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IMPACT OF NANOSCALE POLYANILINE AND FLY ASH ON ENGINEERING PROPERTIES OF ADOBE BRICKS FOR NORTH COAST REGION OF EGYPT

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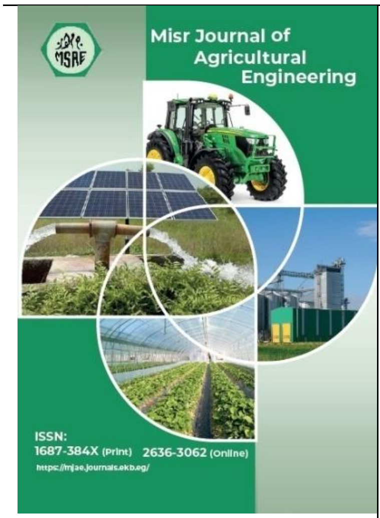

Keywords:
Adobe bricks;
Nanoscale Polyaniline;
Fly Ash

ABSTRACT

This paper describes an experimental investigation on product-based research in the development of geopolymer-stabilized adobe composites (GSAC) using natural soil (NS), fly ash (FA), and Nanoscale polyaniline polymer (PA). An alkaline medium (AM) consisting of a sodium hydroxide and sodium silicate solution was utilized. The molarity of the sodium hydroxide solution was fixed at 14 M. The ratio of sodium silicate solution to sodium hydroxide solution was fixed at 1.5. Four mixes of GSAC were formulated: the control mixture (NS & Water; T1), (NS & AM; T2), (NS, FA &AM; T3), and (NS, FA, PA & AM; T4). An extensive investigation was conducted to examine the compressive strength, physical properties, and durability of GSAC. In addition, the experimental results were confirmed at a micro-level through microstructure analysis using scanning electron microscopy (SEM). Significant effects on all the studied characters were reported. According to the results, the composites formed by PA/FA/NS geopolymer matrix showed a superior yield in the compression and density tests, with the highest value of 7.8 N/mm2 and 2.28 g/cm3, respectively, for compressive strength and density. In the water absorption test, the compounds containing the PA/FA/NS geopolymer matrix showed the lowest yield value, measuring2.02 % and 3.11% after 2 and 24 hr of soaking in water, respectively. The results of the microstructural analysis showed the best interaction between FA and NS particles with the lowest porosity, when PA was added to the matrix.

INTRODUCTION

Bricks have always been an important component of any construction and building material all over the globe. The worldwide annual production of bricks was approximately 1684 billion units in 2023 and is projected to hit around 2217 billion units by 2032, expanding at a CAGR of 3.1% during the forecast period from 2023 to 2032

(Ukwizagira and Mbereyaho, 2023). Therefore, the consumption of earth-based materials such as clay, shale and sand in brick production process results in resource depletion, environmental degradation, high energy consumption, and loss of fertile of agricultural soil , and the neighborhood of brickfield areas are exposed to various health hazards (Sani and Nzihou, 2017). Also, the use of huge amounts of coal in brick manufacturing release of carbon dioxide (CO_2), as well as particulate matter containing black carbon, sulfur dioxide (SO_2), nitrogen oxides (NO_2), and carbon monoxide (CO), exposing workers and neighborhood to health risks (Sani and Nzihou, 2017).

Adobe bricks are simple, inexpensive, fireproof, long-lasting, non-toxic, and have low sound transmission levels through walls while providing enough heat capacity. Additionally, adobe bricks give significant flexibility in the design and construction process. They mold in any shape to fit any design. On the other hand, adobe bricks have poor mechanical properties and high-water absorption. To overcome these defects and increase mechanical properties and performance, stabilizers can be introduced to the soil. Common additions are classified into four types: vegetable waste, animal waste, mineral, or synthetic. In many circumstances, the performance and application of the different additives are still uncertain. Synthetic chemical additives may cause comparable issues as cement, while biodegradable additives afford adequate but potentially short -term life protection (Medvey and Dobszay, 2020).

Several researchers, in developing brick function, used waste materials. They used crumb rubber–concrete combination (Turgut and Yesilata, 2008); waste marble powder (Bilgin *et al.*, 2012); sludge lime (Hasan *et al.*, 2022); rice husk (Paul *et al.*, 2023); granite fines waste (Lokeshwari and Jagadish, 2016); paper mill sludge (Goel and Kalamdhad, 2017); quarry dust (Cai *et al.*, 2023); construction debris (Harikumar *et al.*, 2022); steel plant waste (Chokshi *et al.*, 2018); coal fly ash (Eliche-Quesada *et al.*, 2018); crushed glass (Saraswathy *et al.*, 2019); blast furnace slag (Nim and Meshram, 2020); demolition waste sludge (Dos Reis *et al.*, 2020); straw (Dawood *et al.*, 2021); waste plastic (Wendimu *et al.*, 2021); ceramic powders (Khitab *et al.*, 2021).

Incorporating waste materials into manufacturing bricks, in addition to enhancing their performance, leads to the design of green buildings, and offers a solution to the problem of waste disposal as well as an eco-friendly environment (Salih *et al.*, 2020; Shilar *et al.*, 2023).

