



# Effect of Rice Husk Ash (RHA) and Slag as Partial Replacement of Cement on Reinforced Concrete Slabs

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## Authors' contributions

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

## Article Information

DOI: 10.9734/JERR/2021/v20i1117403

### Editor(s):

(1) Dr. Guang Yih Sheu, Chang-Jung Christian University, Taiwan.

### Reviewers:

(1) Shan Hua-feng, Taizhou University, China.

(2) Ruinian Jiang, New Mexico State University, USA.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/71788>

Original Research Article

Received 20 May 2021  
Accepted 27 July 2021  
Published 02 August 2021

## ABSTRACT

The increasing demand and consumption of cement have necessitated the use of slag, fly ash, rice husk ash (RHA), and so forth as a supplement of cement in concrete construction. The aim of the study is to develop a replacement of the cement with rice husk ash and slag combined with chemical activator. NaOH, Ca(OH)<sub>2</sub>, and KOH were used in varying weights and molar concentrations. Partial replacement of cement was tested for its consistency, setting time, flow, compressive strength, and fire. The consistency and setting time of the Partial Z-Cement (Zero cement) paste increase with increasing RHA content. The replacement of cement mortar achieves a compressive strength of 22–25MPa at 28 days with 5% NaOH or at 2.5 or non used activator molar concentrations. The tested slabs were made of concrete and reinforced with bars with 10 mm diameter having and compressive strength evaluated from the compressive tests. The analysis of the slab deflection behavior has been presented after fire of samples. The results show the different character of the load-deflection relationship of a replacement of the cement with rice husk ash and slag reinforced slabs compared to traditionally reinforced slabs.

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**Keywords:** Reinforced concrete slabs; replacement of the cement; rice husk ash; slag.

## 1. INTRODUCTION

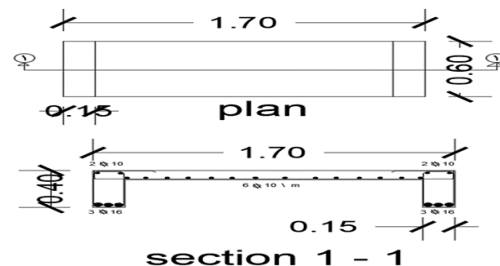
Cement and concrete are important materials for rapid urbanization. Concrete is considered as one of the key elements in the social, economic, and infrastructural development of human society. Ordinary Portland cement- (OPC-) based concrete is one of the significant construction materials in the globe. Up to now, we are still dependent on cement and concrete for the construction of many infrastructures such as buildings, towers, roads, bridges, flyovers, tunnels, industries, and river training works. Approximately 25 billion tons of concrete are produced and consumed annually all over the world. Cement consumption increased to 2.9 billion tons globally in a year and is predicted to increase to 4.5 billion tons by 2021 [1-2]. The manufacture of conventional Portland cement (PC) based High energy demands (requires 4GJ), greenhouse costs and Emissions from gases (13,500 million annually) For greenhouse gases, release of approximately 5–7% of the total CO<sub>2</sub> emissions In the future, it will increase by 50 per cent from current levels. The Building Portland cement industry demand could rise to \$5.6 billion metric tonnes in 2021 which is perceived to be unsustainable [3-6]. Huge quantities of pozzolanic materials are regularly produced as wastes in every part of the world. All of these pozzolanic wastes are usually discharged into ponds, rivers, and lagoons without any commercial return. For instance, slag is a pozzolana generated as industrial by-product from steel industries. Approximately 100 million tons of slag is produced annually worldwide. However, only 35 million tons of slag is used and the rest is disposed [7]. RHA is generated as a waste from rice-processing mills. Approximately 110 million tons [8]. Pozzolans were used as partial placement of cement in most of the past research. Some studies were conducted on the production of geopolymer concrete [9-12]. Several researchers have reported the studies on the mechanical strength as well as microstructural properties of concrete incorporating ultrafine materials as additives, but the prevalence of hybrid rice husk ash-ultra fine slag (RHA-UFS) geopolymers have not been reported yet. The current research is aimed to address the issue of environmental sustainability by utilizing rice husk as a primary aluminosilicate source in the development of geopolymer concrete. Ultrafine slag is used as a source of calcium as a partial replacement of RHA in

geopolymer paste. Properties like compressive strength, water absorption, percentage permeable voids, and permeability are assessed through a wide-ranging experimental program [2], The safe disposal or utilization of such waste byproducts from the industries and agriculture tends to be an interest in research [13]. The main objectives of this study are investigate and to better understand the behavior of slab with replacement of the cement with rice husk ash and slag under flexural loading after fire the specimens through an experimental. As well as Provide recommendations and guidelines for the designers and researchers regarding the analysis and design of reinforced slaps under partial replacement of cement.

