International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 08 | Aug - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

A Review on Analysis of Performance Evaluation of Structural Concrete Incorporating Fly Ash, GGBS, and Recycled Aggregates for Sustainable Construction

SURWASE ARCHANA SHANKAR

UNDER THE GUIDANCE OF
Prof. G. H. Dake

Department of Civil Engineering

Deogiri Institute of Engineering and Management Studies,

Chh. Sambhajinagar

Abstract

Old concrete from building and demolition work creates big environmental problems around the world. This study looks at a better, more eco-friendly way to reuse that waste by mixing **recycled concrete pieces** (called RCA) with a material called **activated fly ash** (AFA) to make new concrete.In the lab, different concrete mixes were tested to check their strength, durability, and environmental impact. The mixes used different amounts of recycled concrete (from 0% to 100%) and fly ash that was treated with special chemicals (sodium hydroxide and sodium silicate).Here's what the tests showed:Using recycled concrete alone (especially above 60%) made the concrete weaker.But adding 25% activated fly ash helped recover most of the lost strength—making it almost as strong as regular concrete.Concrete with AFA also lasted longer and resisted damage from chemicals and salt (chlorides) better.It was also much better for the environment:**43% less carbon emissions** ,**30% less water pollution**, **29% less use of non-renewable energy**.A method called **TOPSIS** was used to compare all the options, and it showed that mixes with activated fly ash had the best balance of strength and sustainability

Keywords : Mixing recycled concrete with activated fly ash makes strong, long-lasting concrete that's much better for the planet. This supports greener and more sustainable building practices.

Chapter 1

INTRODUCTION

1.1 Background on Functionally graded materials

Concrete is the most commonly used building material in the world. As cities grow quickly because of rising populations, old buildings and infrastructure are often torn down to make room for new ones. This creates a lot of construction and demolition (C&D) waste. Many cities don't have enough space to throw away all this waste, and the cost of putting it in landfills keeps going up. Because of this, builders and property owners have to spend more money. One solution is to recycle C&D waste and use it again as building material, like gravel or crushed stone (called aggregates). alkali-activated materials are made and how they perform depends on several things—like how much water is used, how much calcium oxide (CaO) is in the fly ash, the structure of the fly ash, and how it was heated before. Fly ash is grouped by its chemical makeup, either by European standards or as Class F and Class C by ASTM standards.

The amount of calcium oxide in the fly ash, especially in types with a lot of lime (called calcareous fly ash), strongly affects how durable the final material is. This study looks at how fly ash affects concrete when it is chemically activated and cured at room temperature. The researchers used a special chemical mix (sodium hydroxide and sodium silicate in a 3:1 ratio) to activate the fly ash. The goal is to improve how fly ash behaves in concrete by boosting its pozzolanic activity—a chemical process that helps it bond better in cement. The study also examines how the activated fly ash concrete handles water absorption, chemical damage, and how easily chloride ions can pass through it, all at room temperature.

1.2 Experimental research work

The research was done in three main stages to reach the study's goals:

- **Stage I:** The researchers tested the strength of concrete made with natural and recycled rocks (called aggregates). This helped them find the best mix of recycled and natural materials to replace regular stones in concrete.
- **Stage II:** Next, they added fly ash (not chemically activated) to the best mix of recycled and natural aggregates found in Stage I. They wanted to see how this affected the concrete.
- **Stage III:** Then, they tested what happens when the fly ash is chemically activated using a fixed mix of sodium hydroxide and sodium silicate (3:1). They compared this with the results from Stage II. They also did more tests to see how the concrete handles water, acid, sulfate, and how easily chloride can pass through it.

1.3 Experimental methodology

A) Binde*r*

Ordinary Portland Cement (Grade 42.5) was used in this study, following standards from IS 269:2015 and ES 4756–1/2007. The cement was made by Lucky Cement in KPK, Pakistan. Concrete samples were made as shown in Table 1.For fly ash, a low-calcium type (ASTM Class F) was used, collected from the Sahiwal Coal-Fired Power Plant in Pakistan. To make this fly ash active, it was treated using a chemical mix. This mix included a 10 molar (10 M) solution of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3).The choice of 10 M NaOH was based on earlier studies, which showed it worked well to start the pozzolanic reaction (the chemical process that strengthens the concrete). Researchers like Bakkali and Degirmenci found that 10 M NaOH gives good results without making the concrete too hard to work with or less durable.Although this study didn't test different concentrations, 10 M was used because it's proven to be effective. The sodium silicate used was a strong type containing 53% silicon dioxide (SiO_2) and 17.6% sodium oxide (Na_2O), with a density of 1.32 g/cm^3. Sodium hydroxide, made from 99% pure flakes, was mixed with the sodium silicate in a 3:1 weight ratio.Before being used in the concrete mix, the two chemicals were mixed carefully and left to sit for one day to improve their effectiveness.

