AN EXPERIMENTAL ANALYSIS OF FLY ASH BASED GEOPOLYMER CONCRETE

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Abstract - The primary objective of this experimental study is to explore the potential of geopolymer concrete as a substitute for conventional concrete in infilled stub columns and hollow stub columns. A crucial factor under investigation is the varying thickness of a stainless steel tube. The experimental procedure involves applying incremental loads to the columns to observe their mechanical response and behavior. Furthermore, the analytical integration of the properties and attributes of fly ash and geopolymer is undertaken to deepen the comprehension of the experimental findings.. The behaviour of infilled stub column and hollow stub column is studied experimentally by applying gradual load along with analytically integrating the engineering behaviour of fly ash and geopolymer synthesized binder at different mix proportions and at dissimilar curing environments these properties are compared with conventional concrete. The investigation concerns the use of the optimum mix proportion of two locally available pozzolanic waste materials, namely, fly ash and geopolymer, In addition, another local waste material, manufactured sand (M-sand), was used as a replacement for conventional sand in the development of green geopolymer concrete, Twenty-four mortar mixtures were designed with varying binder contents and alkaline activators. The oven dry curing was also kept consistent for all the mix proportions at a temperature of 65∘ C for 24 hours. The highest 28-day compressive strength was obtained, The fly ash replacement beyond 35% also reduced the compressive strength

***Key Words*:** geopolymer , geopolymer concrete , mix proportion M25 grade concrete , fly ash

1.INTRODUCTION

GEOPOLYMER CONCRETE

Geopolymer concrete is a type of concrete that uses a binder called geopolymers instead of traditional Portland cement. Geopolymers are typically formed by activating aluminosilicate materials such as fly ash, silica fume, or slag with an alkaline solution. Geopolymer concrete offers several advantages, including reduced carbon dioxide emissions, improved strength and durability, faster curing times, and resistance to alkali-silica reaction. It can be used in various construction applications and is considered a more sustainable alternative to traditional concrete. However, the availability of geopolymer concrete can vary depending on the region and local market.

AVAILABILITY OF GEOPOLYMER CONCRETE

The availability of geopolymer concrete can vary depending on the region and local market. While geopolymer concrete is gaining recognition and acceptance in the construction industry, it may still be relatively less commonly available compared to traditional Portland cement-based concrete. The availability of geopolymer concrete depends on factors such as the presence of geopolymer manufacturers, the demand for sustainable construction materials, and the local regulations and policies governing its use. However, as the demand for environmentally friendly and high-performance concrete increases, the availability of geopolymer concrete is expected to grow over time

CLASS F FLY ASH

Class F fly ash is a specific type of fly ash that is produced from burning anthracite or bituminous coal. It has a higher content of silica, alumina, and iron oxide compared to other types of fly ash. Class F fly ash is known for its high pozzolanic reactivity, meaning it can react with calcium hydroxide to form additional cementitious compounds. It is commonly used as a supplementary cementitious material in the production of concrete to enhance its strength, durability, and workability. Class F fly ash is finer in particle size compared to other types of fly ash and has a lower calcium conten

PROPERTIES OF GEO POLYMER CONCRETE

- Sets at room temperature
- Non-toxic, bleed free
- Long working life before stiffening
- Impermeable
- Higher compressive strength.

2. Body of Paper

MIX DESIGN

As there is standard procedure to make the mix design, researchers stated as follows that

- Utilize the same mix design as that of Ordinary Portland Cement (OPC).
- Incorporate coarse and fine aggregates in the range of 75% to 80% of the total mixture mass.
- Opt for Low calcium (ASTM Class F) fly ash.

- Maintain a ratio, by mass, of sodium silicate solution-to-sodium hydroxide solution between 0.4 and 2.5. Many studies have favored a ratio of 2.5 due to its cost-effectiveness, considering the comparatively lower expense of sodium silicate solution compared to sodium hydroxide solution.
- Maintain a molarity of sodium hydroxide (NaOH) solution within the range of 12M.
- Maintain a ratio of activator solution-to-fly ash, by mass, between 0.3 and 0.4. Most researchers have used a ratio of 0.35.
- Add superplasticizer in the range of 0% to 2% of fly ash, by mass.
- Additional water can be added if necessary.

Mixing and Casting:

The mix compositions for the concrete mixes are provided in the tables below. Through adjustments in fly ash and activator contents, the mixtures were prepared for investigation. In order to assess the impact of binders, the water content remained constant. A consistent ratio of 1 part binder to 2 parts sand was maintained across all mixtures. To enhance workability and homogeneity, additional water was introduced to the mix. Careful placement of the mortar was carried out in 50 mm cube moulds, and the casting process was divided into three stages, ensuring sufficient compaction.

