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Study on Self Compacting Geopolynmer Concrete

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Abstract: *Self-compacting concrete (SCC) became a strong candidate for various construction applications owing to its excellent workability, low labor demand, and enhanced finish-ability, and because it provides a solution to the problem of mechanical vibration and related noise pollution in urban settings. However, the production of Portland cement (PC) as a primary constituent of SCC is energy-intensive, contributing to about 7% of global carbon dioxide (CO2 emissions. Conversely, the use of alternative geopolymer binders (GBs) in concrete can significantly reduce the energy consumption and CO2 emissions. In addition, using GBs in SCC can produce unique sustainable concrete with unparallel engineering properties. In this outlook, this work investigated the development of some eco-efficient self-compacting geopolymer concretes (SCGCs) obtained by incorporating different dosages of fly ash (FA) and ground blast furnace slag (GBFS). The structural, morphological, and mechanical traits of these SCGCs were examined via non-destructive tests like X-ray diffraction (XRD) and scanning electron microscopy (SEM). The workability and mechanical properties of six SCGC mixtures were examined using various measurements, and the obtained results were analyzed and discussed. Furthermore, an optimized hybrid artificial neural network (ANN) coupled with a metaheuristic Bat optimization algorithm was developed to estimate the compressive strength (CS) of these SCGCs. The results demonstrated that it is possible to achieve appropriate workability and mechanical strength through 50% partial replacement of GBFS with FA in the SCGC precursor binder. It is established that the proposed Bat-ANN model can offer an effective intelligent method for estimating the mechanical properties of various SCGC mixtures with superior reliability and accuracy via preventing the need for laborious, costly, and time-consuming laboratory trial batches that are responsible for substantial materials wastage.*

Keywords: Geopolymer; Concrete; Self-Compacting; Database; Recycled; Artificial Neural Network; Bat Algorithm; Model; Prediction

I. INTRODUCTION

Concrete is a mixture of specific sized aggregates held together by a cementitious binder paste. The durability, strength and workability has made concrete the most used building material. Concrete has been human's greatest weapon for survival and development and has helped man to put roofs over billions of people. However, with the rise of urbanization, rampant use of concrete has started to threaten the humankind due to its disastrous effect on environment. The use of Ordinary Portland Cement (OPC) in concrete design dates back to ancient Macedonia but under present paradigm, it is of great concern. The efforts to make products environmental friendly have been relentless globally. Steel and concrete industries are one of the major CO2 producing industries and are bent on reducing rate of CO2 emission by 2030.

Currently, to address the lack of skilled labor and problems of poor consolidation and finish quality of concrete construction, self-compacting concrete (SCC) technology has emerged and become the mainstream. SCCs have exceptional flowability, pass through rebar, and consolidate under their weight without segregation or bleeding. Apart from their self-compacting ability, SCCs have a high filling and passing ability as welas appropriate segregation resistance, making them ideal for various applications in the construction industries, including precast concrete, repair works, and underwater construction. Nevertheless, traditional SCC requires a high amount of binder to achieve its exceptional engineering properties. The use of Portland cement (PC) as the primary binder in SCC remains a major concern because of the elevated levels of carbon dioxide (CO2) emissions and embodied energy (EE) associated with its production. Cement production constitutes approximately 7% of the global CO2 emissions.

If the cement industries were considered as a country, it would indeed rank third after China and the USA in terms of total CO2 emissions. To overcome this problem, substantial efforts have been dedicated to developing novel construction materials using sustainable alternative binders with less-harmful environmental footprints. Over the last several decades, there has been increasing research into and production of geopolymer binders (GBs) as an environmentally friendly alternative to the conventional PC. Since the CO2 emissions and high energy consumption of PC production are eliminated, GBs have emerged as a sustainable alternative.

Generally, GBs are produced from alumina silicate precursors, often consisting of recycled byproducts and waste materials activated by alkaline solutions to yield geopolymer concrete (GC). GC has been characterized by its excellent durability and mechanical performance compared to that of traditional Portland cement concrete (PCC). Uses of GBs have recently been explored to enhance the sustainability of SCC.

1.1 Self Compacting Geopolymer Concrete

Low calcium fly ash based geopolymer was inculcated to scc as a method to reduce the cement consumption and improving properties of self compatability. Self compacting geopolymer concrete does not need additional compaction equipments for concreting process, as flyash together with alkaline solution and super plasticisers participates in binding process and helps in developing formation and strength. The matrix phase in SCGC help to bind coarse aggregates, fine aggregates and other unblended materials to achieve the required workability properties. Thus superior workability and performance is achieved by improving the plastic and hardened properties.

