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Influence Of Cassava Peel Ash and Metakaolin Based Geopolymer Mortar on the Bond Strength of Concrete

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Abstract-** The critical element for sustainable growth in the construction industry is the development of alternative cements. A new technological process called geopolymerization provides an innovative solution, and the presence of aluminum and silicon oxides in pozzolans has encouraged its use as a source material. The present study investigated the material's properties, practices and bonding properties between geopolymeric repair material (mortar) and concrete substrate. An experimental program was executed to establish a connection between the alkaline activator composition and the properties of geopolymer mortar and concrete in fresh and hardened states. Concentrations of sodium hydroxide and sodium silicate were ascertained that are advantageous for constructability and physical properties. Also, the influence of the properties of the repair materials itself and also the surface preparations of concrete substrate on bond strength was evaluated. The factors affecting the bond strength was studied through slant shear tests made on 72 specimens. The initial and final setting time in 50%CPA/50%MK, 100%CPA/0%MK geopolymer repair mortar is considerably shorter than cement-based mortar, which can be in most cases beneficial for using this type of mortar in repairing concrete structures. 100%CPA/0%MK geopolymer mix delays the initial setting time to 25 minutes, and the final setting time to 60 minutes. Substituting 50%CPA and 50%MK by weight of binder (precursor) in geopolymer mortar is the optimum amount to achieve the good compressive strength and enhanced slant shear bond strength. Grooved surface treatment method gave the highest slant shear bond strength with 7.31 N/mm^2 value. The interfacial transition zone through Scanning Electron Microstructure (SEM) showed that geopolymer made from CPA and MK is chemically bonded to the concrete substrate. The increase in Ca^{++} ion balanced the negative charge of Al^{3+} ions, which lead to a dense interface zone. All the test results indicate that there is potential for the concrete industry to utilize alkaline activated blended Cassava Peel Ash and Metakaolin as an alternative to Portland cement in repair of concrete.

***Index Terms-** Geopolymer Mortar, Geopolymeric, Cassava Peel Ash, Metakaolin and Concrete*

I. INTRODUCTION

1.1 Background to the Study

Growth in human population over the last fifty years has doubled from 3 to 6 billion and it is expected to increase in years to come. It is estimated that by year 2050, more than 85 percent of the world's population would live in urban areas. (Magnani *et al.,* (2015). To serve the needs and changes, large amounts of materials are needed for the construction of houses, office buildings, roads required for decent living (Ngab, 2002). Concrete as a construction material has the largest production of all man made materials. The worldwide consumption of this material is of the order of ten billion tonnes per year, next only to total consumption of water (Nagaraj, 2002). One of the constituent materials in making concrete is cement. Knowing that the raw material from earth sources was scarce and the demand for cement is increasing as a result of economic and population growth, the effort to find alternative materials which must be of both inexpensive and require very little energy to produce has to be undertaken. Thus, it is a current trend nowadays to use by-products or waste materials to partially replace cement in making concrete (Kartini *et al*., 2006). Cement manufacturing industry is one of the carbondioxide (CO_2) emitting sources besides deforestation and burning of fossil fuels. Global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere.

Consequently, extensive research is ongoing into the use of cement replacements, using many waste materials and industrial by products (Kartini *et al*., 2006). To reduce the impact on the environment due to industrial and agricultural waste products such as Rice Husk Ash (RHA) and coconut fibers (COIR) which are the waste products of paddy and agricultural industry (Domke, (2012). , Kartini *et al.,* 2006). Use of these waste products in mortar and concrete not only improves the strength of concrete but also leads to the proper disposal of these materials, resulting in reducing the impact of these materials on environment.

Considerable efforts has been taken Worldwide to utilize the industrial and agricultural waste and its by-product materials having high silica content as supplementary cementing materials or alternative materials to improve the properties of cement or replacement of cement in mortar and concrete (Domke, 2012).

The possibility of employing Geopolymer mortar as a more sustainable repair material compared to OPC concrete has been suggested by researchers in the last two decades (Davidovits, 2002; Pacheco-Torgal *et al.,* 2012) and the application of different types of Geopolymer materials for external reinforcement of reinforced concrete members was investigated (Menna *et al*., 2013; Balaguru *et al*., 1997). The suitability of a material for repair relies upon several factors: foremost, bond strength and compatibility. Therefore, this present study focused mainly on the bonding strength properties of geopolymer concrete/mortar as a repair material incorporated binary blend of cassava peel ash (CPA) and metakaolin (MK) in shear strength bond.