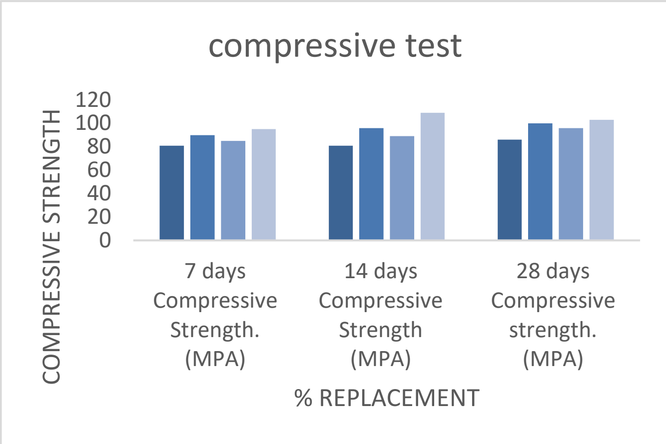
Furthermore, an important aspect to consider is the total binder content in the present study, which is approximately 760 kg/m3. This value is higher compared to the previous value of 460 kg/m3. The use of such a significant quantity of binder, along with a substantial amount of fly ash, would have significantly reduced the setting time. Consequently, determining the appropriate mixing time at varying mixer speeds becomes crucial to achieve a well-balanced mixture and optimal workability.

Curing Regime:

Following casting, the specimens and moulds were promptly covered with plastic film to minimize moisture evaporation. They underwent a 24-hour curing process in an oven at a temperature of 65 degrees Celsius. Subsequently, the specimens were removed from the oven and kept under ambient conditions with an average temperature and humidity of 28∘ C and 70% respectively until the testing day. This curing procedure was adopted from the recommended method to achieve high early-strength geopolymers with acceptable properties.

% Replaced	7 days Compressive Strength. (MPA)	14 days Compressive Strength (MPA)	28 days Compressive strength. (MPA)
0% GEOPOLYMER (CONVENTIONAL CONCRETE)	81	81	86
(5% Geopolymer ,30% Flyash)	90	96	100
(10% Geopolymer ,35% Flyash)	85	89	96
(15% Geopolymer ,40% Flyash)	95	109	103

RESULT OF COMPRESSIVE STRENGTH OF CONCRETE



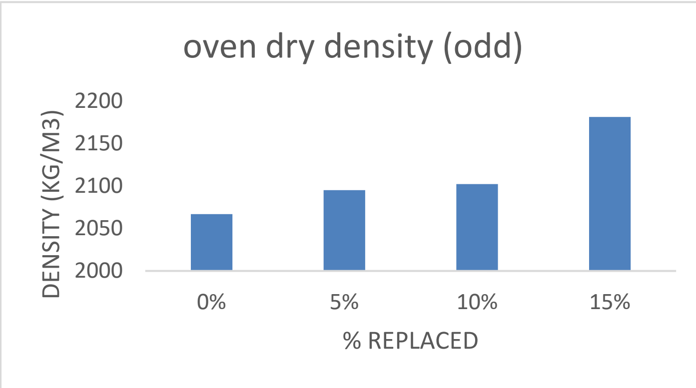
EFFECT OF FLYASH ON THE COMPRESSIVE STRENGTH.

Flyash plays an important role for compressive strength development. A higher concentration of Flyash results in a higher compressive strength of geopolymer concrete .

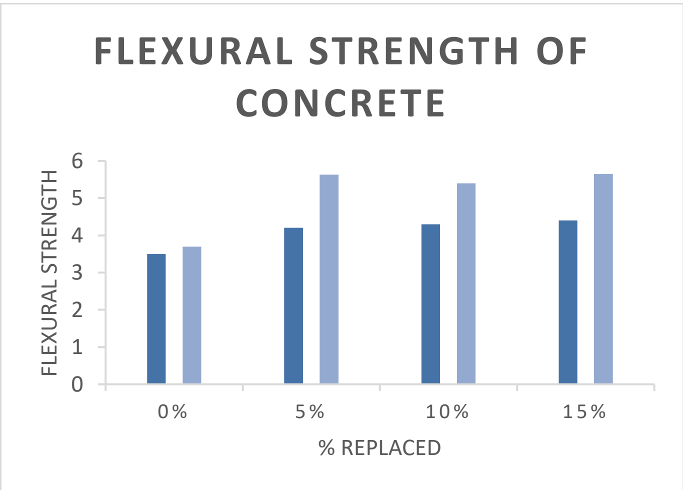
Mix with 35% Flyash, produced the highest strength, while a further decrease in the Flyash content reduced the compressive strength. 17 (30% Flyash with 15% geopolymer,) and 9 (25% Flyash with 15% geopolymer,) showed a decrease in strength of about 12% and 14% with respect to 12.