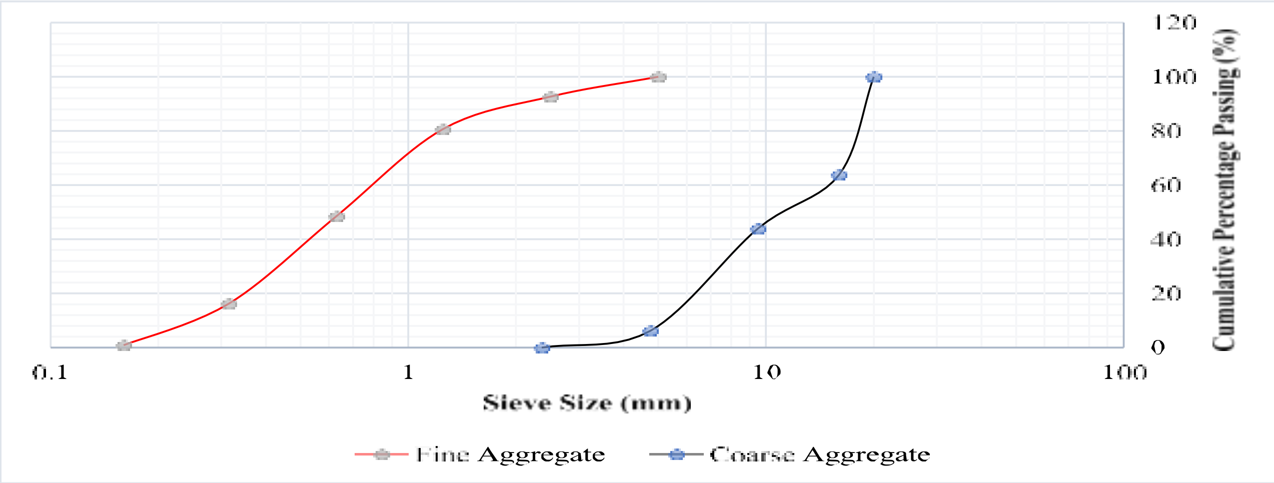

Fig 1.1 Findings and analysis

Activated Fly Ash Rcycled Aggregate Concrete

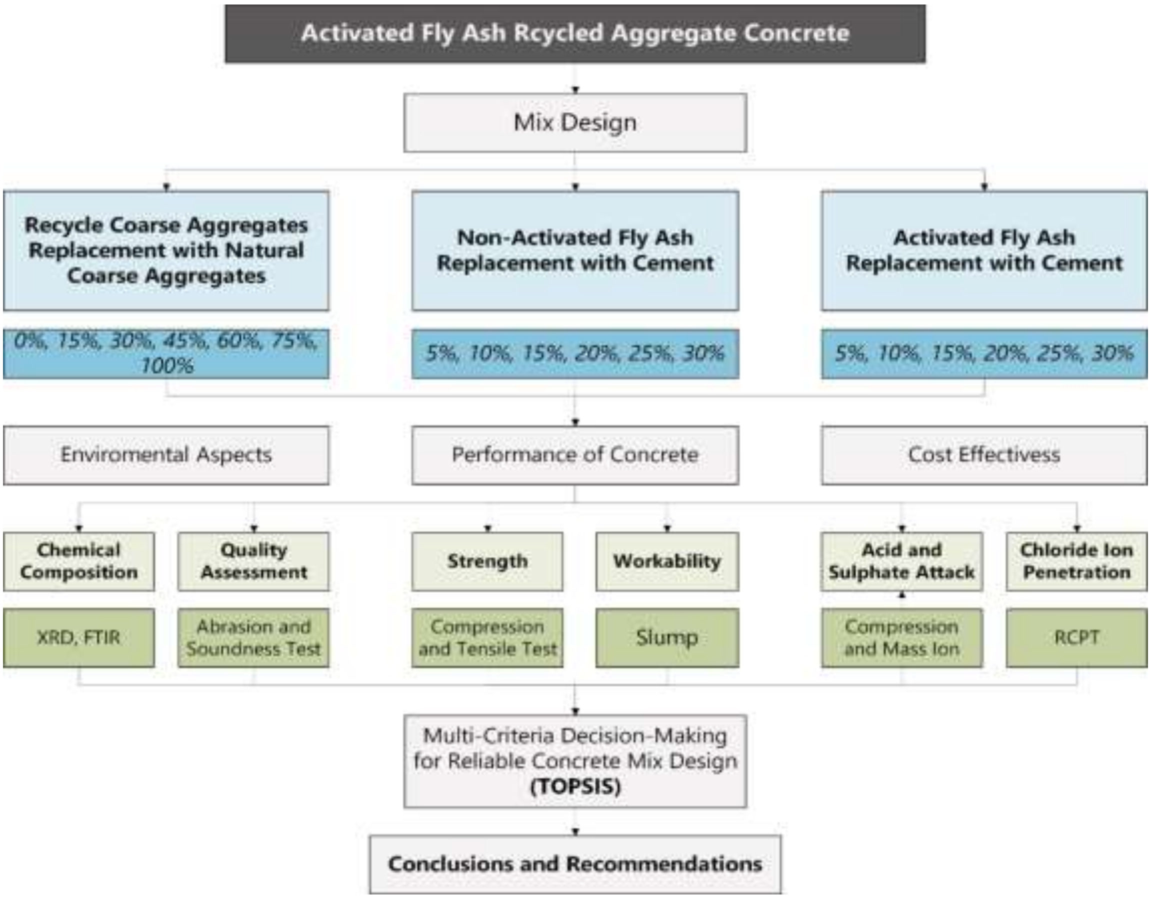

Fig 1.2 Activated Fly Ash Rcycled Aggregate Concrete

1.5 The Concrete advantages of a are listed below.

1 Fly Ash (Class F/C): Partial cement replacement (15–35%) for strength & durability gains

2 GGBS: Partial cement replacement (20–50%) to reduce heat of hydration

3 Recycled Aggregates: Replacing natural aggregates (20–50%) to promote circular construction

4 Workability & Strength: Slump, compressive strength, split tensile, flexural strength testing

5 Durability Testing: RCPT, water absorption, chloride penetration, sulphate attack resistance

6 Long-Term Behaviour: Shrinkage, creep, carbonation depth, and corrosion performance.

1.6 Objectives of the review

- To study the mechanical and durability properties of concrete made with fly ash, GGBS, and recycled coarse aggregates.
- To evaluate replacement levels of OPC and natural aggregates that retain or improve structural performance.
- To assess the carbon footprint reduction and embodied energy savings of blended mix designs.
- To develop design guidelines for structural-grade green concrete suitable for Indian conditions.

Chapter 2
LITERATURE REVIEW

2.1 General

A detailed review of literature has been done in order to assess and evaluate the earlier works done on the strength properties of basalt fibre reinforced concrete with filler materials and recycled aggregate. Literature based on the physical, mechanical, and chemical properties of concrete. From the detailed literature review, inference is studied.

2.2 Review of literature

1. R. Kamala et al. (2012) have studied the literature review on Reuse of Solid Waste from Building Demolition for the Replacement of Natural Aggregates. In this paper, the crushed tile aggregate has been used as partial replacement of convectional coarse aggregate in concrete making of cubes, cylinders, beams. Specimens were casted and tested for compressive strength, split tensile and flexural strength after a curing period of 7, 28, 56 days. But it is observed that the strength decreases from 50% replacement of coarse aggregate. The results show the effectiveness of crushed ceramic waste as partial replacement of conventional coarse aggregate up to 40 percent, without affecting the design strength.

2. Mohd Monish et al. (2013) have investigated on Demolished waste as coarse aggregate in concrete. The effect of partial replacement of coarse aggregate by demolished waste on workability and compressive strength of recycled concrete for the study at 7 and 28 days using experimental study. Three specimens each having 0%, 10%, 20%, and 30% demolished waste as coarse aggregate replacement for mix were cast and tested in order to have a comparative study. From this study, test results showed that the compressive strength of recycled concrete up to 30% replacement of coarse aggregate by demolished waste at the end of 28 days have been found to closer strength to the conventional concrete.

