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2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM



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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
Ms. Rozaina Saleh

ISETC 2025 Proceedings Editors

THE STUDY OF PHYSICAL, MECHANICAL, DURABILITY AND BONDING CHARACTERISTICS OF GRAPHENE OXIDE-ENHANCED GEOPOLYMER MORTAR FOR SUSTAINABLE REPAIR APPLICATIONS

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Abstract: This study investigates the bonding performance of geopolymer mortar with graphene oxide (GO) nanoparticles. Mortars were made by replacing 60% of Class F fly ash with steel slag and adding GO at 0–0.10% by binder weight. Water-to-binder (w/b) ratios of 0.10 and 0.20 were also tested. The effects on flowability, compressive strength, and bi-surface shear strength were evaluated. GO improved compressive strength at both early and late ages. The G1-GO0.04 mix had the highest strength—69.32 MPa (7 days) and 72.36 MPa (28 days). The G1-GO0.06 mix (0.06% GO, 0.10 w/b) showed the highest shear bond strength of 7.60 MPa, an 84% increase over the control. GO up to 0.06% also reduced chloride ion permeability. Mixes with 0.06% GO and both w/b ratios had the lowest values. GO addition made the geopolymer matrix denser and reduced porosity. In summary, low GO dosages and reduced w/b ratios significantly enhanced mortar performance in terms of flowability, strength, bond, and durability.

***Keywords*:** *Geopolymer, repair, bonding, graphene oxide.*

INTRODUCTION

Geopolymer materials present a promising alternative to traditional cement-based materials, offering notable advantages in severe environmental conditions. These materials are also considered more sustainable, contributing to the reduction of greenhouse gas emissions. However, the mechanical and physical properties of geopolymers can be significantly affected by environmental factors, such as sulfate attack. As noted by Altawil and Olgun (2025), a low water-to-geopolymer binder ratio (around 0.35) facilitates the activation of the alkali in the mix and accelerates the geopolymerization process. The water-to-binder ratio (w/b) is a critical factor influencing the effectiveness of geopolymer mortar, affecting its strength, porosity, and workability. To optimize these properties, nanomaterials have been explored as potential nano-reinforcements to enhance the microstructure while reducing water content. According to Arpitha and Parthasarathy (2023), nanomaterials can modify the microstructure of geopolymers, improving their toughness even at lower concentrations. These materials influence the reaction process and refine the pore structure, contributing to improved mechanical strength and durability. GO, an advanced inorganic material, has three primary effects: nucleation, bonding, and filling (Apandi et al., 2023; Anwar et al., 2020; Zailani et al., 2024). These properties can address the weaknesses of geopolymer composites, potentially surpassing the performance of conventional Portland cement (OPC) composites. While extensive studies on nanomaterials in cement-based materials exist, the impact of graphene oxide in geopolymers requires further investigation. GO's high filling capacity and aspect ratio contribute to reducing the size of gel capillaries and increasing the microstructure's density (Zaid et al., 2022). GO has been used in two physical forms: powder (pure) GO, and liquid (aqueous) GO. The dispersibility, homogeneity, consistency, and overall properties of the composite are influenced by the rheological properties of both forms (Shamsol et al., 2024). Liquid GO, which has a higher dispersibility, is generally used in larger concentrations compared to powder GO (Bellum et al., 2020), and exhibits improved dispersibility (Ho et al., 2021).

This study aims to further investigate the influence of graphene oxide (GO) on geopolymer mortar, focusing on the effects of varying water content. The goal is to improve the performance and sustainability of geopolymer-based repair

materials, with a particular emphasis on flowability, compressive strength, rapid chloride permeability test, and bonding strength.

MATERIALS AND METHODS

The materials used in this study for producing GO-modified geopolymer mortar (GO-GPM) include steel slag (SL), class F fly ash (FA), graphene oxide (GO), alkaline activator solutions, and fine aggregates. In this investigation, geopolymer mortar is evaluated as a repair material for concrete substrates, with its flowability, compressive strength, bi-shear bond strength, rapid chloride permeability being the primary performance indicators.

This study evaluated flowability, compressive strength, bi-surface shear bond strength, and rapid chloride permeability of GO-GPM. The flowability of fresh GO-GPM was evaluated according to ASTM C1437. The compressive strength of CS and GO-GPM was tested at 7-, 14-, and 28-days following ASTM C109. To examine the bond between the CS and GO-GPM as a repair material, the bi-surface shear method was chosen due to its simplicity and lack of need for specialized equipment. Standard 150 mm cubic samples were prepared in accordance with ASTM C39. The Rapid Chloride Permeability Test (RCPT) was performed by casting the freshly mixed mortar into cylindrical molds with a diameter of 100 mm and a height of 200 mm, as specified by ASTM C1202.