## 2. RESEARCH PROGRAM

### 2.1 Specifications of Test Specimens

The experimental program includes 102 cubes dimension 150 mm x 150 mm x 150 mm, and six R.C. one way solid slab dimensions (1650 mm x 600 mm) with two beam at end rectangular cross-section, sized 150 mm (width) x 400 mm (height) x 600 mm (length) show in Fig. 1. The parameters which were considered in this study; are replacement of cement with rise husk ash and slag content , fire and cooling. The cubes were divided into fourteen mixes each mix consisted of six cubes and two mixes consisted of nine cubes on one mix.



**Fig. 1. Details of Typical Specimen**

### 2.2 Material Properties

This part presents a summary for the properties of used materials in this research. The used materials were tested in order to investigate their properties. A summary for the properties of the materials used and the mix design for the tested slabs is presented. The Materials used in casting and reinforcement of the tested slabs were:

aggregates (0.8 m on m<sup>3</sup>), sand (0.4 m on m<sup>3</sup>) cement (350Kg on m<sup>3</sup> divided to 70% OPC, 15% R.H.A, 15% slag , water ( 0.5 w/c), reinforcing steel(6Ø10/m on slab 3Ø16 on beams grade 36/52, and NAOH(5% from weight of cement). The process of manufacturing was simulated as closely as the common way of practice of concrete construction. The obtained results were compared with the limits recommended by the local specifications or codes of practice. The characteristics of the materials used in this research were discussed in the following sub-sections.

### 2.3 Test Setup, Instrumentation and Loading

The beams were tested under one-point bending load, as shown in Fig. 2. The load was applied through a 1000 KN MTS actuator at a stroke-controlled rate of 1.2 mm/min. Fig. 1 provides a schematic illustration of the test setup. The displacement was monitored with three linear variable differential transformers (LVDTs); one was placed at the midspan and two were placed at quarter- span from left and right side. During the test, the beam cracking patterns were marked visually, and their corresponding loads were recorded.

The tests were conducted in the structural engineering faculty of the Civil Engineering Laboratories in faculty of Engineering El-Materia, HELWAN UNIVERSITY.