1.2 Statement of the Problem

Recently, there is a shift towards the use of geopolymer (GP) mortar in a wide range of repair applications. Test results by Zhang *et al.* (2010) confirmed the potential use of GP mortar as a protective coating for offshore concrete structures. Coppola *et al.* (2018) developed a slag based GP mortar to retrofit existing masonry and concrete buildings. Songpiriyakij *et al.* (2011) examined the potential of GP paste as a bonding agent in rebar embedded in a concrete substrate. It was observed that the GP paste developed high bonding strength, which was 24%–81% higher than the commercial epoxies. Ferone *et al*. (2013) utilized metakaolin (MK) based GP mortar for the external strengthening of reinforced concrete beams. Despite the intensive research undertaken on GP mortars for understanding the geopolymerization mechanism and optimizing the constituents for attaining enhanced strength (Pereira *et al*., 2018; Pires *et al.,* 2018; Huseien *et al*., 2017), the appropriate selection of GP mortar is still under active research. The repair efficiency depends on the bond strength between the concrete substrate and the overlay repair mortar. There is limited research on the performance of plain and agricultural waste-based GP through the shear bond test.

1.3 Aim and Objectives of Research

The aim of this research is to determine the influence of cassava peel ash and metakaolin based geopolymer mortar on the bond strength of concrete with a view to determining its suitability and compartibility in retrofitting concrete. The objectives of the study are to:

i. Characterise the properties of the pozzolan materials.
ii. Determine the fresh properties of synthesized binary blend geopolymer mortar.
iii. Compare the bonding properties of CPA-MK blend geopolymer mortar with normal CEM I concrete substrate.

Evaluate the morphological properties of the interface zone between geopolymer and CEM I mortar substrate.

II. SUMMARY OF RELEVANT PRIOR WORK

Based on the conclusions found within the literature regarding the synthesis of geopolymers, the following claims can be made:

- Increasing the NaOH and Na_2SiO_3 content reduces the flow of fresh geopolymer. Workability can be improved, however, with the addition of extra H_2O.
- Excessive OH^- ions accelerate dissolution but decrease polycondensation, causing the binder to precipitate early and lose strength.
- Excessive H_2O content creates segregation between the constituents and lowers the strength of the final Conrete.
- At higher rate of mixing leads to an increased amount of air content, which remains enclosed

in the fresh concrete due to its low mobility. Additives that contain CaO reduce porosity as the geopolymer phase coexists with the C-S-H matrix.
- GPC containing high amounts of FA has increased levels of static and dynamic viscosity and, therefore, requires higher compaction energy.
- Decreased strength results from varying the constituents of the alkaline activator less or more than the suitable value.
- Strength increases as an effect of age, longer mixing time and raising the curing temperature.
- The density of GPC is similar to concrete based on PC, varying only slightly due to the effect of age and curing type.
- Fine FA is much more effective for synthesizing high strength geopolymers, providing increased surface area, high workability and excellent volumetric stability.
- The mix design parameters as well as the fineness, crystallographic distribution and chemical composition of the FA dictate the mechanical behavior of geopolymers.

Hence, this study hereby aimed at filling the existing gap on the impact of binary blend of cassava peel ash (CPA) and metakaolin (MK) on the bonding shear strength of concrete/mortar as there is limited studies on the incorporation of CPA as an agro-waste material blended with MK as solid geopolymer repair materials.

III. MATERIALS AND METHOD

3.1 Materials

The material that was used to achieve the aim and objectives of the study is described in detail below:

- Alkaline solution:A combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) was used as the alkaline activator.
- Metakaolin: (MK), the one that was used for this research was obtained from kaolin,sourced from Alkaleri Local Government of Bauchi State, Nigeria.
- Cassava peel ash: Cassava peels (CPA) was collected using polythene bags from Doko, in Lavun Local Government Area of Niger State where Cassava flakes are locally produced. Chemical tests was carried out on the CPA sample to determine the chemical compositions.
- Aggregates: The aggregates used in the experiment where fine aggregate and the coarse aggregate. The coarse aggregate was used in the production of the substrate concrete sample.
- Cement: CEM 1 (42.5N) Portland Cement was used for this research as binders for the concrete substrate specimen. It satisfy the minimum requirement as provided in BS 12(1996). The CEM 1 Portland Cement was Dangote brand of cement from obajana plant conforming to the BS EN 197-1 (2000). The cement was acquire from a merchant store in Minna and kept in air tight container for use.
- Water: Portable water fit for drinking supplied to the concrete laboratory was used throughout the study in mixing and dissolving the alkaline activator and also used for the production of the GPM overlay and concrete substrate specimens.
- Admixture: A water reducing admixture was used in order to achieve a target flow. Super plasticizer (SP) of trade name CONPLAST SP 430 conforming to ASTM C494 (2019) requirements was used as a water reducing admixture to enhance the workability of mortar.

3.2 Methods of Manufacturing Geopolymer Mortar

In this study, targeted strength of the test sample was achieved through a well-considered material proportion design and also through the use of quality materials in the sample production. A mix proportion which is suitable for the production of PCC and GPM were determined through the preliminary test. The fresh properties test involves the testing for initial and final setting time, soundness and flowability of the GPM. Details of how this test are conducted are explained as follows:

3.2.1 Characterizations of the constituent materials

The properties test that was carried out on the constituent materials includes the physical and chemical properties of the constituent materials use for the research.

3.2.1.1 Physical properties

The physical properties of the materials used in the production of the Geopolymer mortar are conducted on the constituent materials like Fine aggregate, Coarse aggregate, Precursors (CPA and MK) for this experiment are particle size distribution, (size analysis), density test and specific gravity test.

i. Particle Size Distribution

The particle size distribution for MK, CPA and fine aggregate was carried out using sieve analysis as described in accordance with BS EN 933-1 (2007). This was done to determine the grading of the aggregates.

ii. Specific Gravity

The specific gravity (Gs) of metakaolin, CPA, and fine aggregate was determined by using pycnometer method in accordance to BS EN 1097-2 (2003). The apparatus used include density bottle and stopper, funnel, spatula and weighing balance. The relationship used to find the specific gravity is given in Equation 3.1:

$$\text{Specific Gravity} = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)} \quad (3.1)$$

iii. Bulk Density

Bulk Density was determined in accordance with BS 812-2 (1995) for the fine aggregates use for this research. The relation below is used to determine the bulk density of the sample: Equation 3.1 was used to calculate the samples bulk density.

$$D = \frac{M}{V} \quad (3.2)$$

D = Density of the aggregate specimen in Kg/m^3
M =Mass of the aggregate specimen in Kg
V = Volume of the aggregate specimen in m^3

iv. Density

In accordance to the ASTM C188 (1995), the density of ash such as CPA and MK used in this experiment was carried out using weight of compacted and uncompacted samples.

3.2.1.2 Chemical properties

Chemical analysis of the precursors (CPA and MK) was carried out using XRF test to determine the oxide composition such as Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3), Iron Trioxide (Fe_2O_3) and others. In order to investigate if they are in line with the ASTM C618 (2018) classes of pozzolana. The ASTM standard stipulates that for any material to be used as pozzolana, it should fall within the following classes; Class N, Class F or Class C.

3.3 Fresh Properties of Mortar

In concrete technology, the workability of concrete is measured by the experiment named slump test. However, for mortars, one of the flow table or the mini-slump cone was used in the fresh properties determination. Also the consistency of water test, initial and final setting time, soundness test is also determined for the CPA-MK geopolymer mortar.

3.3.1 Soundness of GPM

Accordance to BS EN 196-3(2016) the soundness test is a measure of the binder's quality in terms of expansion effect. Using a Le-Chatelier mould, this test was done at a temperature of 25 ± 2^{oc} and humidity of 65 ± 5^{oc}. It was completed following the consistency test (p) to determine the amount of water needed to make a standard paste. The results of measuring the distance between the two indication points was to the nearest 0.5mm (L2).

As a result, the following was used to determine the soundness test:

Soundness (expansion) of cement paste = L1- L2

Where L1 = Value obtained after water immersion for 24 hours at 27 ± 2^{oc}

L2 = Value obtained after 3 hours immersion in water at boiling temperature.