II. LITERATURE REVIEW

Mehmeerengulsan et al. (2019) discussed the work on effect of nano-silica and steel fiber on the fresh and hardened state performance of self compacting geopolymer concretes. They have investigated that incorporation of nano-silica (0%,1%,2%) and steel fiber (0%,0.5%,1%) affected the fresh state properties. A combined utilization of them improved bond strength and flexural performance of the self compacting geopolymer concrete. In addition, the effect of nanosilica was found to be dominant on fresh state properties and compressive strength, while the effect of steel fiber was found to be superior on flexural performance and bonding strength.

Patel &Niraj Shah.(2018) described the work on effect of temperature curing and ambient curing on mechanical properties of Self Compacting Geopolymer Concrete. They have A.Vinothkumar et al. / International Research Journal of Multidisciplinary Technovation /2019, 1(6), 373-377 the effect of percentage (0, 5, 15 and 25%) replacement of Rice Husk Ash on the properties of Self Compacting Geopolymer Concrete. The optimum percentage replacement of Rice Husk Ash with Ground Granulated Blast Furnace Slag is 5% at ambient curing and 15% at 70 °C temperature curing. The higher strength is obtained at 70 °C temperature curing than at ambient curing.

Fareed Ahmed et al (2011) have studied the compressive strength and workability characteristics of low-calcium fly ash based self compacting geopolymer concrete. They have studied effect of extra water, curing time and curing temperature of self compacting geopolymer concrete. The addition of extra water improved the workability characteristics of concrete mixturres. Concrete specimens cured at 70°C produced the highest compressive strength as compared to specimens cured at 60°C, 80°C and 90°C.

Fareed Ahmed Memon et al (2011) investigated the effect of curing conditions on the compressive strength of self-compacting geopolymer concrete. The experiments were conducted by varying the curing time and curing temperature in the range of 24-96 hours and 60-90°C respectively. Concrete specimens cured at 70°C produced the highest compressive strength and increase in compressive strength with the increase in curing time.

Muhd Fadhil Nuruddin et al (2011) described the work on Effect of mix composition on workability and compressive strength of self-compacting geopolymer concrete. The premixing of alkaline solution, super plasticizer, and extra water before being added to the dry mix of concrete has successfully improved the workability and strength. In 48 h and 70

°C of heat curing, 12% addition of extra water to the mixture with water-to-geopolymer solids ratio of 0.33 could improve concrete compressive strength.

PrasannaVenkatesan & Pazhani (2015) examined the strength and durability properties of Geopolymer concrete prepared using Ground Granulated Blast Furnace Slag and Black Rice Husk Ash. Black Rice Husk Ash was replaced with Ground Granulated Blast Furnace Slag at various proportions such as 10%, 20% and 30%. In addition of Black Rice Husk Ash beyond 10% had a retarding effect on the compressive strength. Although upto 20% replacement,the target compressive strength was surpassed and strength was reached at 28 days.

Patel & Niraj Shah (2018) evaluated the effect of Fresh and Mechanical properties of Self Compacting Geopolymer Concrete. The Self-compacting Geopolymer concrete was developed using Ground Granulated Blast Furnace Slag as the primary binder and Ground Granulated Blast Furnace Slag was replaced with 5%, 15% and 25% of Rice Husk Ash. Self compacting geopolymer concrete blended with 100% Fly Ash failed to achieve the required strength at 3, 7 and 28 days at ambient temperature due to incomplete geopolymerization process without heat. The compressive strength, split tensile strength, and flexural strength of self compacting geopolymer concrete is improved up to 5% replacement of Rice Husk Ash with compared to coontrol mix at all ages.

Saad Al-Rawi & Nildem Tayşia (2018) discussed the work on impact of Steel Fiber and Ground Granulated Blast Furnaces slag content on the fresh and hardened properties of fly ash based Self-Compacting Geopolymer Concrete. Two series of self-compacting geopolymer concrete were formulated with a constant binder content of 450 kg/m3 and at an alkaline-to-binder (a/b) ratio of 0.50. Fly ash was substituted with Ground Granulated Blast Furnace Slag with the replacement levels being 0%, 25%, 50%, 75%, and 100% by weight in each Self-compacting Geopolymer concrete series. The increasing the amount of Ground Granulated Blast Furnace Slag on the mixes had a negative effect on the fresh properties. In addition, using of Ground Granulated Blast Furnace Slag in the mixes of SCGC significantly improved the compressive strength.

