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SUSTAINABLE POLYMER-BASED CONCRETE WITH SYNTHETIC FIBER ENHANCEMENT

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ABSTRACT

Concrete has played a vital role in the housing industry over the past few decades, being utilized in a wide range of constructions, from small buildings to large infrastructural dams and reservoirs. A binding agent is a major component of cementitious material. The value of cement is rising daily due to its limited availability and high demand. Simultaneously, global warming is escalating with each passing day. The production of cement also results in the release of greenhouse gases. An investigation has been initiated focusing on cementitious materials, including a trial-based study examining the use of fly ash and GGBS as substitutes for cement. This approach aims to reduce cement consumption and minimize greenhouse gas emissions. An investigation has been initiated focusing on geopolymer cementitious material incorporating nylon crystals. Furthermore, a comparative analysis of this pbc with conventional M20 cementitious material is warranted. Experimental studies were conducted on plain geopolymer cementitious material, and the substitution of cement with Nylon crystal has been completed. In this study, the cementitious materials were prepared by incorporating fly ash, glass, hydroxide, and nylon crystal, with proportions ranging from 100% to 40% by weight of fly ash added to the mixes. A comparative analysis has been conducted between M20 cementitious material and Nylon crystal reinforced geopolymer cementitious material, focusing on their compressive strength, split tensile strength, and bending resistance characteristics. The geopolymer cementitious material developed with Nylon crystal exhibited superior performance in compressive strength, split tension strength, and bending resistance, demonstrating enhanced results at seven, 28, 60, and 90 days compared to conventional cementitious materials. Furthermore, two distinct types of acid attacks are conducted to evaluate the bond strength and compressive strength of both standard cementitious materials and nylon crystal reinforced geopolymer cementitious materials.

Keywords: *Synthetic Fiber, Geopolymer Cementitious Material, Greenhouse Gases, Global Warming.*

Introduction

The construction industry is one of the largest consumers of natural resources and generates significant amounts of waste. With rapid infrastructure development in developing countries, the demand for aggregates from quarries has increased, leading to a depletion of natural resources. Coarse aggregates, which constitute about 60-70% of the volume of cementitious materials, play a critical role in determining the physical and mechanical properties of concrete structures. The mineral characteristics of the aggregates are key to the strength and durability of the concrete mix. The development of composite materials using various admixtures has enhanced the strength properties of cementitious materials, while incorporating waste materials helps reduce the overall density of the mix. Innovative scientific methods are needed to explore alternative aggregate materials to reduce reliance on natural resources. In the context of India, the country is projected to experience substantial population growth, surpassing China by the mid-century. This demographic growth presents two opportunities: a large workforce and a need for extensive infrastructure development. India's 12th Five-Year Plan emphasizes large-scale infrastructure projects, including roads, highways, railways, ports, power, and communication sectors, with an investment target of over one trillion USD.

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Concrete, being the most widely used material in construction, consists of a mixture of sand, gravel, cement, and water. The ability to combine these materials into a solid mass with well-defined characteristics has made concrete the preferred construction material for over 150 years. Its popularity is due to its durability in harsh environments, versatility in being shaped into various forms, and cost-effectiveness. In recent studies, the mechanical properties of cementitious materials have been explored by incorporating synthetic fibers. The optimal percentage of synthetic fiber is determined to enhance mechanical properties, while additional testing is conducted to examine the material's resistance to acid attacks and bond strength. Research, such as that by Dr. Sujid, has demonstrated the potential of using industrial waste materials, like foundry sand and steel slag, in asphalt mixes, showing significant improvements in the characteristics of flexible pavement mixes.

Objectives

- In order to accomplish the goals of this study, the following long-term features of fly ash-based geopolymer cementitious material with the incorporation of nylon crystals will be investigated.
- Compressive, flexural, and split tensile strengths are all included in the strength category.
- Water absorption tests for specimens that are both cylindrical and cubic in shape respectively

Data and Sources of Data

Compressive strength is one of the numerous properties of geo compound cementitious materials based on ash that have been thoroughly described in detail by Djwantoro Hardjito, Steenie E., Dody M.J. Sumajouw, and B.V. Rangan (1992). The cementitious material's age, hardening temperature, curing duration, quantity of geo-polymer of super-plasticizer, remaining amount before hardening, and combination water content were all included as check factors. Compressive strength of cementitious materials does not change with age, and specimens of these materials may be hardened to a greater compressive strength by subjecting them to higher temperatures and longer hardening times. Modern geo-polymer cementitious material is more workable thanks to a super-plasticizer based on naphthene, which they use together.

