silicate 2.0 (ratio between Na_2O to SiO_2) is used. Most of the manufactured silicates were supplied to the detergent company and textile industry as bonding agent. Sodium silicate is used for activating the fly ash and blast furnace slag.

Figure 3-Sodium Silicate Solution (Na_2SiO_3)

G. *Sodium Hydroxide*

Usually this inorganic compound, sodium hydroxide (NaOH) was available in its solid state by means of pellets and flakes. The cost of the sodium hydroxide is purely depending upon the concentration of the solution. Since this geopolymer concrete is a homogenous material and its main purpose is to activate the sodium silicate, so it is recommended to use minimum purity of NaOH solution i.e., up to 94% to 96% purity. In this investigation the sodium hydroxide pellets were used.

G. *EPS Foam*

EPS is Expanded Polystyrene. A versatile plastic available in the form of sheets in varying thickness, moulded and cut pipe section for low temperature insulation of cold stores to preserve perishables, industrial plants operating at temperatures below ambient temperature, thermal insulation in building and versatile packaging material which can be moulded into any shape and design for packing electronics, glassware, and other fragile products.

Milky snow-white EPS improves present ability of the product packed in it. EPS is also used for manufacturing ice boxes, picnic boxes and containers to keep the food hot. From the viewpoint of construction, the roof no matter of what design is the most vulnerable part of the building for absorption of solar radiation particularly in tropical countries like India.

IV. EXPERIMENTAL PROGRESS

Experimental work process includes fabricating steel meshes, preparation of alkaline solutions, mixing of geopolymer mortar, casting of geopolymer wall panel and then undergoes ambient curing for a period of 28 days. After curing, the wall panels are tested for its compressive strength.

A. *Fabrication of Welded Meshes*

0.5 square inch wire mesh and 1.5 square inch weld mesh are cut according to the required dimensions. The meshes were straightened using wooden hammer. There are two layers of wire mesh and one layer of weld mesh. The single layer of weld mesh comes in between the two layers of wire mesh and are sandwiched together using binding wires of 1mm. This bound mesh is folded for the panel dimension 450x300x100 such that they fix appropriate inside the mould.

Figure 4-Layers of Welded Mesh infilled with EPS

B. *Preparation of Alkaline Solutions*

Sodium hydroxide pellets are taken and dissolved in the water at the rate of 16 molar concentrations. It is strongly recommended that the sodium hydroxide solution must be prepared 24 hours prior to use and also if it exceeds 36 hours it terminates to semi solid

liquid state. So, the prepared solution should be used within this time. The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution.

Figure 5-Mixing of Fly ash with Alkaline Solutions

For instance, NaOH solution with a concentration of 16 Molar consists of 16 x 40 = 640 grams of NaOH solids per litre of the water, were 40 is the molecular weight of NaOH. Note that the mass of water is the major component in both the alkaline solutions. The mass of NaOH solids was measured as 444 grams per kg of NaOH solution with a Concentration of 16 Molar. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as 10 Molar: 314 grams, 12 Molar: 361 grams, and 14 Molar: 404 grams.

C. *Mixing of Geopolymer Mortar*

Mortar is prepared according to desired proportion of fly ash, copper slag, ground granulated blast furnace slag, M sand, sodium silicate. First the fly ash, copper slag and ground granulated blast furnace slag is dry mixed and sodium silicate is added gradually in order to nourished geopolymer mortar.

The wall panel is designed for M20. Thus, various trial mixes were casted into 150x150x150mm cubes. Mix ratio is FA: CS: SI and MIX C is chosen as M20 mix

MIX TYPE	REPLACEMENT OF FLY ASH WITH GGBS	COMPRESSIVE STRENGTH (N/mm^2)
MIX A	50%	33.3
MIX B	20%	28.2
MIX C	10%	21.2
MIX D	5%	15.3

D. *Casting*

The fabricated mesh is placed inside the mould (450x300x100mm) along with expanded polystyrene and the geopolymer mortar is added inside the mould through several layers with the help of scoop. After filling the mould with geopolymer mortar, it is well compacted to remove air voids. After a few hours the mould is demoulded and the casted specimen is taken out.

Figure 6-Casting of specimen

E. *Curing*

The casted specimen is left in the dry atmosphere for ambient curing or heat curing, geopolymer does not need water curing or any other systems of curing.

V. TESTING OF SPECIMEN

A. *Testing for Compressive Strength*

After 28 days from the date of casting, the test specimen is whitewashed and tested for compressive strength. The load value is tabulated below.

MIX TYPE	ULTIMATE LOAD (kN)	COMPRESSIVE STRENGTH(N/mm^2)
MIX C	622	20.6

VI. RESULTS AND DISCUSSION

- Trial mixes are done and geopolymer concrete of M20 grade is achieved from the mix ratio 1:1:0.4 (10% of fly ash replaced with GGBS)
- •Using ferrocement combination in preparing this wall panels, improves the load carrying capacity.
- Compressive strength of wall panels of M20 grade from 28 days of ambient curing are 20.20 N/mm^2, 19.62 N/mm^2 and 19.15 N/mm^2
- Ultimate load resisted by the specimen due to compression is 622 kN.

- Crack width for test specimen of compression test is 23 mm and the crack propagation is 450 mm from top.

VII.CONCLUSION

Based on this experimental investigation, the following conclusions are drawn,

- In this project, the use of cement and other natural resources is avoided, even though the desired strength is achieved.
- Cement is completely replaced with fly ash in order to reduce the carbon emission. Thus, it diminishing environmental pollution and making it eco-friendly.
- These Geopolymer wall panels can be used for load bearing walls and partition walls with preferred connections.
- Geopolymer concrete mixture infilled with expanded polystyrene foam reduces heat conductivity and imparts good thermal insulation and high impact resistance.
- Since the implemented curing method does not require more water, the usage of excess water can be reduced. From ambient curing (specimen left in dry atmosphere) it aids rapid attainment of strength.

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