Fareed Ahmed Memon et al (2012) investigated the effect of superplasticizer and amount of extra water on strength and workability properties of Fly ash-based Self compacting geopolymer concrete. The experiments were conducted by varying the amount of extra water (10% to 20%) and dosage of superplasticizer (3% to 7%). The increase in amount of extra water and superplasticizer, the workability was improved. However, the addition of water beyond 15% resulted in bleeding, segregation and decreased the compressive strength of the concrete.

Fadhil Nuruddin et al (2011) have studied the effects of super plasticizer and molarity ofsodium hydroxide alkaline solution on the workability, microstructure and compressive strength of self compacting geopolymer concrete The parameters studied were super plasticizer dosage and molarity of NaOH solution. An increase in strength and a decrease in workability of these concrete samples were examined with the increase in molarity of NaOH solution from 8M to 14M. NaOH Concentration of 12M and super plasticizer dosage of 6% produced satisfactory performance.

III. NEED OF STUDY

The research was made to develop SCGC in external exposure curing conditions, which is similar to cast-in-situ production of concrete in tropical reglions. The major drawback of SCGC is the inclusion of heat curing system to achieve sufficient strength. If additives help reducing curing regime, this can be marked as a break through in research. It has also been proved that inclusion of additives improves durability, bond strength and flexural behavior.

IV. RESEARCH OBJECTIVES

The main aim of this study is to identify the out come of using additives on SCGC so that current hurdles in developing SCGC under elevated curing conditions can be eliminated.

The objectives identified.

- To achieve a suitable SCGC mix using OPC as additive. Here OPC was used to reduce the dosage of superplasticisers in SCGC.
- To find out maximum replacement possible for class F fly ash using class C fly ash in SCGC,so that curing method was altered to external exposure conditions.

- To assess mechanical properties of SCGC with class C fly ash (SCGC-C) and compare with same grade of normal SCC.
- To find out flexural behavior of SCGC with class C fly ash and to compare with ANSYS reports.
- To analyse the durability and microstructures charecteristics, when class C fly ash was involved in SCGC.

V. METHODOLOGY

- The materials like Cement, River Sand, Rice Husk Ash, Natural Coarse Aggregate, and grade of concrete are selected and their characteristics has been thoroughly analyzed.
- Using these materials, Design mix is done with required w/c ratio for M25 concrete grade.
- The different proportions of Rice Husk Ash is replaced with cement is done. The cubes, beams and cylinders are casted and tested for different mix proportions.
- Finally, with obtained results, comparison will be done and conclusions are drawn.

VI. SCOPE OF THE INVESTIGATION

- The scope of the work ios limited in achieving a viable SCGC mix in terms of workability and strength, there by promoting cast-in-situ production.
- EFNARC guidelines, 2002 are adopted to set up the SCC and SCGC, with available resoures in the labouratory.
- Mechanical properties such as compressive strength, tensile strength,flexural strength were compared with similar strength of normal SCC.
- Acid attack, sulphate attack, corrosion resistence were tested on account of durability, and microstructure was analysed using SEM analysis.

VII. CONCLUSION

This paper evaluated the impacts of different FA contents as partial substitution for GBFS on the structural, morphological, and mechanical (fresh and hardened) properties of some newly developed SCGCs. Furthermore, an optimized hybrid artificial neural network (ANN) coupled with a metaheuristic Bat optimization algorithm was developed to estimate the compressive strength (CS) of SCGC mixtures. The following conclusions were drawn from the results of mechanical, structural, and morphological properties:

1. The results confirmed that partial replacement of GBFS with up to 50% FA as a precursor binder in SCGCs yielded excellent workability and mechanical properties, meeting the EFNARC criteria for SCC.
2. SCGC mixtures made either with high volume of FA or GBFS resulted in high plastic viscosity values. For instance, the plastic viscosity of the mixture was increased from 79 to 86 cP with the increase of FA dosage from 60% to 70%. This increase in the plastic viscosity of mixtures made with high GBFS and FA levels was likely due to their chemical compositions and physical properties.
3. The results of microstructural analysis of SCGCs including XRD and SEM showed an improvement in the number of non-reacted particles, cracks, and pores when the FA content was increased as partial substitution for GBFS. This in turn enhanced the porosity and reduced the density as well as the C,N-(A)-S-H gel.
4. SCGC mixtures prepared with up to 50% of FA partial replacement for GBFS can mitigate the disposal cost and environmental footprint of such by-products. Consequently, carbon dioxide emissions can be reduced from the cement production, while eliminating the high energy and natural resource intake in the building sector and contributing to improved development and sustainability.
5. The results confirmed that the proposed informational Bat-ANN model attained the most reliable and robust predictive results for estimating the CS of SCGC mixtures, as confirmed by various statistical metrics revealing its superior accuracy compared to other informational models. Accordingly, such an informational model can reduce the need for costly, time-consuming, and material wasteful trial batches in the laboratory.