Warren A. Dick, Huisheng Shi, and Xiaolu Guo (2009) Class C fly ash geopolymer (CFAG) microstructure and compressive strength were investigated in this study. This study found that the optimal modulus, defined as a molar ratio of SiO2/Na2O of 1.5, was achieved by activating class C fly ash (CFA) with a mixed alkali activator (sodium hydroxide and sodium silicate solution), leading to a high compressive strength. Class fly ash, when activated with an alkaline solution, causes the alumino-silicate to dissolve, giving the impression that the sphere is being attacked and fractured. The use of fly ash in geo-polymer materials not only helps to save energy and resources, but it also indirectly lowers the emissions of carbon dioxide gas produced during cement production. Both the ecosystem and our limited resources will benefit from this.

With low calcium flyash and slag replaced at five different percentages, Ganapathi Naidu, A.S.S.N. et al. (2012)9 attempted to investigate the strength properties of geopolymer cementitious material. All five combinations made use of sodium hydroxide (41 kg/m3) and sodium silicate (103 kg/m3) solutions as alkalis. The greatest compressive strength that could be maintained for 28 days was 57 MPa, with a flyash to slag substitution ratio of 28.57 percent. The same mixture has a modulus of 43.56 MPa after two hours of exposure to 500°C.

Studying the effect of different concentrations of lignin- and poly-carboxylic ether-based plasticizers on the workability of geopolymer cementitious materials based on fly ash was an effort by Aminul Islam Laskar and Rajan Bhattacharjee (2012). The workability of fly ash based geopolymer cementitious materials is negatively affected by superplasticizer and plasticizer beyond a certain molar strength of sodium hydroxide. Slump becomes more pronounced as sodium hydroxide's essential molar strength is decreased. Slump, rheological parameters, and fly ash-based geopolymer cementitious materials with plasticizer and superplasticizer added show a strong association.

Research Methodology

Geo polymer cementitious material is created by replacing cement with flyash and ggbs and adding nylon crystals; the purpose of this investigation is to learn how this material behaves in terms of strength. We compare the outcomes produced by this blend to those of the standard, or "regular," M20 grade blend. In the trial-based procedure, a total of forty cubes measuring 150mm × 150mm × 150mm are cast and tested. After7,14,28, and 90 days of curing, the specimens were tested. The specimens were subjected to the compressive test.

Description of Materials

- **FLYASH**

Flyash is a byproduct generated from industrial processes and other sources, such as the combustion of various materials. The specific gravity of fly ash is measured at 2.123.

- **GGBS**

Ground granulated blast furnace slag serves as the main substitute for cement in this geopolymer cementitious material.

The specific gravity test must be performed prior to mixing. The specific gravity of Ground Granulated Blast Furnace Slag (GGBS) is measured at 2.86.

- **CEMENT**

Ordinary Portland cement is utilized for general construction purposes. The binding agent utilized must comply with the following specifications.

The appropriate strength must be developed.

The representation of appropriate theological behavior is essential.

Generally, similar types of cements exhibit significantly different geological and strength characteristics. The fineness of Portland cement directly correlates with the early strength of cementitious material. An increase in fineness results in a higher surface area exposed to water, facilitating a more rapid hydration process. This trial-based investigation utilizes ultratech 53 grade ordinary Portland cement.

Results and Discussion

The trial findings of conventional cementitious material specimens and those of Geo polymer cementitious material specimens will be discussed in the next chapter. The outcomes of the tests conducted on PBC and CC will be compared. Here, we tested the PBC and CC for compressive strength, split tensile, bending resistance, water absorption, and acid resistance, and we compared the findings.

Compressive Strength Test

After7,14, and 28 days, the compressive strengths of CC and PBC were determined. For more precise results, the PBC specimens were evaluated at7,14, and 28 days after heat curing with three cubes each; the compressive strength at each time point was then averaged. At the same time, three examples of the water-cured CC were evaluated for correctness, as is customary.

For 7 days of Curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	19	19.6	19.3	19.3
PBC + 1%sf(nc)	12.09	12	12.60	12.23
PBC + 2%sf(nc)	13.40	13.06	13.23	13.23
PBC + 3%sf(nc)	14.40	14.60	14.40	14.45
PBC + 4%sf(nc)	13.50	13.05	13.20	13.25

For 14 days of Curing(N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	19.30929	20.02	20.02	19.44943
PBC + 1%sf(nc)	14.014	14.4144	14.03402	14.15414
PBC + 2%sf(nc)	15.5155	15.05504	15.2152	15.25524
PBC + 3%sf(nc)	15.9159	15.19518	15.6156	15.57556
PBC + 4%sf(nc)	15.5155	15.4154	15.47546	15.46545

