OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

"Innovative Retrofitting for the Structural Upgradation of Pavements with Geopolymer Concrete"

Devendra Birla[1], Prof. Somaya Gangotiya[2], Prof. Kishor Patil[3]

[1]*M.Tech Scholar, Department of Civil Engineering, Sushila Devi Bansal College of Engineering, Indore*

[2]*Guide, Department of Civil Engineering, Sushila Devi Bansal College of Engineering, Indore*

[3]*Co-Guide, Department of Civil Engineering, Sushila Devi Bansal College of Engineering, Indore*

Abstract: This research explores the development and application of low-calcium (Class F) fly ash-based geopolymer concrete (GPC) as a structural retrofitting material for pavements. Traditional Ordinary Portland Cement (OPC) production contributes significantly to global CO2 emissions and climate change. Geopolymer concrete, formed through the chemical activation of industrial by-products like fly ash with alkaline solutions, offers a "green" alternative with superior mechanical properties and durability. This study details the experimental investigation into the fresh and hardened properties of GPC, including consistency, setting time, compressive strength, flexural strength, and split tensile strength. Results indicate that GPC can achieve high early strength through thermal curing, with 28-day compressive strengths reaching up to 62 MPa. The study concludes that GPC is a viable candidate for thin white-topping (TGC) and ultra-thin white-topping (UTGC) applications, providing a sustainable and long-lasting solution for pavement upgradation..

Keywords: ETABS, Blast Load, Earthquake load, Base shear, displacement

---

I. INTRODUCTION

1.1 General

Road traffic has seen an unprecedented increase globally, a trend expected to persist in the coming years. Even developed nations face significant funding shortages for new infrastructure and, more critically, for the repair and maintenance of existing roads. In developing countries like India, the situation is more severe. India maintains the world's second-largest road network, totaling approximately 58.98 lakh km, including 1,32,500 km of National Highways and Expressways. Most of these are bituminous pavements that deteriorate over time, requiring substantial financial and physical resources for strengthening.

1.2 Environmental Impact of Traditional Binders

Concrete production is the second-largest producer of carbon dioxide, accounting for 5% of the global carbon footprint. Ordinary Portland Cement (OPC) production is a primary driver of climate change due to CO2 emissions from fossil fuels. With global cement consumption projected to rise to 5 billion tons per year, there is an urgent need to rethink the role of industrial waste and reduce reliance on OPC.

1.3 Geopolymer Concrete (GPC)

First proposed by Davidovits in 1978, geopolymers are binders produced by the polymeric reaction of alkaline liquids with silicon and aluminum found in geological or by-product materials like fly ash. Unlike OPC, which relies on hydration to form C-S-H gel, GPC utilizes a process called "geopolymerization". In this study, Class F fly ash is used as the primary binder to create a sustainable material for pavement work

II. OBJECTIVE OF STUDY

The specific objectives of this project are described as follows:

Design and produce a mixture of GTGC/GUTGC with different aggregate sizes with F class fly ash.

Design and produce a finishing surface for GTGC.

Examine the mechanical properties of each mixture in terms of compressive strength, flexural strength also, the density and compactly of the mixtures are were assessed in this study.

Various types of te sts perform which is necessary for pavement design.

III. PROBLEM FORMULATION

Ultra-thin geopolymer concrete (UTGC) is one of the most common concrete pavement methods using Portland cement. Due to the environmental issues associated with Portland's manufacturing, there is a recent trend to replace it. Alkali activated fly-ash concrete (AAFC) has been proposed as a solution to this problem. However, this type of concrete is used in RCC is rarely investigated.

The application of TGC/UTGC in pavements has become increasingly viable because of the beneficial characteristics of such concrete. TGC with zero slump is placed with conventional or high-density paving equipment and compacted using rollers. This eliminates the need for forms during placement and the need for a finishing procedure, hence increasing the speed of construction.

The use of TGC can increase early strength development that allows constructed pavements to be opened to traffic at an earlier age. Reducing the construction duration and enhancing early- age and long-term performance, are the key solutions for decreasing direct and indirect costs.

IV. MATERIAL USED

4.1 The Fly ash is used as a cementitious material drawn from the burning of coal at high temperatures. The source fly-ash used in this research was class F fly-ash.

4.2 Fine Aggregate: The most important function of sand is to provide workability and uniformity in the mixture. Clean and dry river sand available locally was used. Sand passing through IS 4.75mm Sieve was used for casting all the specimens. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

4.3 Coarse Aggregate: In the present investigation locally available crushed basalt stone aggregate of size 20mm passing and retained in 10mm,10mm passing retain on 6mm,4.75mm retain on 2.36mm,2.36mm passing retain on 1.18mm IS sieve used and the various tests were carried out as per IS:383:2016.