Soundness value was computed from the mean of duplicate samples to the nearest 0.5mm

3.3.2 Setting time of GPM

The test method is adopted in measuring the setting time and consistency of GPM is called the vicat test method. This test is done in concomitant with ASTM C191 (2020).

(a) Schematic diagram of a vicat apparatus

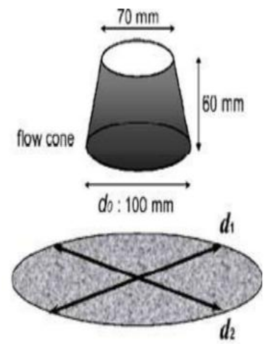
Initial Setting time test

Plate I: Initial Setting time and Final settingtime test using the vicat apparatus

3.3.3 Mini-slump test for flowability of GPM

The cone is placed centrally within the circle on the table (Plate I (a) shows the standard cone dimensions). Then, the cone was filled with GP fresh mortar immediately after mixing in a single operation without any mechanical compaction. The cone was allowed to stand not more than thirty seconds and, during this time, all spilled mortar was removed from the baseplate. Plate I presents the operation procedure of the flowability test. Equation 3 illustrated the formula used in calculating the flow diameter

$$\text{Flow diameter} = \frac{(D_1 + D_2)}{2} \qquad (3.3)$$



(a) Schematic diagram of a Mini slump test cone and diameters

(b) A geopolymer mix

(c) cone was lifted vertically in a single movement

(d) the diameter of the flow in two perpendicular dimensions was measured

Plate II: Flowability test for Geopolymer Mortar

3.4 Tests on hardened of specimens

The tests to be carried out on hardened GPM (overlay) and Portland cement concrete (substrate) specimens include the following:

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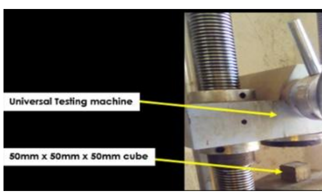
Compressive strength

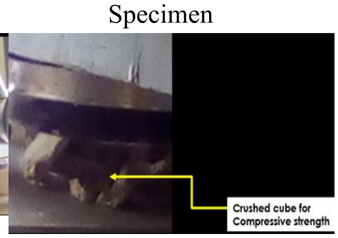
In order to evaluate the compressive strength of CPA-MK geopolymer mortar, a cubic specimen of 50 mm x 50 mm x 50 mm was used. The specimens were tested for ages of 3, 7, 28 and 56 days. Plate VIII shows the 50 mm mould, 50 mm mortar sample and testing of the 50 mm cube mortar sample and the failure pattern of the GPM cube that was used in the experiment.

(a) Steel Cubic mould containing fresh mortar

(b) GPM and PCM cubic Specimen



(c) Cube testing under compressive load



(d) GPM and PCC Cube failure pattern

Plate III: Compressive Strength test

- Slant shear test

For half slant-shear specimen, the hardened CEM 1 cement concrete (substrate) also called Portland cement concrete (PCC) was diagonally slanted at 30° angle from vertical (Plate X). According to ASTM 882/C882M (2020), the bond angle of 30° recommended represents the failure stress corresponding to a smooth surface is close to the minimum stress. The dimension of slanted specimen is presented in Plate IX. Step-by-step preparation of half slanted specimen and bond test under uniaxial load are given in Plate X.

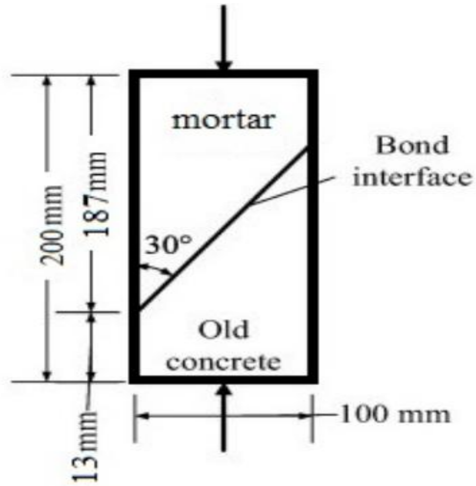


Plate IV: Slant shear specimen dimensions

IV. RESULTS AND DISCUSSIONS

4.1 Physical Properties of Constituent Materials (CPA, MK & Fine Aggregate)

As shown in Table 4.1, the result indicates the physical properties of the CPA and MK The result was found satisfactorily as it meets up with the necessary requirement for the production of mortar. The MK (503.9 Kg/m^3) was observed to be lighter than CPA (649.7 Kg/m^3).

