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OPTIMIZATION OF ALKALI ACTIVATOR ON THE STRENGTH PROPERTIES OF FLY ASH BASED GEOPOLYMER REPAIR MATERIALS

Flexible and rigid road pavement deteriorates over time and needs high-performance patching repair materials. Cold mix asphalt patching is an easy and inexpensive repair material to repair potholes and other damaged roads. However, the repaired road pavement fails because it doesn't have adequate compressive and bonding strength to the substrate. Thus, this research uses high-performance geopolymer repair materials to patch against road pavement potholes substrate. Geopolymer repair materials could improve the bonding strength, making them suitable for road repair purposes. For making geopolymer repair materials, the main materials used were high calcium aluminosilicate source materials such as fly ash, sodium hydroxide, sodium silicate, and water. This study tested the compressive and bonding strength of geopolymer repair materials after 1, 7, 14, and 28 days. This study found that the compressive strength of 90 g of alkali activator was the highest, at 37.0 MPa. The bonding strength improved gradually from day 1 to day 14, and then considerably on day 28. The compressive strength and bonding strength both increase in direct proportion to the amount of alkali activator present. Alkali activator is optimal at 90 grams for compressive strength and bonding strength of geopolymer repair materials.

Keywords: Alkaline activator; Strength; Fly ash

1. Introduction

Ordinary Portland Cement, commonly known as OPC, is largely viewed as the most essential component of the building industry. Manufacturing one ton of OPC results in the direct generation of 0.55 tons of CO_2, and it also requires the combustion of carbon fuel to produce an additional 0.40 tons of CO_2 [1]. As a result of this, most of the studies investigated the effectiveness of geopolymer concrete (GPC), which is better for the environment than ordinary Portland cement concrete. The utilization of GPC not only brings about a reduction in the emissions of CO_2 but also brings about the utilization of waste materials from industrial processes, such as fly ash (FA) [3-6] and ground granulated blast furnace slag (GGBFS) [7]. Most of the research on GPC is conducted in a laboratory and focuses on its strength, durability, structural parameters, and microstructural features. Globally, the potholes on flexible road pavement are a major concern for the civil engineering community. The time-dependent deteriorations are the result of inherent material degradation, attack from harmful environmental conditions, and overloading, which lead to cracking, spalling, and ultimately the loss of structural serviceability. Therefore, there is an urgent need to improve the performance of existing road pavements by repairing and reinforcing them in order to extend their service lives. The most common repair material used is Cold Mix Patching Materials (CMPMs). CMPMs were used to patch the road surface especially to repair the pothole. Numerous studies [10] indicated that cold-mix asphalt was developed for the rehabilitation of ageing flexible pavement structures in order to improve compatibility with bitumen substrates. Cold Mix Patching Materials (CMPMs) have largely replaced Hot Mix Asphalt (HMA) for repairing potholes and also for other localized damages. Although these materials provide instant serviceability, however, they have a relatively short lifespan, and this has motivated researchers to develop novel pothole repair solutions. Due to their higher durability and mechanical performance, research and development of geopolymer binders have great promise for repairing old pavement structures. Evaluation of the compressive strength and bonding strength between geopolymer repair materials and bitumen substrate is an important property in the application of such

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an eco-friendly technology and high-performance geopolymer repair materials. This study examined the effect of alkali activator content on the formulation of geopolymer repair materials. The compressive and bonding strength of geopolymer repair materials are evaluated and discussed.

2. Material and experimental procedures

2.1. Materials

The X-ray Fluorescence Analysis (XFA) chemical composition of High Calcium Precursor Fly Ash (HCPFA) were 72% CaO, 15% SiO_2, 4.3% Al_2O_3, 3.96% Fe_2O_3, 2% SO_3, 1.08% K_2O, 1.30% MgO and 0.36 others. The alkali activators utilised to activate the HCPFA were NaOH (12M) and Na_2SiO_3. The river sand as fine aggregates and coarse aggregates with size 8 mm were used to make Geopolymer Concrete Cube and Geopolymer Repair Material cube. Hot Mix Asphalt was also used as substrate for geopolymer Repair Material Cube.

2.2. Mix Proportion of Geopolymer Concrete Cube

In this research study, geopolymer concrete samples were prepared in which the concrete consisted of High Calcium Fly Ash (HCPFA). TABLE 1 outlines the relative amounts of solid to liquid and materials incorporated into the concrete mix. For the geopolymer concrete cube, 12 samples of 50×50×50 mm cubes for each variation of water content in alkali activator solution dosage were cast. A total of 48 cubes samples were cast and tested for the compressive strength test for 1,7,14 and 28 days, which used three samples of each variation as an average reading measurement.