Mbereyaho *et al.* (2014) find that the addition of grasses in clay-silt brick improved the compressive strength from 1.14 MPa to 1.70 MPa. on the other side, when earth blocks were stabilized Ordinary Portland Cement (OPC), the maximum compressive strength of 3.11 MPa was achieved with 70% of sand, 20% of clay and 10% of OPC (Patowary *et al.*, 2015). In practical, compressive strength value for stabilized earth building blocks may be less than 4 MPa and for small building loads like in single story buildings, a compressive strength value from 2 MPa to 4 MPa may be even sufficient (Ukwizagira and Mbereyaho, 2023).

Every year, millions of tons of fly ash are generated from thermal power stations and petrochemical industry all over the world. They create problems in disposal operations and tremendous environmental concerns. The pozzolanic properties of fly ash make it a suitable candidate as a cement alternative in brick manufacturing. Fly ash bricks are safer, more durable, economical, have higher strength compared to conventional bricks, and are suitable for the construction of masonry structures (Chindaprasirt *et al.*, 2021; Murugesan *et al.*, 2023). Bricks with 100% fly ash are about 28% lighter than clay bricks and have a compressive strength greater than 40 MPa. Moreover, fly ash bricks have a reddish color similar to that of normal clay bricks (Pawar and Garud, 2014), an 18% reduction in weight, more compressive strength, and less water absorption (Naganathan *et al.*, 2015). Utilization of fly ash leads to a reduction in cement consumption in construction activities, which results in a reduction of greenhouse gases (Krithika and Kumar, 2020). With fly ash, geopolymer concrete matrix with industrial waste as binder content decreased carbon emissions by 30% to 50% (Kumar and Srinivasu, 2022).

Nanoparticles, defined as ultrafine particles with diameters ranging from1 and 100 nanometers (10-12 nm), behave differently from macroparticles. Fundamental properties can be improved to generate materials that perform better than macrolevel materials. There has been a lot of scientific research in recent decades on the various applications of nanoparticles in construction, electronics, manufacturing, cosmetics, and medicine. The advantages of using nanoparticles in construction are immense, promising extraordinary physical and chemical properties for modified construction materials (Mohajerani *et al.*, 2019). Nanoparticles have unique physical and chemical properties that make it possible to design systems with high sensitivity, large surface areas, special surface effects, high functional density, catalytic effects, and high strain resistance (Teizer *et al.*, 2012). PA is one of the most important conducting polymers owing to its easy preparation and doping process, good electrical conductivity and environmental stability, and potential use as an electrochromic device, sensor, and corrosion -protective paint (Raghavendra *et al.*, 2003). Adding fly ash to the PA matrix regulates the conductivity of the material (Gvozdenović *et al.*, 2011).

A novel macroporous brick fabricated and composited with a conductive polymer (PA) was suggested as a promisingly capable structure, augmenting the safety of our lives against hazardous electromagnetic irradiations. The macroporous structure of bricks reduced energy consumption and improved electromagnetic interference shielding efficiency in buildings (Peymanfar *et al.*, 2020).

This study aims to develop new geopolymer adobe materials that are used in the manufacturing of alternative adobe bricks by using Nanoscale polyaniline polymer and fly ash as soil stabilizers and to determine the mechanical, physical, and chemical properties of the new geopolymer adobe materials.

MATERIALS AND METHODS

In this study, soil samples were the main components for manufacturing moisture resistant geopolymer adobe composite material. The soil sample was used as the base material. At the same time, FA and PA were utilized as a soil stabilizer. The current study was conducted at the Department of Agricultural & Biosystems Engineering, Faculty of Agriculture, Alexandria University, Egypt, over the period from June to September 2021.

2.1. Materials

The soil sample (Fig. 1a) was collected from Burj Al Arab Station for Agricultural Research and Experiments, Faculty of Agriculture, Alexandria University, Egypt. The soil sample was taken from the top layer (30 cm) using a shovel and placed in polyethylene bags. The soil texture is sandy clay loam (70% sand, 8% silt, and 22% loam), with a bulk density of 1.35

g/cm^3 and a field capacity of 24.33%. The scanning electron microscope shows the shape of soil particles, where irregular-shaped grains appear (Fig. 2a). Also, the chemical elemental analysis of soil was estimated in Table 1 by Wavelength Dispersive X-Ray Fluorescence Spectrometry. The total percentage of oxides (SiO_2, Al_2O_3, and Fe_2O_3) in soil was 60.72%. This value is lower than the minimum required value of 70% for using pozzolans. The soil loss during the ignition was about 24.89 %. This value is higher than the allowed value of 12%, the maximum percentage required for using pozzolans. It means that the soil contains more unburned carbon, which is not pozzolanic material.