6. Aside from the positive environmental impacts, the developed SCGCs also offered a superior product in terms of mechanical properties, which is of great interest to concrete manufacturers. This alternative material for OPC-based self-compacting concrete has far-reaching suitability and may serve to fulfill sustainability goals for companies in the business of ecological construction, especially in precast concrete making.

From the analysis and discussion of test results obtained from this research, the following conclusions can be drawn:

1. Use of fly ash based self-compacting geopolymer concrete as an alternative binder can help reduce CO_2 emission of concrete as compared to ordinary Portland cement.
2. The fresh state tests comes about demonstrate that an expansion in the molarity of sodium hydroxide between 8M to 14M expanded the viscosity and cohesiveness of SCGC mixtures.
3. Utilizing fly ash contents in (SCGC) mixtures from 400 Kg/m^3 to 500 Kg/m^3, enhanced the compressive strength of self-compacting geopolymer concrete (SCGC) especially when superplasticizer dosages increased.
4. Longer curing time between 24 to 72 hours at a temperature of 70°C enhances the geopolymerization procedure bringing about higher compressive strength at early ages.
5. Higher value of compressive strength for SCGC reached to 52.8 MPa at age 91 days.
6. The mechanical properties of SCGC are only a fraction of the compressive strength, as in the case of SCC with Portland cement.

REFERENCES

[1]. Guneet Saini, Uthej vattipalli (2020) “Assessing properties of alkali activated GGBS based selfcompacting geopolymer concrete using nano-silica”

[2]. Sushree Sangita Rautray, Biswajyoti N. Mohanty, Manas R. Das (2020) "Performance of Self compacting geopolymer concrete using Bacillus Licheniformis”

[3]. Paul O. Awoyera, Mehmet S. Kirgiz, A. Viloriae, D. Ovallos-Gazabon (2020) “Estimating strength properties of geopolymer self-compacting concrete using machine learning techniques” ht

[4]. Khuram Rashid, Xiaoda Li , Yan Xie , Jun Deng , Faji Zhang (2020) “Cracking behavior of geopolymer concrete beams reinforced with steel and fiber reinforced polymer bars under flexural load” h

[5]. Mahima Ganeshan, Sreevidya Venkataraman (2020) “Interface shear strength evaluation of self compacting geopolymer concrete using push-off test” ht. [6] Mehmet Eren Gulsan, Radhwan Alzeebaree, Ayad Ali Rasheed, Anil Nis, Ahmet Emin kurtoglu etal. (2019) “Development of fly ash/slag based self-compacting geopolymer concrete using nano-silica and steel fiber”

[6]. Muhammad N.S.Hadi, Haiqiu Zhang, Shelley Parkinson (2019) “Optimum mix design of geopolymer pastes and concretes cured in ambient condition based on compressive strength, setting time and workability”

[7]. Afsaneh Valizadeh, Farhad Aslani , Zohaib Asif and Matt Roso (2019) “Development of Heavyweight SelfCompacting Concrete and Ambient-Cured Heavyweight Geopolymer Concrete Using Magnetite Aggregates”

[8]. Rajesh Suryanarayan, Dr. Hake S.L (2019) “Effect of NA2SIO3/NAOH Ratio for fly ash based selfcompacting geopolymer concrete” Volume: 06 Issue: 12

[9]. Saad Al-Rawi and Nildem Tayşi (2018) “Performance of self-compacting geopolymer concrete with and without GGBFS and steel fiber” Advances in Concrete Construction, DOI:

[10]. Chameera Udawattha, Rangika Halwatura (2018) “Geopolymerized self-compacting mud concrete masonry units” https://doi.org/10.1016/j.cscm.2018.e00177.

[11]. Habeeb Lateef Muttashar, Mohd Azreen Mohd Ariffin, Mohammed Noori Hussein, Mohd WaridHussin, Shafiq Bin Ishaq (2017) “Self compacting geopolymer concrete with spend garnet as sand replacement” .

[12]. Yamini J. Patel, Niraj Shah (2018) “Development of Self-compacting geopolymer concrete as a suitable construction material”