For 28 days of Curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	21.836	21.7948	21.939	21.8669
PBC + 1%sf(nc)	16.995	17.0568	16.5006	16.8508
PBC + 2%sf(nc)	17.5924	18.128	17.922	17.8808
PBC + 3%sf(nc)	19.467	18.643	18.6018	18.5606
PBC + 4%sf(nc)	17.51	18.025	18.1074	17.8808

Split Tensile Test

The tensile strength of CC and PBC was assessed at 7, 14, and 28 days. Following heat curing, the PBC specimens were tested at 7, 14, and 28 days, with three cubes each to ensure better accuracy. The average was calculated as the split tensile strength for each specified time period. The water-cured CC was tested concurrently with three specimens for accuracy.

A table was prepared to compare the test values of both types of cementitious material.

For 7 days of Curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	2.369	2.3381	2.06	2.2557
PBC + 1%sf(nc)	1.2772	1.339	1.339	1.3184
PBC + 2%sf(nc)	1.442	1.6274	1.751	1.6068
PBC + 3%sf(nc)	1.545	1.6995	1.7407	1.6686
PBC + 4%sf(nc)	1.442	1.545	1.442	1.4729

For 14 days of curing(N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	3.09	3.1518	3.1209	3.1209
PBC + 1%sf(nc)	2.2248	2.163	2.2145	2.1939
PBC + 2%sf(nc)	2.3072	2.369	2.472	2.3793
PBC + 3%sf(nc)	2.4205	2.472	2.4926	2.4617
PBC + 4%sf(nc)	2.369	2.369	2.3484	2.3587

For 28 days of curing(N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	3.193	3.296	3.2445	3.2445
PBC + 1%sf(nc)	2.266	2.369	2.4102	2.3484
PBC + 2%sf(nc)	2.575	2.472	2.5544	2.5338
PBC + 3%sf(nc)	2.678	2.781	2.884	2.781
PBC + 4%sf(nc)	2.6162	2.5235	2.6265	2.5853

Flexural Strength

After14,28, and 60 days, the CC and PBC bending resistances were determined. In order to get the most accurate results, the PBC specimens were examined at 14, 28, and 60 days after heat curing. Each test was conducted using three cubes, and the bending resistance at each time period was calculated by taking the average. At the same time, three examples of the water-cured CC were evaluated for correctness, as is customary.

14 days of Curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	2.472	2.266	2.369	2.369
PBC + 1%sf(nc)	1.442	1.648	1.6068	1.5656
PBC + 2%sf(nc)	1.854	1.751	1.7922	1.8025
PBC + 3%sf(nc)	2.0703	1.957	2.0394	1.9879
PBC + 4%sf(nc)	1.854	1.8849	1.8334	1.8643

For 28 days of Curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	4.12	4.2745	4.2745	4.223
PBC + 1%sf(nc)	3.4505	3.502	3.399	3.4505
PBC + 2%sf(nc)	3.708	3.605	3.5638	3.6256
PBC + 3%sf(nc)	3.9552	3.8522	4.0788	3.8934
PBC + 4%sf(nc)	3.7286	3.6668	3.5432	3.6462

For 60 days of Curing (N/mm2)

Specimen	Sample 1	Sample 2	Sample 3	Average
CC	5.459	5.356	5.253	5.356
PBC + 1%sf(nc)	4.4908	4.429	4.5526	4.4908
PBC + 2%sf(nc)	4.5732	4.532	4.6144	4.5732
PBC + 3%sf(nc)	4.7483	4.7174	4.635	4.60719
PBC + 4%sf(nc)	4.223	4.532	4.5217	4.429

Conclusion

- It is observed that the slump values of the cementitious material decrease as the percentage of synthetic fiber increases. This reduction can be attributed to the presence of the nylon crystals, which hinder the free flow of the cementitious material.
- The optimal dosage of synthetic fiber in the geopolymer concrete (PBC) was found to be 15%, offering the best balance of workability and strength.
- Compressive strength tests show that the PBC outperforms conventional cementitious materials. The compressive strength values at 7 days increase with the addition of nylon crystals, reaching 23.40 MPa at 15% dosage.
- At 14 days, the compressive strength continues to rise, with the maximum value of 25.56 MPa recorded at 15% nylon crystal addition.
- The 28-day compressive strength of the PBC follows a similar trend, with the highest value of 28.02 MPa observed at 15% nylon crystal content.
- The split tensile strength of the PBC also improves with increasing nylon crystal content, peaking at 3.70 MPa at 15%, before slightly declining at higher percentages.

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