3. K. Ramadevi et al. (2017) have examined on Experimental study on strength properties of concrete with different aspect ratios of basalt fibre. In this paper, an attempt to predict the impact of basalt fibre in the design strength of M40 grade concrete. The concrete specimens are cast and tested for three different length of basalt fibre such as 16 mm, 19 mm and 24 mm are used for the fibre content of 1%, 2% and 3% to the volume of the concrete. From experimentally study, the variation of mechanical properties with the fibre length and optimum dosage of fibre content is found out. Finally result shows that using of higher fibre length increases in compressive strength, split tensile strength and flexural strength compared to plain concrete control specimen.

4. Patil Dinanjali et al. (2017) have investigated on Performance Evaluation of Basalt Fibre Concrete. The Experimental investigation on basalt concrete has been carried out to evaluate properties of basalt fibre concrete. The testing carried out on 24 concrete cubes for compressive strength, 12 numbers of cylinders was tested for split tensile test and 4 numbers of beams was teste for various percentage of fibre like 0, 0.25%, 0.50%, and 0.75%. Testing after 28 days average compressive, flexural, split tensile strength is maximum when 2% fibre is used. About 20% to 30% increase in strength is observed. From this study, it is concluded that use Basalt fibre in concrete is an effective technique to enhance performance of concrete.

5. Kiran Rayanagouda Police Patil et al.(2019) have evaluated on Experimental study on strength properties of concrete with partial replacement of cement by Alccofine & replace fine aggregate by m sand. From this study, strength properties of concrete by replacing cement by Alccofine partially. Different percentage of 5%, 10%, 15%. and 20% of Alccofine by volume of cement. The mechanical properties studied here are compressive strength on concrete cubes at 7 & 28 days of curing and flexural strength on beams at 7 & 28 days of water curing. It is observed from the result that the Alccofine material increases the strength to a large extent at 20% replacement level of cement and there is no reduction in mechanical strength properties by substituting river sand by m sand.

6. Swar Shah et al.(2018) have investigated on Strength and Durability study on Concrete with Alccofine as Cement Replacement. In this study, 20% cement replacement by Alccofine1203 Concrete of M30 Grade is prepared and compressive strength and flexural strength is measured. High Strength Concrete M60, M70, M80 is prepared with 5% cement replacement by Alccofine1203 addition to the M30 grade of concrete and compressive, flexural, split tensile strength is tested. From the experimental Work shows that Replacement of Cement by Alccofine is giving acceptable results. Hence the observed result shows that Alccofine is proper material which can use as partial replacement of cement.

7. Biseena M Kareem et al.(2019) have observed on Effect of Alccofine on Glass Fibre Reinforced Self Compacting Concrete. In this thesis discussed about the effect of Alccofine on the glass fibre reinforced self-compacting International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 02 | Feb 2020 www.irjet.net p-ISSN: 2395-0072 © 2020, IRJET | Impact Factor value: 7.34 | ISO 9001:2008 Certified Journal | Page 1198 concrete. Various percentages of cement are replaced by Alccofine in the glass fibre reinforced self-compacting concrete. Evaluated the fresh and strength properties and it is comparing with the normal glass fibre reinforced selfcompacting concrete. Addition of Alccofine to the glass fibre reinforced self-compacting concrete enhances its strength properties. Thus, the percentage level of Alccofine is increased more than 10 %, it acts as a filler material only and the strength gradually decreases by increasingthepercentageofAlccofine.

8. Malvika Gautam et al.(2017) have investigated on Effect of Alccofine on strength characteristics of Concrete of different grades-A Review. From the experimental study the result of Alccofine material increases the mechanical strength (both in compression and in flexure) to a large level at nearly 10% replacement level of cement have been observed. It is concluded that the 7 days compressive strength when compared between control mix and cement replaced

by 10 % Alccofine an increase in strength is observed. Thus, the result shoes that percentage level of Alccofine is increased beyond that level it acts as a filler material and yields good workability to the concrete.