Table 4.1: Physical properties of the constituent materials

Physical properties	Test Value (Kg/m^3)	
	CPA	MK
Density	649.7	503.9
Specific gravity	2.3	2.2

4.2 Chemical Composition of Constituent Materials

Table 4.3 present the chemical analysis of oxide percentage quantity of the Pozzolanic constituent materials (PC, MK and CPA).

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Table 4.2 Chemical Composition of Constituent Materials

Properties	Constituent Materials			ASTM C18(2005) Limits	
	PC	MK	CPA		
SiO_2	19.57	72.39	80.83	$SiO_2 + Al_2O_3 + Fe_2O_3$	≥70
Al_2O_3	5.47	20.35	0.77		
Fe_2O_3	3.24	1.12	1.55		
CaO	64.19	0.01	4.24		
MgO	2.01	0.12	0.05		
LOI	2.98	2.35	0.20	10% max.	
K_2O	0.45	3.12	5.50		
Na_2O	0.26	0.34	0.06		
SO_3	2.74	-	0.83	4.0% max.	
TiO_2	-	0.90	-		
Mn_2O	1.25	0.02	0.05		

The result shows the chemical composition of the constituent materials, the sum of SiO_2, Al_2O_3, and Fe_2O_3 was found to be greater than 70%. This implies that cemetitious constituent materials satisfy the chemical requirement for N-class of pozzolana in accordance with ASTM C618 (2018).

4.3. Setting time of the binding materials

4.3.1 Initial and final setting time

The laboratory results are illustrated in Figure 4.2. The setting time of the geopolymer mortar tested is higher than the cement-based mortar except for the 100% CPA binder material. Figure 4.2 illustrates a graph that demonstrates the initial and final setting time for all mix designs, including cementbased and geopolymer mortar.

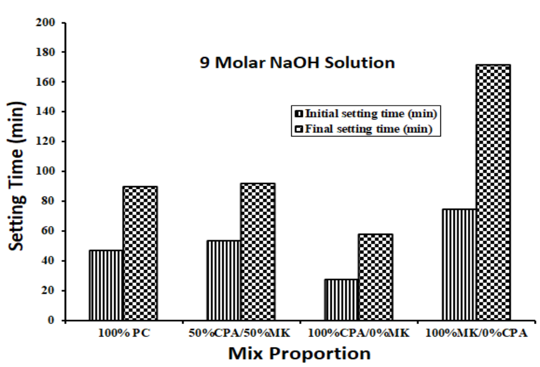

Figure 4.2: Comparison of the setting time in all the mix proportion

4.4 Results from the Experiments on the Hardened Mortar

4.4.1 Compressive strength of Geopolymer Mortar

Table 4.5 presents the compressive strengths of CPA and MK blended geopolymer mortar. The results show that the cube compressive strength of the geopolymer mortar decreased as 100% CPA was introduced to the mix, and likewise as 100% MK was used in the mix.

The variation of compressive strength of the geopolymer mortar mixtures containing 50% CPA/50% MK, 100% MK and 100% CPA with respect to that of the control mix (CEM 1 mortar) also referred to as CEM 1 Portland Cement (PC). Comparing the value of the control mix (100% PC), i.e., mortar without any geopolymer content, the geopolymer mix 50% CPA/50% MK, 100% CPA and 100% MK decreased the compressive strength by 51.7%, 70.5% and 80.2%, respectively at the age of 28 days. Further reductions in compressive strength of 41.5%, 39.7%, 51.7% and 47.6% compared to the PC mortar were observed in mortar containing 50% CPA/50% MK for the curing times of 3, 7, 28 and 56 days, respectively. In geopolymer mortar mixtures containing 100% CPA and 0% MK, the compressive strength values decreased by 63.9%, 66.3%, 70.5% and 65.2% compared to that of PC mortar for the curing times of 3, 7, 28 and 56 days, respectively. The reduction in compressive strength of the mixes containing MK and CPA is attributed to the delay in hydration and slow pozzolanic activity of the geopolymer solid, which negate the increase in compressive strength.