TABLE 1

Different percentages of solid to liquid with the material

High Calcium Precursor (HCP) (g)	Fine aggregate (g)	Coarse aggregate (g)	Alkali content (g)	SS:SH
200	400	400	90	2.5
200	400	400	100	2.5
200	400	400	110	2.5
200	400	400	120	2.5

NOTES: S – Solid, L – Liquid activator and water, SS – sodium silicate, SH – sodium hydroxide

2.3. Geopolymer Concrete Cube Mixing

Laboratory used two mixing stages: pre-mixing and complete mixing. Pre-mixing was three minutes of dry solid material like aggregates, sand, and high calcium precursor in a bowl. On the other hand, the alkali activator solution (NaOH, Na_2SiO_3, and bowl) took two minutes to prepare. The pre-mixed material and alkali activator were then thoroughly mixed for four minutes. Transfer the mixture into the clean mould and vibrate for 2 minutes, compacting three layers. The specimen was cured in a mould for 24 hours and then opened at room temperature until the compressive strength test. Each day's compressive strength data is collected.

2.4. Geopolymer Repair Material Cube Mixing

Geopolymer Repair Material Bonding Cube mould was made by splitting the mould in half with polystyrene and a hard plastic cover. In a cleaned and greased mould, asphalt was tamped 70 times by rod in three layers on half side of mould. After 5 days in the sun, the remaining half of the mould was poured with geopolymer concrete. The process of making and mixing geopolymer cubes for the second half of the mould was repeated. The specimen was cured in a mould for 24 hours and then opened at room temperature until the bonding test. 1,7,14, and 28 days bonding strength measurements were recorded.

2.5. Sample preparation and testing

2.5.1. Compressive Strength Test

The compressive strength of the geopolymer concrete cubes cured at room temperature for 1, 7, 14 and 28 days was tested according to ASTM C109. The cubes were measured for size and weight to ensure they were 50×50×50 mm. The compressive strength testing machine's bearing surface was cleaned. The cube's flat surface was then placed in the machine, with the specimen in the middle of the base plate. The weights were applied at 0.90 mm/min until the cube shattered. The maximum load and stress were noted. The nature of failure was also noted.

2.5.2. Bonding Strength Test

Geopolymer Repair Material and Cold Mix Asphalt bonding strength is tested using a split test. The ASTM C882 standard describes this test as evaluating the bonding strength of aged asphalt pavement with newly overlay Geopolymer Repair Materials. The sample was made using a 50×50×50 mm cube mould with half asphalt and half Geopolymer Repair Material concrete. The loading was applied to just a section of the geopolymer concrete at a rate of 3 mm/min.

3. Results and discussion

3.1. Compressive Strength of Geopolymer Concrete Cube

Fig. 1 shows the amount of alkali activator that was added to the mix design caused the compressive strength of the geopolymer repair material to increase. This effect was caused by the addition of sodium hydroxide and sodium silicate solution in the formation of C-A-S-H and N-A-S-H geopolymer gel. However, the formation of geopolymer gel deteriorates with an increase in the water content, which causes the creation of microcracks in the hardened geopolymer repair material. This can be seen from Fig. 1, the trend of the compressive strength which starts to decrease after 110 g of alkali activator mix design. This finding is consistent with the statement that was reported in the previous research [9]. Water molecules engage in the geopolymerisation process and influence the distribution of pores in the geopolymer due to the high water-to-solid ratio. According to [9,10,12], the geopolymerisation process at the early age of 7 days was not totally reactive for fly ash precursor. However, as time passes, the geopolymer's density rises and its microstructure improves, and the optimum content of the alkali activator should be identified.

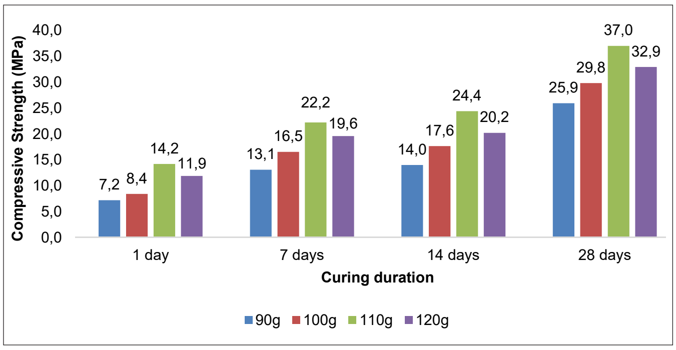

Fig. 1. Compressive Strength (MPa) of Geopolymer Repair Materials for 1,7,14 and 28 days of curing duration

3.2. Bonding Strength of Geopolymer Repair Material Cube

As shown in Fig. 2, the bonding strength of the geopolymer repair material increased with increasing alkali activator amount. Another association between curing time and the bonding strength of geopolymer repair materials has been discovered. The pattern shifted with the addition of an alkali activator. The bonding strength of 90 g, 100 g, and 120 g of alkali activator increased from day 1 to day 28, respectively. The bonding strength of the geopolymer repair material with a 110 g alkali activator increased from 90 g to 110 g, then fell significantly on the 120 g solution contained in the mix design.