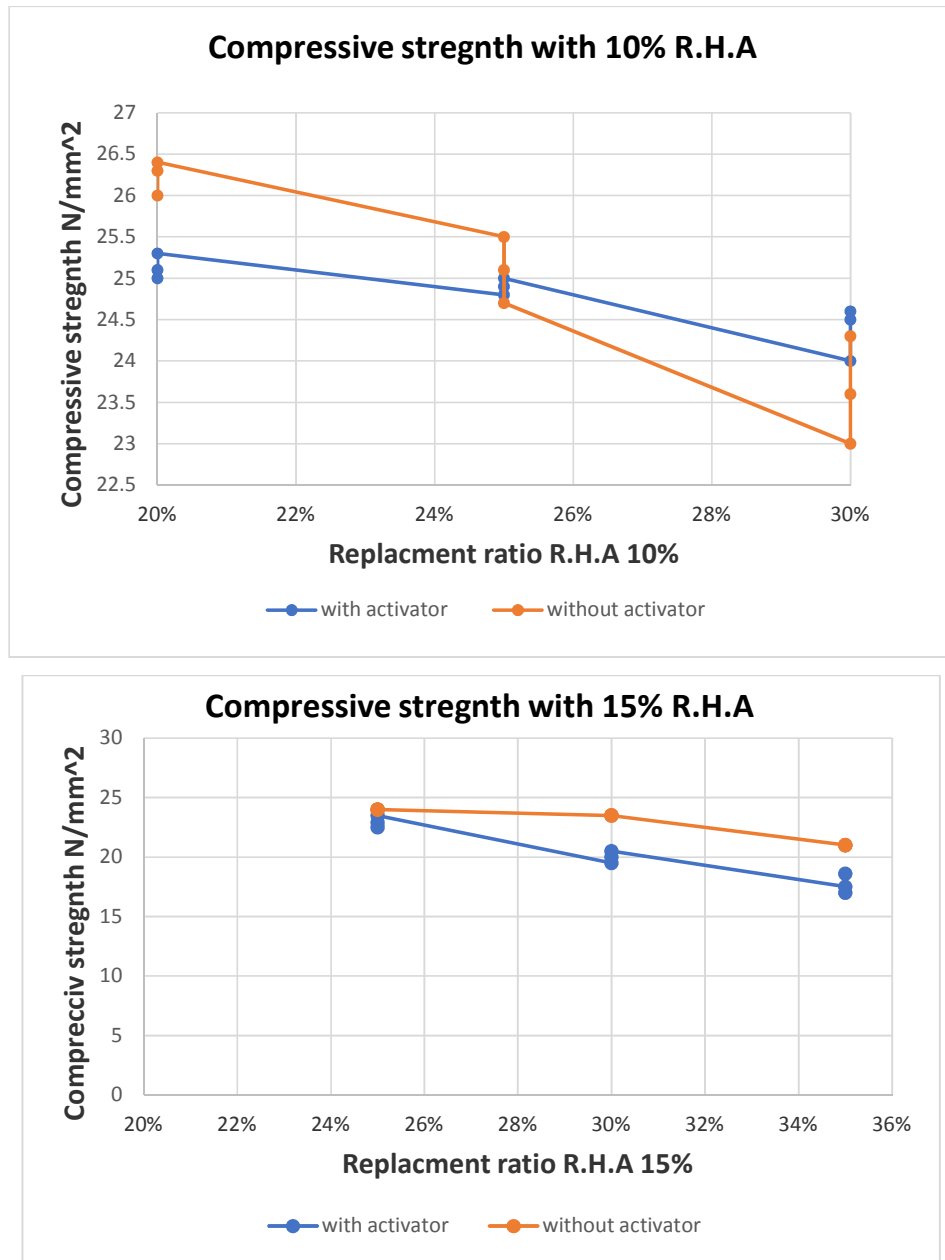
### 3. RESULTS AND DISCUSSION

In all mixes, the compressive strength decreased with increasing the R.H.A and slag ratio about 30 %. Fig. 3 up to 10% Maximum compressive strength at age of 28 day was 26N/mm2 with replacement of cement in the rate of 10% R.H.A and 10% slag without activator (for mix w/c=0.5 & cement%=80) whereas the lowest compressive strength was 18 N/mm2 with replacement of cement in the rate of 15% R.H.A and 20% slag with activator (For mix: w/c=0.5 & cement%=65)

From Fig. 4 it can be seen that the failure load was equal to 35 kN for 100% cement, 35.7 kN for replacement of cement 30% (15% R.H.A, 15% slag) and. The failure load was increased by 1% compared to the slab without replacement. Also it was found that the deflection at Maximum load was equal to 35.5 mm for 100% cement, 19.8 mm for replacement of cement 30% (15% R.H.A, 15% slag). The deflection decreased by 44 %. Hence, it can be said that the geopolymer RC slabs are ductile than beams without geopolymer. From Fig. 4, it was found that by using geopolymer, the cracks width generally decreased. Also, the number of cracks was decreased by adding geopolymer ratio equal to 5 %. The failure mode for RC tested specimens did not change. It can be seen that by adding geopolymer the number of cracks and the crack width change.



Fig. 2. Test setup and slabs under testing



**Fig. 3. Relationship between compressive strength and replacement ratio after 28 days**  
*Group 1 (Flexural failure-No fire)( control specimens)*

Fig. 5 shows that the failure load was equal to 32.5 kN, 27.2 kN and 26.5 kN for S4 with fire 0.5 Hr, S5 with fire 1 Hr and S6 with fire 1.5 Hr, with replacement equal to 15%R.H.A, 15% slag. The failure load decreased with increase time of fire. And also it was found that the deflection was equal to 27.03 mm, 27.55mm, and 18.36mm for S4, S5 and S6 respectively. The deflection decreased by 33 % after 0.5 Hr fire. Fig. 5 shows that the failure mode for all slabs remained

flexural mode, and by addition geopolymer the number of crakes through the cover at the tension side decreased and the crack width decreased.