While, Class F fly ash (FA) is used as the main component for manufacturing geopolymer mortar. FA (Fig. 1b) is a by–product of the combustion of powdered coal or other materials in thermal power plants, it was obtained from the Sika Egypt company. A helium pycnometer determined the true density of FA to be 2.29 g/cm^3. The scanning electron microscope shows the shape of FA particles, where regular-shaped grains appear (Fig. 2b). The grain sizes of fly ashes differ between 1–150 µm. On the other hand, the chemical composition of FA is determined by using the X-ray fluorescence technique as presented in Table 1. Fly ashes contain substantial amounts of SiO_2, Al_2O_3, and Fe_2O_3. The amount of SiO_2, $Al_2 O_3$, and $Fe_2 O_3$ corresponds to 84.61% of fly ash chemical composition and satisfies the conditions in ASTM Standards for fly ashes.

Also, PA (Fig. 1c) is a very popular conductive polymer that has been rediscovered in recent years (Beygisangchin *et al.*, 2021). It has good environmental stability, easy polymerization, low cost, hydrophilic, nonionic, and high hydraulic conductivity. The SEM images of PA are displayed in Fig. 2c. The PA particles have a rod-like shape with a diameter of 0.45–0.72 µm and a length of 1.2–3.05 µm. On the other hand, the alkaline solution was a combination of sodium silicate and sodium hydroxide (14 M) solutions with a ratio of 1.5:1 sodium silicate to sodium hydroxide, purchased from a local supplier. The sodium silicate solution (Na_2SiO_3) comprises Na_2O = 13.7%, SiO_2 = 29.4%, and water = 55.9% by mass. The alkaline solution (Fig.1d) was prepared by mixing the sodium silicate solution, sodium hydroxide solution and water for each sample as shown in Table 2. In this research, the use of pure tap water with no obvious contaminants was utilized.

Table 1: Elemental composition of fly ash and soil material as precentage of weight

Parameters,%	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	P_2O_5	Cl^-	LOI
Fly ash	48.72	30.66	5.23	6.50	1.10	0.88	1.02	0.45	0.729	0.001	4.71
Soil	5.12	27.53	29.19	6.72	3.97	1.20	0.45	0.52	0.200	0.21	24.89

Fig. 1. The images of materials used in this study: (a) soil, (b) Fly ash, (c) Polyaniline, and (d) sodium silicate & sodium hydroxide solution.

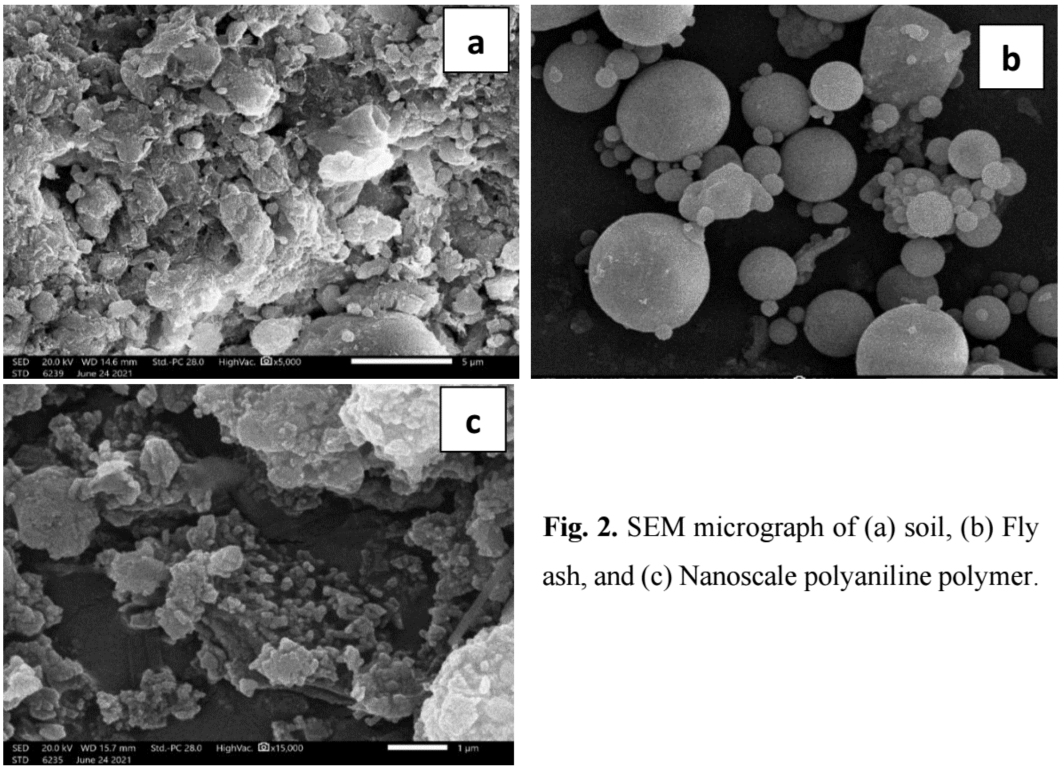

Fig. 2. SEM micrograph of (a) soil, (b) Fly ash, and (c) Nanoscale polyaniline polymer.