V. EXPERIMENTAL PROCEDURE

5.1 Mix proposition and testing of GPC1 specimens

Twelve cubes of size 150X150mm, Twelve cubes of the size of 7.06cmX7.06cm, a beam of 70cmX15cmX15cm and three-cylinder of size 150mm diameter 300mm high were cast and out of which three cubes each were used to determine the compressive strength and three cylinders each was used to determine the split tensile strength at 3days,7days 14days for different grades of GPC1 and its mortar A total 159 numbers of specimens were tested in this study to find out the grades of Geopolymer concrete zero compacted geopolymer concrete All GPC1 mixes designed using mix design procedure outlined by scientists of SDBC LABS. the mix proposition taken in this experiment is 1:2.06:3.3 and 1:1.8:3 ratio for geopolymer concrete and 1:2 ratio taken for geopolymer mortar that is developed by SDBC LABSscientists. Where the first part is fly-ash second is fine aggregates and the third one is coarse aggregates. It is recommended to have necessary precautionary measures while working on a geopolymer because the heat generation of alkaline liquid will be more. The aggregates were prepared in saturated-surface-dry (SSD) condition. GPC1 can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. The concrete ingredients are collected and mixed in the mixer mixture along with alkaline material in solidform for about 40 minutes. Then after water is added to the mixer. After the mixing, the flow value of fresh Geopolymer concrete was determined per Slump Test IS 1199:2018 Part 2. as shown in figure 4.7. After the slump test, fresh concrete was placed in the respective molds as described in the IS 516:2019 Part 4 and as shown in Figure The fresh concrete was cast and compacted by using the tamping rod and the molds were vibrated on a vibrating table for10 minutes. The specimens were placed in a hot air oven for 48 hours at 60ºC as shown in the figure and then at 35℃ up to testing of specimens. Demoulding was done after 24 hours as shown in the figure. some batches are also cured at ambient temperature in the open environment as shown in the figure. Thus, the compressive strengths, flexure strength, and tensile strength (as per ASTM C190-85) of concrete were determined on the same day as perIS 516: 2019 Part 1.

Figure 5.1 Prepared material, Moulds ,Beams and Cylinder

5.2 Compressive strength testing

The Test was carried out on 150mm x 150mm x 150mm size cube to determine the Compressive strength of Geopolymer Concrete at a rate of loading 5.2KN/S and7.06mmX7.06mm7.06mm at the rate of 2.9KN/S as per IS516:2019 Part 1.A 3000kN capacity standard Compression Testing Machine was used to conduct the test shown in Figure The test result of the specimens and the average of the strength of three specimens is taken.

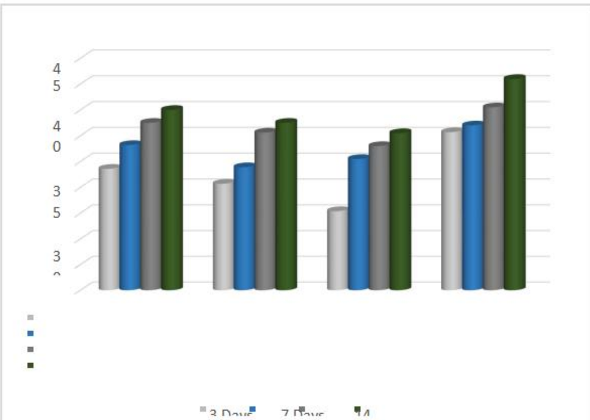
Figure 5.2 Testing of cube

VI. RESULT AND DISCUSSION

6.1 Results

6.2 Compressive strength

The compressive strength of materials was determined after 3, 7, 14, 28 days of curing. Compressive strength of Fly-ash based geopolymer mortar.



0	GC M 1	GC M 2	GC M 3	GC M 4
3 Days	23.6	20.7	15.4	30.7
7 Days	28.2	23.9	25.5	32
14 Days	32.5	30.6	28	35.5
28 Days	35	32.5	30.5	41

Figure 6.1 Effect on compressive strength of mortar by different propositions of fine aggregate sand the addition of silica fumes

Results showed that the variation in graded fine aggregates and the addition of silica fumesrequired for ultimate compaction.

6.3 Compressive strength of Geopolymer concrete.

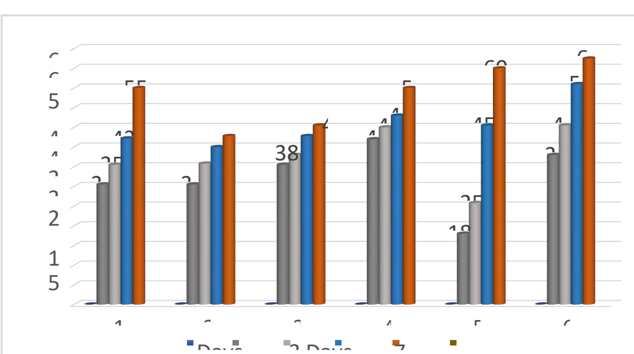


Figure 6.2 Compressive strength comparison of different Geopolymer concrete geopolymer mix at 3,7,14 and 28 days

6.3 Flexure strength/Modules of rupture

Concrete deforms more in tension than in compression because concrete is weak in tension that's why we only tested those batch which has good compression. GCG1, GCG2 & GCG 6were tested for Flexure strength after 28 days