9. K.Sathes Kumar et al. (2017) have examined on Strength and Analysis of Basalt Fibre in Concrete. In this study, mechanical strength such as compressive strength and flexural strength of M25 grade of concrete with basalt fibre and without basalt fibre are conducted to observe the strength .This paper provides data of fibre reinforced concrete containing fibres of 12mm length of various percentage such as 0.5%, 1%, 1.5%, 2% by weight of cement. Thus, strength increased for 0.5 and 1% and gradually decreased for the further percentages.

10. Fathima Irine I.A (2014) have studied on Strength Aspects of Basalt Fibre Reinforced Concrete. The aim of this paper is to investigate and compare the mechanical strength of basalt fibre reinforced concrete with plain M30 grade concrete. The cube, beam and cylindrical specimens have been casted with basalt fibre reinforced concrete containing 1kg/m3, 2kg/m3 and 4kg/m3 basalt fibre. The observed result shows that the failure pattern of the specimens and the formation of cracks is more in the case of concrete without fibres than the basalt fibre reinforced concrete. It is concluded that the presence of fibres in the concrete acts as the crack arrestors.

11. Abitha A. M et al.(2017) have evaluated on Properties of Concrete Incorporating Fly Ash and Basalt Fibre. In this study, performance of concrete with the addition of 0.1%, 0.15%, 0.3% and 0.45% chopped basalt fibre along with partial replacement of cement with 35% fly ash is consulted in the study. The experimental study specifies a lesser strength for fly ash concrete at the initial stage with an increasing trend at the future stage. The inclusion of basalt fibre accelerates the strength gain compensating the decrease in initial strength. In basalt fibre reinforced concrete, the failure pattern shows good bonding and crack resistance property of the fibre. Thus, the result concluded that combination of the two materials can create positive impacts in the construction industry.

12. Krishan Pareek (2019) have investigated on Effect of Recycled Aggregate on Mechanical and Durability Properties of Concrete . In this paper, an attempt is made to cumulate the various certainty and properties of cement with recycling waste. we observe that mechanical properties of concrete with recycled aggregate are slightly have lower strength to normal concrete. The mechanical properties like compressive strength, split tensile strength, flexural strength can be improved by using additives such as micro silica, GGBS & fly ash left subsequently burning coal and through appropriate surface treatment of RA and by using different mixing method such as dry mixing method. Finally, from the study it can be said that RA obtained from C & D waste must be considered as a sustainable material which is not only economic but environmentally friendly also.

13. Akshaykumar Moogi et al.(2018) have examined on an experimental investigation on strength and durability characteristics of basalt fibre reinforced concrete produced by partially replacing cement with fly ash and GGB. In this experiment effect of fibres and supplementary materials on the strength of concrete for M30 grade have been studied by keeping the constant percentage of basalt fibres and replacing 30% of the cement content by GGBS and fly ash in concrete. In this experiment 1.5% of total dosage of fibre content was fixed with Supplementary materials Fly ash

GGBS in varying percentages i.e. 0%FA-GGBS, 100%FA-GGBS, 25%FA75%GGBS, 50%FA-50%GGBS and 75%FA25%GGBS of total dosage (i.e.30%) by weight of cement. In this experiment it is also aimed to study the effect BFRC when subjected to sulphate attack. Results are taken after 90 days curing and 90 days of sulphate attack. The optimum supplementary material content while studying the strength parameters of all specimens is found 100%FA-0%GGBS." Hence 50%FA.

14. Rooba Chakravarthy et al. (2016) have investigated on Mechanical Properties of High-Volume Fly Ash Concrete Reinforced with Hybrid Fibres, Previous research efforts seem to have utilized a single type of fibre or two types of fibres. In this research work, three types of fibres such as steel, polypropylene, and basalt of varying percentage 0%, 0.50%, 0.75%, and 1% by volume of concrete, were mixed in varying proportions with concrete specimens substituted with 50% flash. Thus, the test results show the significant improvement in strength properties could be attained by a particular hybrid fibre reinforcement combination. when the fibre combination exceeded 3% then workability of concrete was affected. Thus, a limiting value for adding fibres and the combination achieve maximum strengths have been identified in this research.