2.1.1. Treatments of specimens

In order to conduct an examination of the adobe mixes, four distinct treatments were generated. The quantities of materials utilized in each adobe composites series are presented in Table 2.

Table 2: Quantity of materials used in each adobe mixture of different treatments.

Treatments	Soil, g	Fly ash, g	NaOH, g	Na_2SiO_3, g	Water, g	PA, g
T1	1000	0	0	0	415	0
T2	1000	0	140	210	65	0
T3	666	334	140	210	65	0
T4	666	334	140	210	65	10

2.1.2. Preparation of test specimen

The materials for the used mixture were weighed and mixed in a dry condition for 5 min. The dry mixture was subjected to the addition of sodium hydroxide and sodium silicate solutions, followed by stirring for a duration of 10 minutes. The geopolymer mixture that was acquired was carefully put into a mold with dimensions of 40 x 40 x 160 mm^3. The samples were subjected to a temperature of 80 ^oC for a duration of 24 hours within the oven. Subsequently, the specimens were extracted from the molds. Subsequently, the specimens underwent a curing process at ambient temperature for a duration of 28 days.

2.2 Methods

2.2.1 Mechanical tests

The compressive strength (CS) of the geopolymer samples was tested according to the European Standard (DIN EN 196-1). A servo-hydraulic material testing system with a maximum capacity of 100 kN was used to apply a constant loading rate test of 140 kg/cm^2/min until the resistance of the example to the expanding load separates and no more noteworthy burden can be limited. The most amazing weight associated with the samples is to be recorded and the nearness of the strong and any unusual components in the sort of failure is noted. A specimen of dimensions of 40 x 40 x 40 mm^3 was used for each test. Three replicates for each treatment were tested. The CS was calculated as follows:

$$CS = \frac{Fu}{W^2}$$

Where:

CS :Compression stress, MPa.

Fu : Ultimate load, N.

W : Width of sample, mm.

2.2.2. Physical properties

2.2.2.1. Bulk density. For determining the bulk density of hardened composites, a set of samples, each of dimensions 40 x 40 x 160 mm^3, were tested. Three replicates of each treatment were tested after 28 days of removing the mold. All samples were dried at 105 ± 5 ^oC until a constant weight was achieved and then placed in the air to cool. The weight and volume of each dried specimen were measured. The bulk density was determined according to the following equation:

$$\rho_b = \frac{W_d}{V}$$

Where:

ρ_b : Bulk density of the sample, g/cm^3.

W_d : Weight of dry sample, g.

V : Volume of the sample, cm^3.

2.2.2.2. Water absorption. Three replicates were used for each test after 28 days to determine water absorption. The samples underwent a drying process at a temperature of 105 ± 5 °C until a stable weight was obtained. Water absorption was determined using the American Standard Testing Method ASTM (D-1037): the dried specimens were weighed to the nearest 0.01 g. Subsequently, the specimens under investigation were immersed in water at ambient temperature for a duration of 24 hours. The specimens were hung to drain the water for 10 min and the excess surface water was wiped off and then weighed to the nearest 0.01 g. The amount of absorbed water after 24 h was calculated as a percentage of the original weight of test specimens.

$$W = \left(\frac{W_a - W_d}{W_d}\right) * 100$$

Where:

W: water absorption, %

W_d: specimen dry weight, g.

W_a: weight of saturated sample in air, g.

2.2.3. Scanning electronic microscope (SEM)

A scanning electron microscope (JSM-5300; JEOL, Japan) was used to investigate the soil structure, FA, and geopolymer adobe composites. The samples were gold sputter-coated before analysis and the microscope was operated at 20 kV, as described by Ali et al. (2021).

RESULTS

3.1 Compressive Strength

The compressive strength is one of the main engineering parameters that give an indicator of the quality of the construction materials. The variation of the compressive strength related to the treatment used is shown in Fig. 3. The Obtained results revealed that for the all-tested treatments, compressive strengths were higher than those for the control treatment (T1).

It is clear from the data that using AM and FA without or with PA had an effect on compressive strength. As shown in Fig. 3, treatment T4 had the highest compressive strength (7.8 MPa) than T1, T2, and T3. Compressive strength increased by 47.17 % (for T2 treatment), 188% (for T3 treatment), and 1460 % (for T4 treatment) compared toT1 treatment, respectively. The obtained strength of the used treatment in the study comes in the range between 2 and 10 MPa for the stabilized adobe composite, as reported by Meukam *et al*. (2004) with a cement content of 3–10%.

The development of compressive strength is due to the following reasons: (a) The addition of AM to soil can enhance its strength by forming compound groups between SiO_2 and Al_2O_3 in soil by the polymerization reaction. (b) Fly ash is known to exhibit pozzolanic properties, meaning it can react with AM in the presence of moisture to form more additional cementitious compounds. These compounds contribute to the strength and durability of adobe materials by filling voids, and binding the particles together, and (c) The addition of polyaniline in small amounts to geopolymer adobe bricks can potentially enhance their mechanical strength.

Polyaniline is a conductive polymer that can improve the interfacial bonding between the geopolymer matrix and the aggregates. This improved bonding can lead to an increase in the strength of the adobe material.