RESULTS AND DISCUSSION

Flowability

The flowability results for graphene oxide-modified geopolymer mortar (GO-GPM), with GO powder concentrations of 0%, 0.02%, 0.04%, 0.06%, 0.08%, and 0.10%, and different w/b ratios (G1: 0.10; G2: 0.20), are presented in Figure 1. Due to the hydrophilic functional groups and high specific surface area of GO, it tends to absorb water, reducing the amount of free water available for diffusion. This phenomenon is further confirmed by the data in Figure 3. However, the inclusion of additional water in the mixture significantly enhances flowability, with the highest flowability observed at a w/b ratio of 0.20. The control mix exhibited a flowability of 153 mm, indicating poor flowability. Among the modified mixtures, G1-GO0.04 and G2-GO0.10 demonstrated a 30% improvement in flowability, falling within an acceptable workability range and making them the most optimal mixtures in this test. In conclusion, a conventional water-based system is preferable for achieving better flowability than an alkaline activator without water. The optimal mixture depends on balancing the activator and GO, as GO's inclusion continues to reduce flowability.

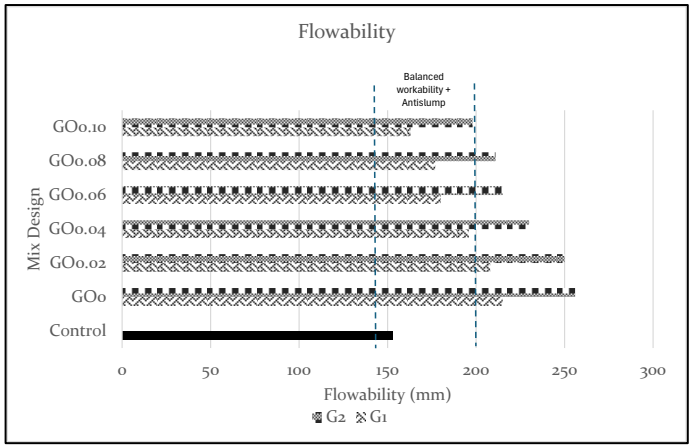
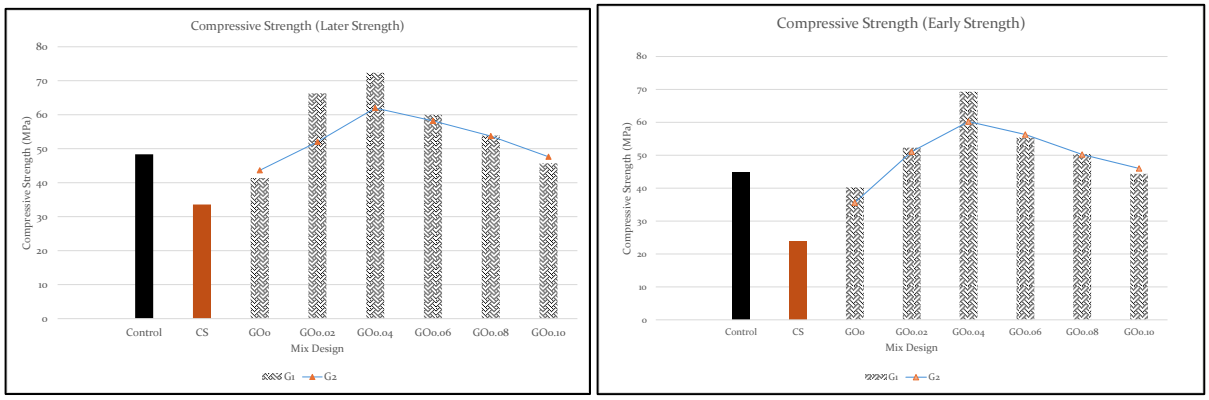


Figure 1. Results of Flowability Test

Compressive Strength

The compressive strength results for graphene oxide-modified geopolymer mortar (GO-GPM) with GO powder additions of 0%, 0.02%, 0.04%, 0.06%, 0.08%, and 0.10%, as well as concrete substrate (CS), at 7 days (early strength) and 28 days (late strength), are shown in Figure 2 (a) and Figure 2 (b), respectively. The inclusion of GO enhanced the compressive strength of geopolymer mortar at both early and later ages. The best performance was observed in the G1-GO0.04 mixture, which achieved compressive strengths of 69.32 MPa at 7 days and 72.36 MPa at 28 days. The addition of graphene oxide in geopolymer concrete improves compressive strength at early ages by acting as a mechanical filler, leading to a denser structure (Bellum et al., 2020). At a water-to-binder ratio of 0.2 and 0% graphene oxide (G2), the compressive strength decreased by 17.14% at 7 days and 9.06% at 28 days compared to the control mixture, which had no added water and 0% graphene oxide.