4.4.2 Influence of geopolymer precursor on the interfacial bond strength of the composite

Table 4.6-4.8 illustrates the test results and the calculated shear capacity of the specimens along with the bond interface (τ_n), thus demonstrating the bond strength of the specimens. To simplify the comparison between the collected experimental data, the bar chart demonstrates that the cement-based (100% PC) mortar shows a better cohesiveness to the substrate layer of concrete than the 100% CPA and 100% MK mortar. However, the bond strength of 50%CPA/50%MK (equal percentage) geopolymer mortars was observed to be higher than the cement-based mortar. This growth of bond strength in blended CPA/MK

Geopolymer mortar can be as a result of the increment of C-S-H gel by reason of increasing the percentage of silica (see Table 4.3).

Table 4.3: Slant shear test results of groove interface specimens

Groove	28 Days			56 Days		
Mix ID	σ_0 (N/mm^2)	σ_n (N/mm^2)	τ_n (N/mm^2)	σ_0 (N/mm^2)	σ_n (N/mm^2)	τ_n (N/mm^2)
100% PC	9.42	9.23	4.08	13.76	13.49	5.96
50%CPA/50%MK	13.81	13.53	5.98	16.86	16.53	7.31
100% MK /0% CPA	6.02	5.90	2.61	8.74	8.57	3.79
100% CPA /0% MK	7.02	6.88	3.04	11.13	10.91	4.82

Table 4.4: Slant shear test results of mesh interface specimens

Mesh	28 Days			56 Days		
Mix ID	σ_0 (N/mm^2)	σ_n (N/mm^2)	τ_n (N/mm^2)	σ_0 (N/mm^2)	σ_n (N/mm^2)	τ_n (N/mm^2)
100% PC	8.01	7.8498	3.46833	10.67	10.4566	4.62011
50%CPA/50%MK	9.64	9.4472	4.17412	12.05	11.809	5.21765
100% MK /0% CPA	4.03	3.9494	1.74499	6.84	6.7032	2.96172
100% CPA /0% MK	4.96	4.8608	2.14768	7.46	7.3108	3.23018

Table 4.5: Slant shear test results of smooth interface specimens

Smooth	28 days			56 days		
Mix ID	σ_0 (N/mm^2)	σ_n (N/mm^2)	τ_n (N/mm^2)	σ_0 (N/mm^2)	σ_n (N/mm^2)	τ_n (N/mm^2)
100% PC	5.57	5.46	2.41	7.92	7.76	3.43
50%CPA/50%MK	7.22	7.08	3.13	10.28	10.07	4.45
100% MK/0%CPA	2.39	2.34	1.04	5.92	5.80	2.56
100% CPA/0%MK	3.46	3.39	1.50	6.03	5.91	2.62

Geopolymer is formed using precursors containing alumina (Al_2O_3) and silica (SiO_2) such as CPA and MK activated with alkali solutions. The Al_2O_3 and SiO_2 in the precursor thus dissolve and form a three-dimensional amorphous aluminosilicate network (Davidovits, 1994). Nevertheless, the sialate network of geopolymer which composed of tetrahedral anions $[SiO_4]^{4-}$ and $[AlO_4]^{5}$- need positive ions such as Na^+, K^+, Li^+, Ca^{++}, Na^+, Ba^{++}, NH^{4+}, H_3O^+ to compensate the electric charge of Al^{3+} in tetrahedral coordination as shown in Figure 4.5. When geopolymer is patch against the spalled of the reinforced concrete structure made from Ordinary Portland Cement (OPC), geopolymer is chemically bond to substrate

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due to the reaction products at the interface transition zone between OPC substrate (Somna *et al.*, 2011; Temuujin *et al.,* 2009).

4.4.2.3 Interfacial transition zone through Scanning Electron Microstructure (SEM)

The interfacial transition zone through Scanning Electron Microstructure (SEM) shows that geopolymer made from CPA and MK is chemically bond to the concrete substrate as shown in Plate XI. Moreover, the increase in Ca^{++} ion balanced the negative charge of Al^{3+} ions, which leading to a dense interface zone as shown in Figure 10. Therefore, the microstructure images give clear picture in order to evaluate the bond strengths of geopolymer repair materials. Geopolymer made with CPA and MK is good candidates as an alternative bonding material for repair works.