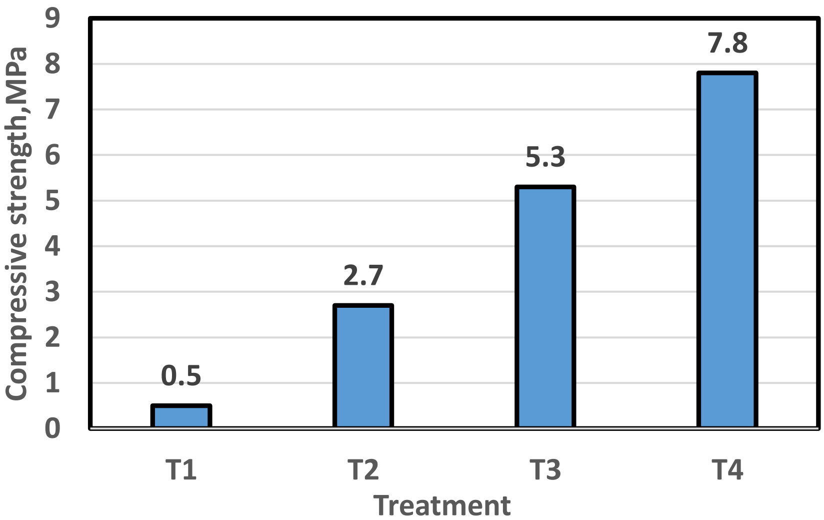

Fig.3: The relationship between different treatment and compressive strength

3.2. Bulk density

The variation in density was observed in terms of the different treatments, as shown in Fig. 4. Density observations showed that the density was increased in treatments compared with control treatment (T1). The density of GSAC ranged between 2.05 and 2.28 g/cm^3. All of the treatments were within the normal range of bulk density of adobe materials, which ranged between 1.3 and 2.5 g/cm^3 (Ige and Danso, 2021). Treatment (T4) showed a greater bulk density value compared with T1, T2, and T3 by 9.62, 6.05, and 2.24%, respectively. The specific value of GSAC depends on many factors, such as the proportion of fly ash, activator type, curing temperature, and compaction methods employed during the manufacturing process.

In this study, density increases due to the following reasons: (a) The AM is a viscus solution, and when it is mixed with the soil grains (Treatment T2), it causes the soil grains to slide smoothly over to gather, which leads to a reduction in the interstitial spaces; therefore, density increases compared to the control treatment T1. (b) By adding fly ash to the mixture of soil and AM (Treatment T3), this leads to an increase in the sliding of the soil particles over each other. This is because the fly ash particles are spherical in shape and have smaller dimensions than the soil particles, which leads to filling the interstitial spaces and thus increasing the density of treatment T3 compared to treatments T1and T2. (c). Polyaniline is a polymer that acts as an attractive material for soil particles due to the generation of electrostatic charges by adding it, which works to reduce the interstitial voids and increase the density, especially when added in an alkaline medium (Treatment T4).

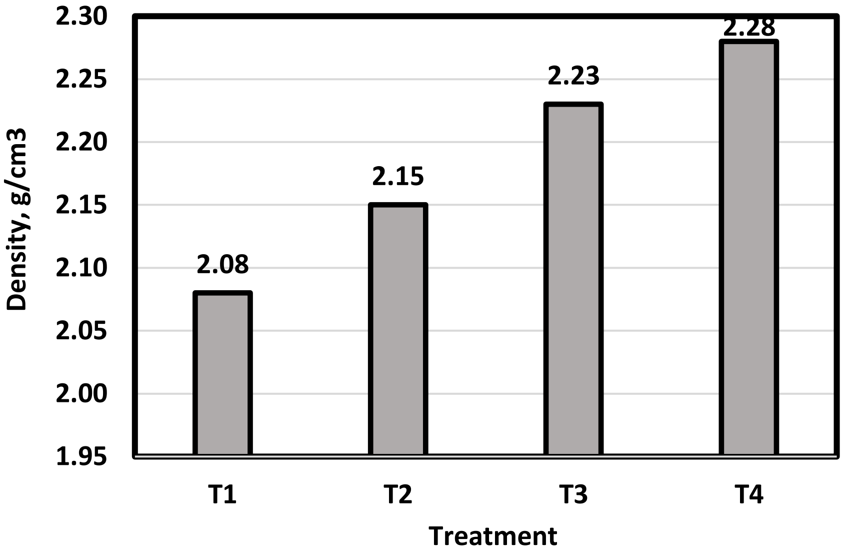

Fig.4: The relationship between different treatment and bulk density

3.3 Water Absorption

Fig. 5 shows the water absorption test results. It has been seen that the water absorption of the tested specimens changed with the treatment used. T1 specimens failed immediately when soaked in water due to the fact that the water worked on the soil particles. This is a normal phenomenon for adobe composites, which are made without any stabilizer's (Wiehle *et al.*, 2022).