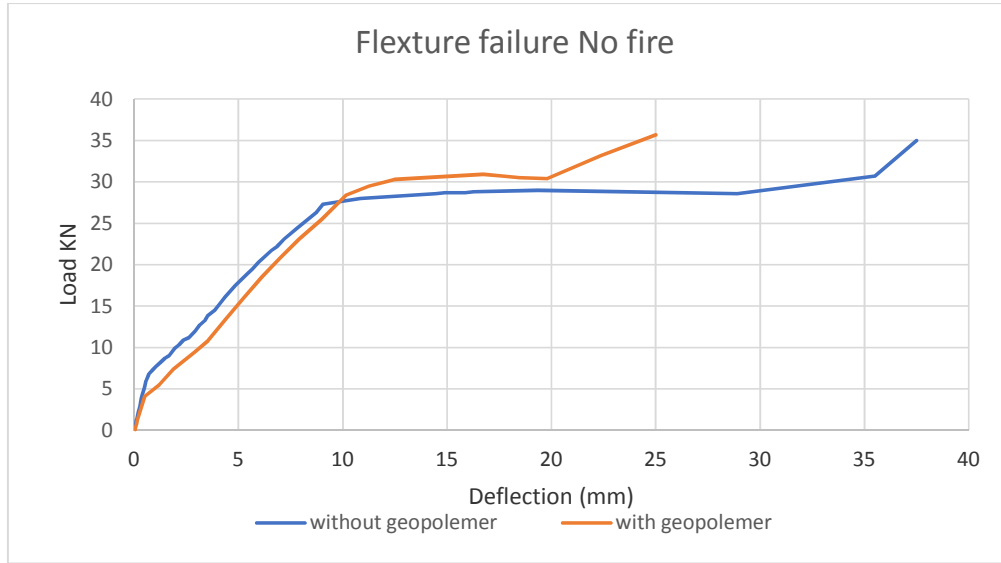
Fig. 6 shows that the failure load was equal to 33.2 kN with 100% cement and 15 Hr fire for S3, 26.5 kN with geopolymer and 1.5 Hr fire for S6. The failure load decreased with use geopolymer. And also it was found that the deflection was

equal to 23.04 mm for S3, 27.55mm, and 18.36mm for S6. The deflection decreased by 30 % with geopolymer after 1.5 Hr fire .

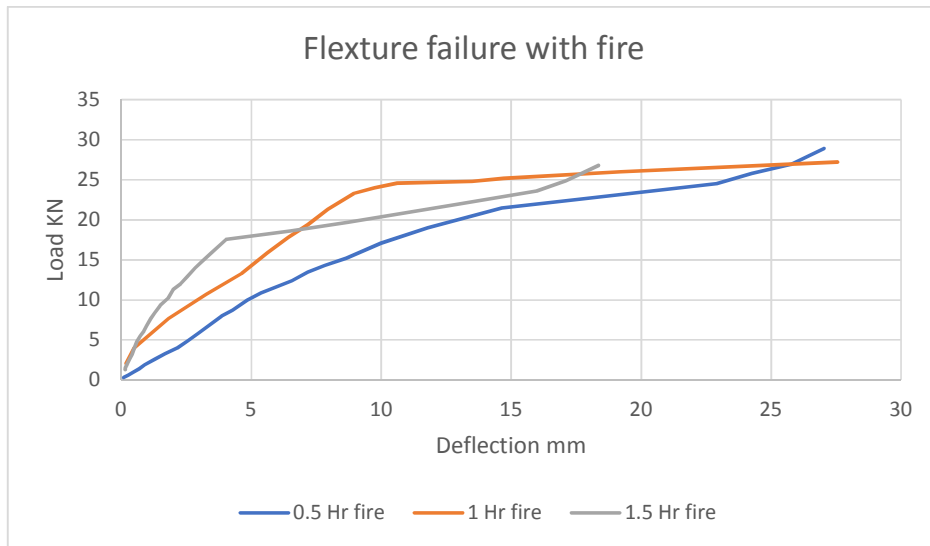
Fig. 6 shows that the failure mode for all slabs remained flexural mode, and by addition geopolymer the number of crakes through the cover at the tension side decreased and the crack width decreased.

Table 1. Represent a comparison between Comparisons between the Experimental Results with theoretical equations of different Codes.

Compare results illustrate how closely the values of laboratory test results with theoretical results. We find that the results of equations Egyptian Code closer to the results of laboratory tests of the results of the ACI Code.



**Fig. 4. Effect of geopolymer ratio on Load Deflection Curve for slabs flexural failure mode and No Fire**  
*Group 2 (Flexural failure-with fire Cooling by Water)*



**Fig. 5. Effect geopolymer ratio on Load Deflection Curve for slabs Flexural failure-with fire Cooling by Water**  
*Group 3 (Flexural failure-with fire Cooling by Water)*