The maximum bonding strength reported is 6.98 MPa for 110 g of alkali activator. The lowest bonding strength (3.77 MPa) containing 120 g of alkali activator was obtained. The trend of the graph depicting the bonding strength between geopolymer material and asphalt substrate was explained by the permeability of geopolymer repair material concrete into the asphalt and the chemical interaction between these two surfaces. The higher the alkali activator content of the geopolymer repair material, the greater the potential for geopolymer repair material to infiltrate the asphalt concrete pavement. Consequently, the geopolymer gel fills additional asphalt pores, so strengthening the link between the old asphalt substrate and the new geopolymer repair material [11,12]. During the 14-day geopolymerisation process, temperature changes may affect the microstructure of the geopolymer. Therefore, after fourteen days of curing, the strength dropped. Fig. 2 demonstrates that the best alkali activator for bonding strength in road repair is 110 g, with the maximum bonding strength for each curing interval.

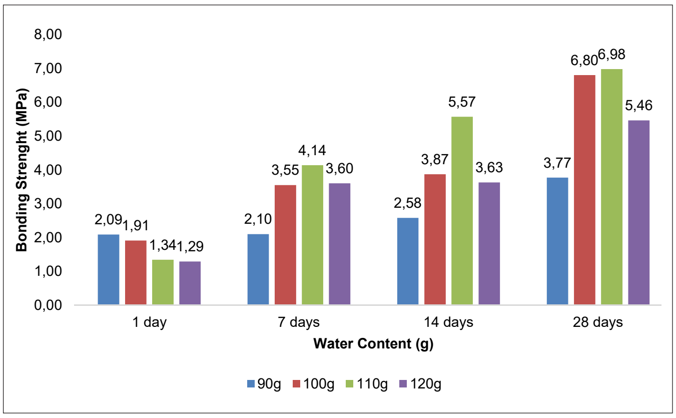

Fig. 2. Bonding Strength of Geopolymer Repair Materials for 1,7,14 and 28 days of curing duration

3.3. Relationship between Compressive Strength, Bonding Strength and the Alkali Activator Content of Geopolymer Cube

Compressive strength, bonding strength, and alkali activator are all shown to have a positive quadratic relationship in Fig. 3, which depicts this relationship in three dimensions. Because the compressive strength increased linearly with the alkali activator level as the bonding strength grew, it unexpectedly reduced at the 14-day mark. The opposite of what the researchers discovered can be said here [9,13]. According to the findings of that research, there is a positive linear correlation between compressive and bonding strength. On the other hand, the trend of the graph is quadratic when it comes to the connection between compressive strength and alkali activator.

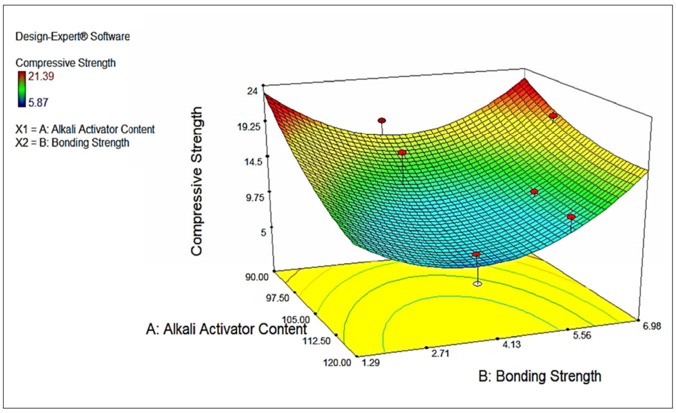

Fig. 3. Relationship of Compressive Strength, Alkali Activator Content, and Bonding Strength of Geopolymer Repair Material

4. Conclusion

The following findings are drawn from the experimental work in this study.

1. An increase in the amount of alkali activator caused a increment in the compressive strength of the geopolymer repair material. For geopolymer repair material that have been cured for 28 days, the optimal dosage of alkali activator to obtain high compressive strength is 110 g. This corresponds to a compressive strength of 37.0 MPa.
2. The compressive strength of the material improved as the curing time went on, reaching its peak at 28 days for all of the different alkali activator formulations.
3. The bonding strength of the geopolymer repair material rose with increasing alkali activator dosage for 90, 100, and 110 g variants respectively.
4. The best amount of alkali activator to utilize for the bonding strength test is 110 grams. This is the optimal dosage that can be employed.
5. Since the relationship between compressive strength, bonding strength, and the amount of alkali activator dosage is a positive quadratic, we may draw the conclusion that the relationship between compressive and bonding strength is inversely proportional to the amount of alkali activator dosage.

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