While T2, T3, and T4 treatments can stay in shape after up to 120 hours of water immersion. The rates of absorbed water increase with increasing the immersion time in water. All the tested treatment samples (T2, T3, and T4) had no damage to their shape (they did not collapse but kept staying in shape). As shown in Fig. 5, the geopolymer adobe samples had a water absorption ratio of 4.5,3.8, and 3.1 % at 24 hr immersion for T2, T3, and T4, respectively.

Also, water absorption increased to 6.9, 4.2, and 3.8 % at 120 hr immersion for T2, T3, and T4, respectively.

As reported by (Najar *et al.*, 2021) the water absorption of geopolymer adobe materials typically ranges from 10% to 30%. In this fact, all the tested samples had lower water absorption than the normal adobe material. Therefore, the adobe material produced in this study had very good durability against water. The reduction in water absorption may be due to the following reasons: the addition of AM, FA, and PA increases the density and decreases the porosity of the adobe materials, which reduces the water absorption.

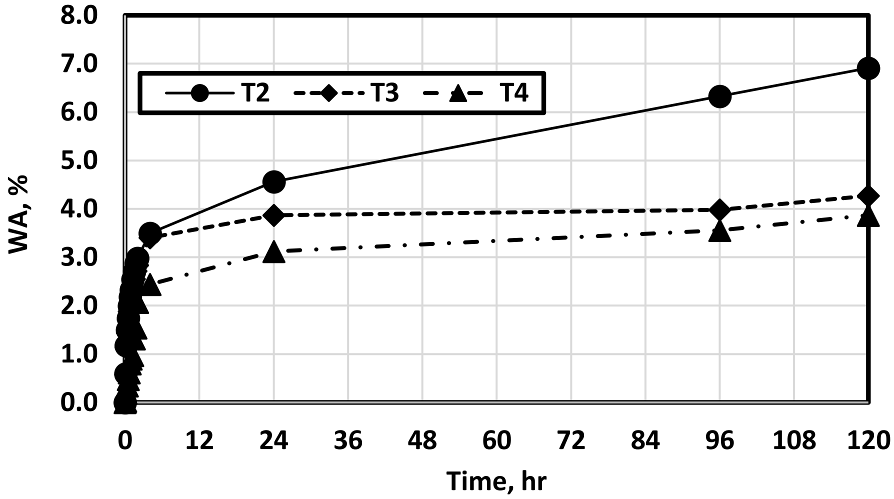

Fig.5: The relationship between different treatment and water absorption (WA).

3.4. SEM Analysis

The SEM images of different hardened soil composites are displayed in Fig. 6. SEM state-of-the-art analysis provides an enlarged image of the size, shape, composition, crystallography, and surface structures. It evaluates the differences in the surface and other physical and chemical characteristics of a specimen.

Fig. 6a shows the microscopic reaction characteristics of the treatment (T1), which consists of soil and water, shows that by adding water to the soil, and soil particles agglomerate, which leads to an increase in the size of soil grains and the appearance of voids between the grain blocks and each other, and this is a normal effect. It occurs when moisture increases and soil with a high calcium content dries up. By adding the alkaline solution to the soil form (Fig. 6b), geopolymer chains were formed between silicon oxides and aluminum oxides, leads to increase the cohesion between soil particles, which resulting to increasing soil resistance with a decreasing in the size of the interstitial voids between the soil particles each other.

By replacing the soil by fly ash, the silicon and aluminum oxide content increases, which resulting to increases the volume of accumulated soil particles and reduces the volume of inter-block spaces. The reason for this is due to the slipping between soil particles, which occurrence due to the interaction between the spherical shape of fly ash particles and the viscosity of the alkaline solution. Also, the geopolymer chains developed by adjusting the silica to alumina ratio (Fig. 6c).

On the other hand, when polyaniline polymer was incorporated in the reaction, the cohesion and bonding between all soil particles increases, so that the soil texture appeared very compact without any voids, which increased the composite resistance (Fig. 6d).