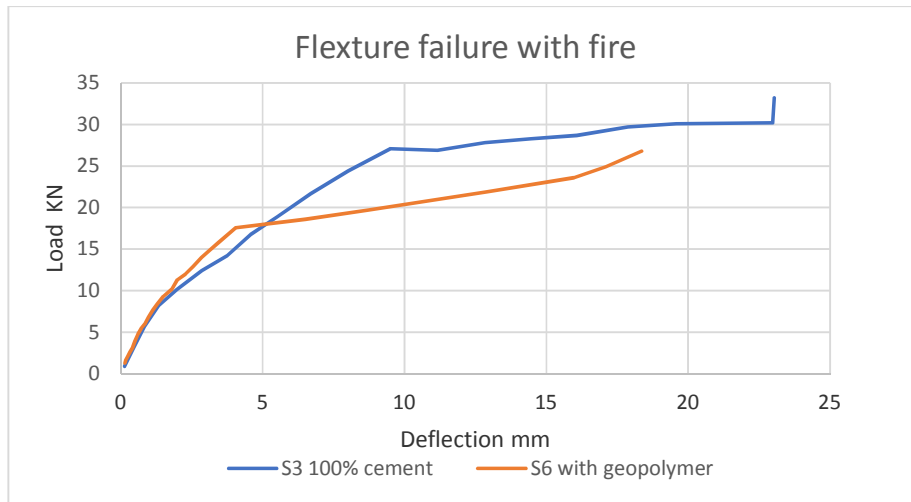


Fig. 6. Effect of geopolymer ratio and control slab with 100% cement on Load Deflection Curve for slabs With flexural failure mode, Fire and Cooling by water

Table 1. Comparison the Experimental Results with Code Values

Beam no.	Fcu MPa	Exp. Results (kN)	ACI Code		Egypt Code	
			Load (kN)	Ex/ACI	Load (kN)	Ex/Egy.
S1-1-0%-C	25	35	24.4	1.43	24.9	1.4
S2-1-30%-C	24.5	35.7	24.37	1.46	24.878	1.435
S3-1-0%-H	22.5	33.2	24.22	1.37	24.71	1.34
S4-2-30%-H	23.76	28	24.3	1.18	24.79	1.16
S5-3-30%-H	23.27	27.2	24.25	1.21	24.76	1.109
S6-4-30%-H	22.05	26.5	24.1	1.21	24.6	1.07

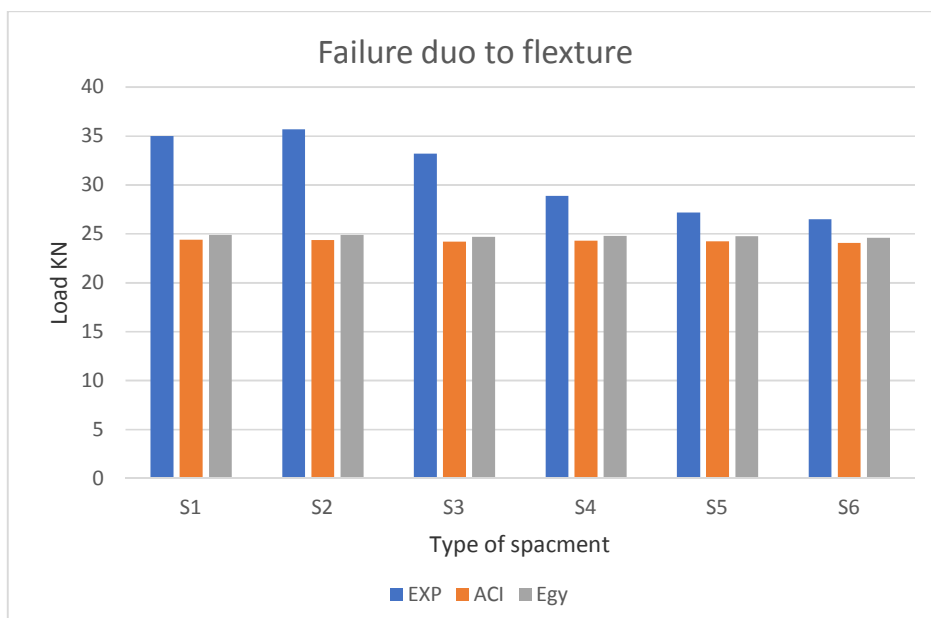


Fig. 7. comparison the experimental results with the code results



## 5. CONCLUSION

The following conclusions can be drawn from conducted experimental and Analytical studies:

### Compression Strength

1-In all concrete mixtures compressive strength increased with decreasing geopolymer% ratio from 100% to 30% by cement weight with water cement ratio (0.5). the optimum ratio of geopolymer in concrete equal 30% by cement weight with water cement ratio(w/c) 0.5.

2-For specimens without geopolymer which were exposed to fire and cooling by water the failure load decreased by average 5%, compared with the referential slab.

3-For specimens containing geopolymer which were exposed to fire and cooling by water the failure load decreased by average 34%, compared with the referential slab. And The ductility in case of cooling by water higher.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:

The peer review history for this paper can be accessed here:  
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