Chapter 3

CONCLUSIONS

The main goal of this study was to reuse **Recycled Coarse Aggregates (RCA)** by replacing **Natural Fine Aggregates (NAFA)** and **Artificial Fine Aggregates (AFA)** in concrete. The idea was to test how strong and durable the concrete would be when RCA is used. A detailed plan was followed, and the study found some important results:**RCA has a big effect on durability**, especially on two tests: **soundness loss** and **micro-Deval abrasion loss** (which measure how well the material holds up over time)As the amount of RCA in the mix goes up, **both soundness loss and abrasion loss increase**, meaning the concrete becomes **less durable**.For **micro-Deval abrasion loss**:At **0% RCA**, the loss is **10.12%**At **60% RCA**, it rises to **19.40%**At **100% RCA**, it jumps to **28.89%**For **soundness loss**:At **0% RCA**, the loss is **9.1%**At **60% RCA**, it goes to **12.7%** At **100% RCA**, it reaches **13.8%** These results show that while RCA can be reused, it makes the concrete **less resistant to wear and damage**,Managing construction and demolition waste (CDW) in a smart way can help developing countries find valuable materials that can be reused for new projects. This not only saves money but also improves the well-being of communities. The study suggests a new idea—using recycled concrete (RCA) and fly ash from CDW. This shows a modern way to deal with waste that supports building in a greener, more sustainable way. It also helps lower carbon emissions and encourages responsible use of resources.This method supports the circular economy, which focuses on reducing waste, reusing materials, and helping the environment and economy at the same time. Using better waste management and sustainable building practices helps save resources and reduces harm to nature.This idea supports several Sustainable Development Goals (SDGs), such as:Better industry and infrastructure (Goal 9),Sustainable cities (Goal 11),Responsible use of resources (Goal 12),Fighting climate change (Goal 13),Protecting land and nature (Goal 15) .Together, these efforts can help create a cleaner, more sustainable future.

References:

[1]. Ahmad W, Ahmad A, Ostrowski KA, Aslam F, Joyklad P. A scientometric review of waste material utilization in concrete for sustainable construction. Case Stud Constr Mater 2021;15:e00683

[2]. Assi LN, Carter K, Deaver E, Ziehl P. Review of availability of source materials for geopolymer/sustainable concrete. J Clean Prod 2020;263:121477.

[3]. Bakkali H, Ammari M, Frar I. NaOH alkali-activated class F fly ash: NaOH molarity, curing conditions and mass ratio effect. Constr Build Mater 2016;126:34–42. https://doi.org/10.1016/j.conbuildmat.2016.09.079

[4].Mustapha Fouaidi, Abdellah Hamdaoui, Mohammad Jamal, Bouazza Braikat (2018) : **"A high order mesh-free method for buckling and post-buckling analysis of Engineering Analysis with shells"**

[5]Ismail AJ, Younis KH, Maruf SM. Recycled aggregate concrete made with silica fume: experimental investigation. Civ Eng Archit 2020;8:1136–43. https://doi.org/ 10.13189/cea.2020.080540.

[6] Shehata N, Mohamed OA, Sayed ET, Abdelkareem MA, Olabi AG. Geopolymer concrete as green building materials: recent applications, sustainable development and circular economy potentials. Sci Total Environ 2022;836:155577

[7] Wiley & Sons, 2023. https://books.google.com/books?hl=en&lr=&id=S0G0EAAAQBAJ&oi=fnd&pg=PR11&dq=rapid+urbanization+and+concrete+materials&ots=xoTmEDX8wD&sig=5fJ822u4o5J-8X7p8NLqrrx58dY (accessed May 1, 2024).

[8] Abdumo'minov O, Rajabov R. Prospects for construction materials production. Int Bull Eng Technol 2023;3:23–7.

[9] Christensen TB, Johansen MR, Buchard MV, Glarborg CN. Closing the material loops for construction and demolition waste: the circular economy on the island Bornholm, Denmark. Resour Conserv Recycl Adv 2022;15:200104.

[10] Kabirifar K, Mojtahedi M, Wang C, Tam VW. Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: a review. J Clean Prod 2020;263: 121265.

[11] Nawaz MA, Ali B, Qureshi LA, Aslam HMU, Hussain I, Masood B, et al. Effect of sulfate activator on mechanical and durability properties of concrete incorporating low calcium fly ash. Case Stud Constr Mater 2020;13:e00407.

[12]. Jiao Z, Li X, Yu Q, Yao Q, Guan X, Hu P. Chloride resistance of class C/class F fly ash-based geopolymer mortars with different strength grades. Case Stud Constr Mater 2023;18. e01811.