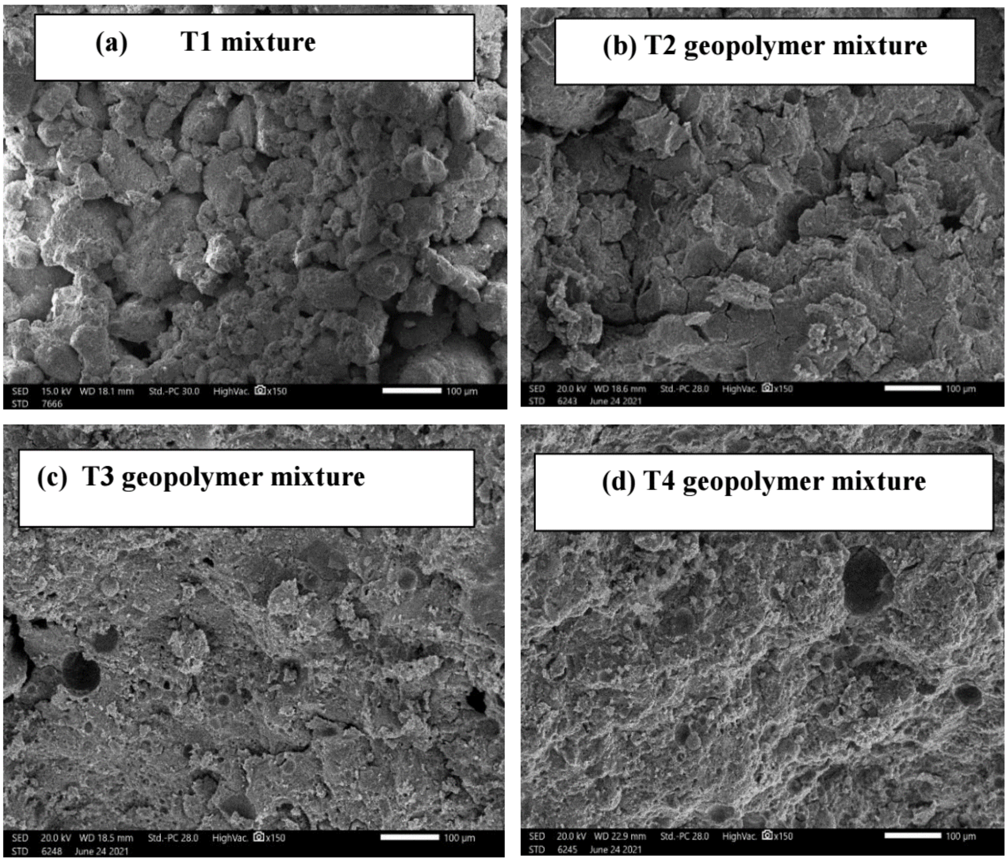

Fig. 6. SEM micrograph of (a) soil material, (b) geopolymer adobe material, (c) fly ash adobe material and (d) fly ash -polyaniline adobe material

DISCUSSION

In this study, the FA geopolymer adobe material with and without polyaniline polymer was produced and tested by measuring its bulk density, water absorption, and compressive strength after 28 days of curing in order to create a moisture-resistant geopolymer adobe material with a high compressive strength.

When soil and FA were combined in the presence of AM (as in mixturesT2 And T3), geopolymer synthesis took place, and the resulting geopolymer paste agglomerated the small particles into big soil grains. As shown in Fig. 7, the underlying chemical reactions that govern the geopolymer reaction are displayed schematically with Equations (1 & 2) (Cao et al., 2018). Initially, aluminosilicate precursors release Al^{+3} under highly alkaline conditions, which then forms AlO^{-4} tetrahedra that attracts group I cations to balance charges (Khale and Chaudhary, 2007).

These react with SiO_2 tetrahedra to form a three-dimensional amorphous polymeric chain (Muhammud and Gupta, 2022) The formation of the intermediate form of geopolymer precursor from the synthesis of silica and alumina in the presence of NaOH solution is described by Equation (1). The formation of a geometrics chain composed of Polysialate (-Si-O-Al-O-) bonds is described by Equation (2). Due to the chemical reaction, compressive strength improved from 0.5 MPa (for T1 composite) to 2.7 and 5.3 MPa, for T2 & T3 composites, respectively (Fig. 3). Also, density of T2 and T3 composites increased from 2.08 g/cm^3 (for T1 composite) to 2.15 and 2.23 g/cm^3, respectively (Fig. 4). While, composite water resistance (durability) was improved. The water absorption of 4.56% and 3.86%, which was reached after 24 hours of soaking in water, for the T2 and T3 mixtures, respectively (Fig. 5). SEM micrograph shows a reduction in the composite porosity, T3 composite shows the lowest porosity (Fig. 6c) than T1 composite (Fig. 6a) and T2 composite (Fig. 6b).

However, when polyaniline, sodium hydroxide (NaOH), and sodium silicate (Na_2SiO_3) are mixed together (as in T4 mixture), several reactions can occur as follow:

1. Interaction with Sodium Hydroxide (NaOH)

Polyaniline is classified as a conducting polymer that exhibits the ability to undergo both protonation and deprotonation reactions. When polyaniline is mixed with sodium hydroxide, the following reactions can occur:

- Protonation: Polyaniline can react with NaOH to form water-soluble polyaniline salt. The reaction involves the deprotonation of NaOH and the protonation of polyaniline. The resulting product is a water-soluble polyaniline salt, which can be represented as $(C_6H_5NH_2)_n + OH^- \rightarrow (C_6H_5NH_3^+)_n + OH^-$. This protonation reaction makes polyaniline more soluble in water.
- Swelling: Polyaniline can also undergo a swelling effect when mixed with NaOH solution. The interaction between polyaniline and NaOH can result in the polymer absorbing water and swelling.

2. Interaction with Sodium Silicate (Na_2SiO_3)

Polyaniline does not directly react with sodium silicate. However, sodium silicate can act as a dispersing agent or stabilizer for polyaniline. It may aid in a solution's uniform dispersion of polyaniline particle. It's important to keep in mind that the precise reaction and behavior of polyaniline may change based on things like the reagent concentration, the reaction circumstances, and the kind of polyaniline (e.g., emeraldine base or salt form).

