شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

# بسم الله الرحمن الرحيم

HANAA ALY

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# جامعة عين شمس

## التوثيق الإلكتروني والميكروفيلم

## قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات

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تحفظ هذه الأقراص المدمجة بعيدا عن الغبار

***HANAA ALY***

**Ain Shams University**
**Faculty of Engineering**
**Structural Engineering Department**

# Mechanical Characteristics of Ambient Cured Alkali-Activated Slag Concrete Exposed to Elevated Temperature

**By**

**Ismail Ahmed Mohamed Amer**

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**A Thesis**

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of Doctor of Philosophy in Civil Engineering
(Structural Engineering)

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## STATEMENT

This thesis is submitted to the Faculty of Engineering, Ain Shams University, as a partial fulfillment for the degree of Doctor of Philosophy in Civil Engineering (Structural Engineering). The work included in this thesis was carried out by the author, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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# PUBLICATIONS ARISING FROM THIS THESIS

1. I. Amer, M. Kohail, M. S. El-Feky, A. Rashad, and M. A. Khalaf, "A review on alkali-activated slag concrete," Ain Shams Eng. J., vol. 12, no. 2, pp. 1475–1499, 2021. https://doi.org/10.1016/j.asej.2020.12.003

2. I. Amer, M. Kohail, M. S. El-Feky, A. Rashad, and M. A. Khalaf, "Characterization of alkali-activated hybrid slag/cement concrete," Ain Shams Eng. J., vol. 12, no. 1, pp. 135–144, 2021. https://doi.org/10.1016/j.asej.2020.08.003

3. I. Amer, M. Kohail, M. S. El-Feky, A. Rashad, and M. A. Khalaf, "Evaluation Of Using Cement In Alkali-Activated Slag Concrete," Int. J. Sci. Technol. Res., vol. 9, no. 5, pp. 245–248, 2020. http://www.ijstr.org/paper-references.php?ref=IJSTR-0620-36892

**AIN SHAMS UNIVERSITY**
**FACULTY OF ENGINEERING**
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Abstract of the Ph.D. Thesis Submitted by
Ismail Ahmed Mohamed Amer

# ABSTRACT

Concrete manufacturing is believed to be one of the major contributors to global warming, and this is mainly attributed to the use of Portland cement as a binding material. Cement industry is thought to be responsible for about 8% of global $CO_2$ emission. To reduce the environmental impact of concrete manufacturing, efforts are still going on to find alternatives to Portland cement. Alkali-activated material, a new environmentally friendly inorganic binder derived by alkaline solution activating alumino-silicate source material (such as slag, fly ash and metakaolin), has attracted significant attention in recent years as a practical alternative to Portland cement. In addition to efficient use of industrial by-product, using alkali-activated material as a binder greatly reduces greenhouse gas, $CO_2$ emissions and energy requirements during its manufacturing.

During the last few years, many studies were conducted over the world to investigate different physical and mechanical characteristics of Alkali-Activated Concrete (AAC) in order to introduce it as an alternative to the traditional Ordinary Portland Cement (OPC) concrete. Most of these studies were conducted on paste and mortar not on concrete and very limited studies used the ambient curing condition for concrete. Moreover, the use of Ground Granulated Blast Furnace Slag (GGBFS) alone as a binder and as a fully replacement for OPC in concrete was rare; therefore, more studies for Alkali-Activated Slag Concrete (AASC) are still required.

This research work was carried out to investigate experimentally and analytically physical, mechanical and bond characteristics of AASC and compare them with those of similar Conventional Concrete (CC) at ambient temperature and after exposure to elevated temperatures.

***Three main phases are included in this research work:***

***The first phase*** studied the efficiency of utilizing the hybrid cement (OPC + GGBFS) to produce AAC at ambient curing conditions considering the effect of four important parameters (GGBFS to OPC ratio, $Na_2O$ ratio, solution modulus "Ms" and water to binder ratio "W/B") on both workability and compressive strength using Taguchi method. Microstructure analysis using Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectroscopy (EDS) was performed to investigate the polymerization products. Test results have showed that using alkali activator with hybrid cement (GGBFS + OPC) cannot be considered an effective method to produce AAC due to the very low workability obtained. On the other hand, using GGBFS only as a binder material was effective enough to produce AAC with high compressive strength and suitable degree of workability at ambient curing conditions.

***The second phase*** investigated mechanical and physical characteristics of ambient cured AASC after exposure to elevated temperatures. The effect of temperatures (25, 300, 600 and 900 °C) on the ambient cured AASC and on a similar CC (for a comparison purpose) was investigated by observing the physical and mechanical changes. The effect of using polypropylene fibers on both AASC and CC was also investigated. Test results have showed that the

AASC has achieved higher mechanical properties than similar CC at ambient temperature. Results also have showed that the AASC has a higher resistance to elevated temperatures than the CC due to higher resistance to spalling and cracking. Also, the AASC recorded higher residual mechanical properties after exposure to elevated temperatures.

***The third phase*** was designed to investigate experimentally and analytically the bond behavior between AASC and steel rebars considering some important parameters (rebar diameter and development length to diameter ratio) before and after exposure to elevated temperatures using beam-end bond testing technique. An analytical study was carried out to compare the experimentally obtained results with those obtained from the well-known available equations in the literature and also in the CEB-FIP model code for concrete structures. A modified model was proposed to predict the bond behavior of AASC. Comparison between results calculated from both models (the proposed modified model and the CEB-FIP model) with the experimental results has showed the following:

- The CEB-FIP model provides more conservative values of bond strength than the experimental results which increase the safety level when estimating bond strength for AASC in design purposes.
- The proposed modified model achieved a higher correlation with the experimental results than the CEB-FIP model at ambient temperature.

**Keywords:** Alkali-Activated Concrete, GGBFS, Alkali Activation, Solution Modulus, Ambient cured, Taguchi method, Mechanical Characteristics, Bond Behavior, Polypropylene Fiber, Elevated Temperature, Beam-end bond testing technique

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