(a) (b)

Figure 2. Results of Compressive Strength (at (a) Early Age, and (b) Later Age)

Bi-Surface Shear Bond Strength

Figure 3 presents the bi-surface shear bond strength results at 28 days for all the samples. The bi-surface shear bond strength between the concrete substrate and GPM samples ranged from 4.22 MPa to 7.60 MPa for mixtures with a water-to-binder ratio (w/b) of 0.10 (G1), which is higher than the typical bond shear strength of common repair materials. For mixtures with a w/b ratio of 0.20 (G2), the bond strength was lower compared to the G1 samples for each graphene oxide (GO) percentage of 0.02%, 0.04%, and 0.06%. However, the inclusion of GO dosages of 0.00%, 0.08%, and 0.10% in G2 samples resulted in an increased bond strength compared to G1 samples for each respective GO dosage, although the highest bond strength of G1 samples was not surpassed. It was observed that the surface shear bond strength improved when lower dosages of GO were used with a lower w/b ratio of added water.

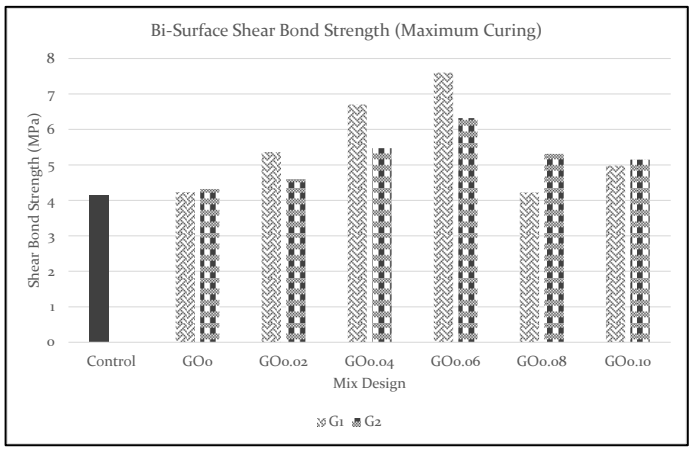


Figure 3. Results of Bi-Surface Shear Bond Strength at Later Age

Rapid Chloride Permeability Test (RCPT)

Figure 4 presents the results from the Rapid Chloride Permeability Test (RCPT). The data indicate that the addition of graphene oxide (GO), up to a concentration of 0.06%, generally reduces chloride ion permeability. The lowest chloride permeability values were observed at this GO concentration for both mixtures with water-to-binder (w/b) ratios of 0.1 and 0.2. Notably, the G1 mixture demonstrated a more significant reduction in chloride permeability with GO incorporation compared to G2, particularly at GO concentrations of 0.04% and 0.06%. At these concentrations, the RCPT values recorded were 1863 Coulombs and 1469 Coulombs, respectively, which are considered moderate according to ASTM C1202. These results suggest that the G-1FA60SL matrix benefits more from the densifying effect of GO.

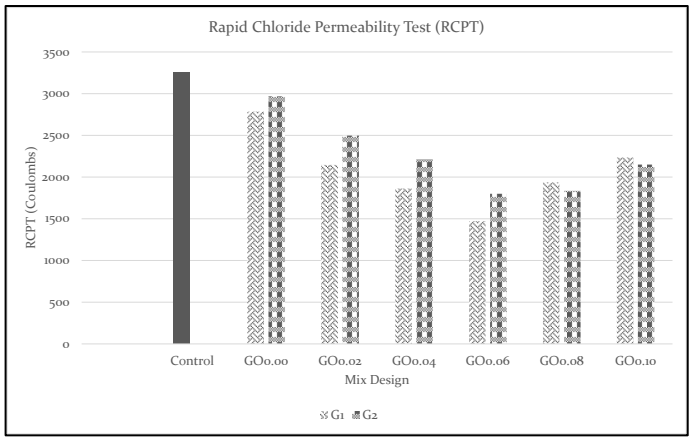


Figure 4. Results of Rapid Chloride Permeability Test

CONCLUSIONS

In conclusion, all the properties tested are significantly influenced by the addition of GO and water content, even in the absence of exceptional adhesion techniques or surface treatments. Geopolymer mortar (GPM) with 0.06% GO and an added 0.10 water-to-binder ratio (w/b) (G1-GO0.06) achieved the highest bi-surface shear bond strength of 7.60 MPa, representing an 84% increase compared to the control samples, which contained 0% GO and no additional water. The addition of GO enhanced the compressive strength of geopolymer mortar at both early and later stages. The

optimization of the mixture depends on balancing the activator and GO, as the flowability tends to decrease with higher GO dosages. The rapid chloride permeability test revealed the outstanding resistance of graphene-modified geopolymer mortar samples to chloride ion penetration. With an optimal graphene oxide content of 0.04% and 0.06% in geopolymer samples with a w/b ratio of 0.10, chloride ion permeability was notably lower compared to other mixtures.

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Sekian, terima kasih.

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Setuju.

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