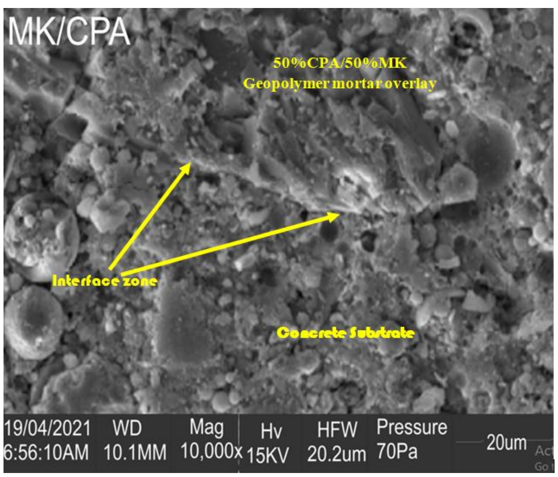

Plate V: SEM micrographs of interfacial transition zone between geopolymer and concrete substrate.

The microstructures image of these geopolymer, concrete substrate and interface could be identified from unreacted CPA and MK, agglomeration of Portland cement and small line crossing along the interfacial, respectively. The negatively charged Al and tetrahedrally coordinated Al (III) atoms inside the network are charge-balanced by alkali metal cations such as Na^+ or K^+ (from alkaline activator) and Ca^{++} (from Portland cement grains reacting with water). Thus, geopolymer which is rich in Si^{4+} and Al^{3+} ions can react with $Ca(OH)_2$ at the surface of substrate leading to bonding strength development at the contact zone.

Summary of Findings

1. The CPA/MK based mortar is noticeably more flow-able/workable in comparison with equivalent cement-based mortar.

2. The initial and final setting time in 50%CPA/50%MK, 100%CPA/0%MK geopolymer repair mortar is considerably shorter than cement-based mortar, which can be in most cases beneficial for using this type of mortar in repairing concrete structures.

3. 100%CPA/0%MK geopolymer mix delays the initial setting time to 25 minutes, and the final setting time to 60 minutes.

4. In this research, substituting 50%CPA and 50%MK by weight of binder (precursor) in geopolymer mortar is the optimum amount to achieve the good compressive strength and enhanced slant shear bond strength.

5. Grooved surface treatment method gave the highest slant shear bond strength with 7.31 N/mm^2 value.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This experiment's primary goal is to produce an alkali-activated mortar without using cement and with appropriate characteristics for repairing concrete structures. The functionality of this mortar in repairing the concrete structures can extend the lifetime of existing structures. Since the proper workability and setting time are considered two essential characteristics of repair mortar, the effect of precursor materials (CPA and MK) were evaluated on the geopolymer mix by carrying out flowability and vicat test. After that, compressive strength of mortar at the ages of 3, 7, 28 and 56 days with 100 × 100 × 100 mm cubic specimens is evaluated. Moreover, the bond strength of mortar was evaluated using the slant shear test with 100 × 200 mm cylindrical specimens at 28 and 56 days. The compressive strength and slant shear properties of the interface between plain concrete substrate and CPA/MK geopolymer mortar showed that the bond strength in the slant shear test was very strong, as the interfacial failure occurred in the plain concrete substrate without interfacial separation or debonding between the plain concrete substrate and geopolymer mortar. The CPA/MK based mortar is noticeably more flow-able/workable in comparison with equivalent cement-based mortar. The initial and final setting time in 50%CPA/50%MK, 100%CPA/0%MK geopolymer repair mortar is considerably shorter than cement-based mortar, which can be in most cases beneficial for using this type of mortar in repairing concrete structures. 100%MK/0%CPA geopolymer mix delays the initial setting time to 25 minutes, and the final setting time to 60 minutes. 50%CPA and 50%MK by weight of binder (precursor) in geopolymer mortar is the optimum amount regarding compressive strength. Grooved surface treatment method gave the highest slant shear bond strength with 7.31 N/mm^2 value.

5.2 Recommendations

The following are recommended from the outcome of this experiment.

1. Towards tackling waste management issues and forth with reduce CO_2 effect on the environment, geopolymer precursor from agricultural waste and earth explore source (CPA and MK) are recommended in geopolymer mortar mix meant for concrete repair.
2. In areas of large cassava farming and high deposits of naturally occurring clay mineral whose main component of kaolin is the mineral kaolinite. The use of CPA and MK is recommended for the production of binder for construction works.

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