OVEN DRY DENSITY (ODD)

% Replaced	Flow (%)	Density (kg/m3)
0% GEOPOLYMER (CONVENTIONAL CONCRETE)	71	2067
(5% Geopolymer ,30% Flyash)	76	2095
(10% Geopolymer ,35% Flyash)	79	2102
(15% Geopolymer ,40% Flyash)	78	2181



Sr.no	% Replaced	Flexural strength 7 days (MPa)	Flexural strength 28 days (MPa)
1	0% GEOPOLYMER (CONVENTIONAL CONCRETE)	3.5	3.7
2	(5% Geopolymer ,30% Flyash)	4.2	5.63
3	(10% Geopolymer ,35% Flyash)	4.3	5.4
4	(15% Geopolymer ,40% Flyash)	4.4	5.63



3. CONCLUSIONS

Furthermore, the effective utilization of fly ash eliminates the need for landfill disposal, making it an environmentally beneficial approach. To promote its use, the Government of India should consider providing free transportation of fly ash to nearby cities. Additionally, extracting sodium hydroxide and sodium silicate solutions from waste materials in the chemical industry would contribute to reducing the overall cost of geopolymer concrete.

The compressive strength of the mortars was extensively examined over a 28-day period to evaluate the feasibility of replacing conventional mortar with fly ash-based geopolymer mortar.

(i) The compressive strength of the geopolymer mortar exhibited an increase with higher geopolymer content up to 20%. However, further replacement of geopolymer resulted in a significant reduction in strength.

(ii) The mixture consisting of 40% fly ash with 15% MK (Metakaolin) demonstrated the highest strength among the tested mixes.

(iii) In the majority of specimens, a significant proportion of the geopolymer mortar's compressive strength, around 90%, was achieved within 7 days.

(iv) The presence of finer particles in fly ash contributed to a denser mix, highlighting the importance of maintaining a partial substitution of fly ash in the mortar at approximately 35%.

(v) It can be concluded that by combining the maximum volumes of fly ash and geopolymer, a sustainable construction material can be developed as an environmentally friendly alternative to Ordinary Portland Cement (OPC) for producing geopolymer mortars.

REFERENCES

1) Lloyd, N and Rangan, B.V 2009 Geopolymer Concrete – sustainable cementless concrete, proceedings of Tenth ACI International conference on recent advances in concrete tehnology and sustainability issues, Seville, PP 33-53
2) Hardjito, D. and Rangan, B.V. (2005 Development) and properties of Low calcium fly ash-based Geoploymer Concrete Research Reprot GCI Faculty of Engineering Curtin University of Technology, Perth.
3) Djwantoro Hardjito, Steenie E. Wallah, Dody M.J.Sumajowand B.Vijaya Rangan (2009). On the development of fly ash based geopolymer concrete. ACI materials journal. Title No 101 M 52.
4)Rangan, B,V. and Wallah, S.E. (2006), Low – Calcium fly AshBased Geopolymer concrete: long- Term Properties, Research Report GC2, Faculty of Engineering Curtin University of Technology, Perth.
5) Kunal kupwade – patil and Erez Allouche (2011), Effect of alkali silica reaction in Geopolymer concrete.World of coalash conference,May,9-12-2011,Denver,CO, USA
6) Paratibha Aggarwal, Rahul Pratap Singh and Yogesh Aggarwal, ―Use of nano-silica in cement based materials—A review‖, Cogent Engineering (2015), 2: 1078018. 8. T. Bakharev, ―Geopolymeric Materials Prepared Using Class F Fly Ash and Elevated Temperature Curing‖, C and CR, 2004
7) Robbie M. Andrew, Global CO2 emissions from cement production, Center for International Climate Research. Hydrology and Earth Sciences System-2017.
8) M. Schneider, M. Romer, M. Tschudin, H. Bolio, ―Sustainable cement production-present and future‖, Cement and Concrete Research 41 (2011) 642–650.
Nakshatra B. Singh, ―Review- Fly Ash-Based Geopolymer Binder: A Future Construction Material‖, 12 July 2018.
9)Farina I, Modano M, Zuccaro G, Goodall R, Colangelo F, Improving flexural strength and toughness of geopolymer mortars through additively manufactured metallic rebars, Composites Part B (2018).
10) P. Yellaiah, Sanjay Kumar Sharma and T. D. Gunneswara Rao, Tensile Strength of Fly ash Based Geopolymer Mortar, ARPN Journal of Engineering and Applied Sciences, 2014.
11)Pan, Zhong tao, Yifang cao, Richard wuhrer, Measurement and Prediction of Thermal Properties of Alkali-activated Flyash/slag Binders at Elevated Temperatures, RILEM 2016.