Modulus of rupture for GPC11

Density- 2523Kg/m^3

Minimum dimension of failed beam a=26.5 cm>20cmFb = Modulus of rupture

$$F = \frac{30.92\times600\times1000}{150\times150^2} = 5.5MPa$$
b

= Modulus of rupture

F = 30.92×600×1000 = 5.5MPa

b 150×1502

Modulus of rupture for GPC12

Density- 2476Kg/m^3

Minimum dimension of failed beam a=12.7<17 cm

Since the minimum length of the failed beam is not satisfying any three cases of modulus of rupturSo, the beam is failed in flexure

Modulus of rupture for GPC16

Density – 2504Kg/m^3

Minimum dimension of the failed beam a 26.2cm>20cm

Fb = Modulus of rupture

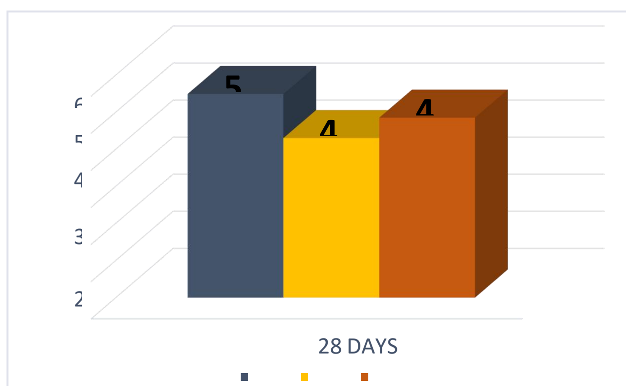


Figure 6.3 Flexure strength comparison graph

VII. CONCLUSION

1. The use of Fly ash can be efficient with the partial replacement of cement 100% thereis no necessity to expose the geopolymer to a longer curing period.
2. As the curing temperature in the range of 30°C to 90°C increases, the compressive strength of fly ash-based geopolymer concrete

also increases..

3. More than 50% strength of cube achieved in 3 days for thermal curing and for ambient curing it takes 7 days so the initial temperature must require for geopolymer concretepaste for proper polymerization.
4. The maximum compressive strength of cube obtained after 28 days is 60MPa for ambient curing and 62MPa for thermal curing.
5. The maximum flexural strength of the beam after 28 days obtained as 5.5MPa which is sufficient for geopolymer concrete on pavement.

VIII.REFERENCES

1. Adam, Andi Arham. 2014. “The Effect of Temperature and Duration of Curing on the Strength of Fly Ash Based Geopolymer Mortar.” Procedia Engineering 95 (Scescm). Elsevier B.V.: 410–414. doi:10.1016/j.proeng.2014.12.199.
2. Andrews-phaedonos, Fred. “Geopolymer Green Concrete: Reducing the Carbon Footprint - The VicRoads Experience,” 386–406.
3. Andrews-phaedonos, Fred. 2014. “Specification and Use of Geopolymer Concrete.”
4. 9th Austroads Bridge Conference, 1–12.
5. Andrews-Phaedonos, Fred. 2016. “Specification of Geopolymer Concrete : General Guide.” Austroads Ltd., 22.
6. Annual Report. 2019. “Ministry of Road Transport and Highways (MoRTH), Government of India, New Delhi,” 1–124.
7. Cui, Yifei, Kaikai Gao, and Peng Zhang. 2020. “Experimental and Statistical Study on Mechanical Characteristics of Geopolymer Concrete.” Materials 13 (7). doi:10.3390/ma13071651.
8. Damtoft, Jesper Sand, J Lukasik, Duncan Herfort, D Sorrentino, and Ellis Gartner. 2008. “Sustainable Development and Climate Change Initiatives.” Cement and Concrete Research 38: 115–127. doi:10.1016/j.cemconres.2007.09.008.
9. Davidovits, Prof Joseph. 2002. “30 Years of Successes and Failures in Geopolymer Applications . Market Trends and Potential Breakthroughs .,” 1–16.
10. Duxson, Peter, John L. Provis, Grant C. Lukey, and Jannie S.J. van Deventer. 2007. “The Role of Inorganic Polymer Technology in the Development of ‘Green Concrete.’” Cement Concrete Research37(12): 1590–1597. doi:10.1016/j.cemconres.2007.08.018.
11. Edouard, Jean-baptiste, and Jean-baptiste Edouard. 2011. “By,” no. May.
12. Fan, Fenghong, Zhen Liu, Guoji Xu, Hui Peng, and C. S. Cai. 2018. “Mechanical and Thermal Properties of Fly Ash Based Geopolymers.” Construction and Building Materials 160. Elsevier Ltd: 66–81. doi:10.1016/j.conbuildmat.2017.11.023.
13. Fernández-Jiménez, Ana, and Angel Palomo. 2009. “Properties and Uses of Alkali Cements.” Revista Ingenieria de Construccion 24: 213–232.
14. Gartner, Ellis. 2004. “Industrially Interesting Approaches to ‘Low-CO2’ Cements.” Cement and Concrete Research 34: 1489–1498. doi:10.1016/j.cemconres.2004.01.021.