On the other hand, the use of polyaniline, sodium hydroxide, and sodium silicate combination in geopolymer concrete may enhance some of the material's characteristics. Instead of Portland cement, geopolymer concrete uses an alkali-activated binder that is often created from industrial by-products like fly ash or slag.

The addition of polyaniline, sodium hydroxide, and sodium silicate to geopolymer concrete can have the following effects:

- Enhanced mechanical properties: Polyaniline is a conductive polymer that can improve the mechanical strength and toughness of materials when incorporated into them. By adding polyaniline to geopolymer concrete, it may enhance its mechanical properties such as compressive strength, flexural strength, and impact resistance.

- Improved durability: Polyaniline has shown potential as a corrosion inhibitor and can provide protection against the deterioration of concrete due to environmental factors, such as chloride attack or carbonation. By incorporating polyaniline into geopolymer concrete, it may help improve its resistance to corrosion and increase its durability.

- The scientific reasons behind these potential improvements lie in the unique properties of polyaniline. Its presence can reinforce the geopolymer matrix, resulting in enhanced mechanical strength. Additionally, polyaniline's ability to act as a corrosion inhibitor can protect the material from degradation. The electrical conductivity of polyaniline can further modify the properties of geopolymer concrete, making it suitable for specific applications.

- In this study, the addition of polyaniline to the geopolymer matrix (T4 composite) improves all the engineering properties of adobe material. Compressive strength was increased from 5.3 MPa for T3 composite to 7.8 MPa for T4 composite (Fig. 3). Also, density was increased from 2.23 for T3 composite to 2.28 g/cm^3 for T4 composite (Fig. 4). While, water absorption at 24 hr was decreased from 3.86 % for T3 composite to 3.11% for T4 composite (Fig. 5).

Finally, it should be pointed out that the actual improvements in properties would depend on various factors, including the concentration of polyaniline, the composition of the geopolymer concrete, curing conditions, and the specific application requirements. Experimentation and optimization would be required to ascertain the exact effects and advantages of incorporating this mixture into geopolymer concrete.

CONCLUSIONS

Based on the obtained results, the following conclusions may be drawn:

- Cement in construction should be reduced because it will increase the emission of CO_2 in the world. The use of cement in building construction will add to the effects of greenhouse gases on the environment, because the limestone calcinations and burning coal by the cement industry would result in emissions of carbon dioxide gas (CO_2). Therefore, this research using fly ash and nano polyaniline polymer for cement substitute to stabilizing adobe materials.
- Hazardous effects and disposal problems of waste materials like fly ash can be reduced through this study.
- All geopolymer brick samples with fly ash and nano-polymer manufactured in this study were classified as good quality with compressive strength of above 5.3 MPa.
- As observed in SEM images, the use of alkaline concentration with or without nano-polymer encouraged the fly ash joining in geopolymeric reaction, enhancing the properties of geopolymer adobe materials.
- Stabilizing adobe materials with Nanoscale polyaniline and fly ash prove to be energy efficient and aim towards to producing a “Greener Eco-friendly materials for Construction”.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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تأثير البولي انيلين النانوي والرماد المتطاير على الخواص الهندسية للطوب اللبن بمنطقة الساحل الشمالي في مصر

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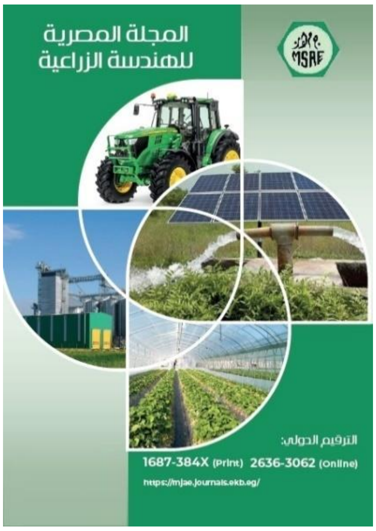

الكلمات المفتاحية:
الطوب اللبن؛ البولي انيلن المتناهي الصغر؛ الرماد المتطاير

الملخص العربي

تصف هذه الورقة بحثًا تجريبيًا حول تحسين خواص الطوب اللبن المصنع من التربة باستخدام الرماد المتطاير (FA) و البولي انيليتن النانوي (PA) عن طريق تفاعل البلمرة باستخدام محلول قلوي (AM) يتكون من خلط محلول هيدروكسيد الصوديوم ومحلول سيليكات الصوديوم. حيث تم تثبيت مولارية محلول هيدروكسيد الصوديوم عند ١٤ مول كما تم تثبيت نسبة محلول سيليكات الصوديوم إلى محلول هيدروكسيد الصوديوم عند ١,٥. يتناول البحث دراسة الخواص الهندسية لأربعة خلطات اساسية للطوب الجيوليمري GSAC وهي : الخلطة الاولي (خليط التحكم T1) يتكون من التربة و ماء الخلط (Water & NS) ؛ الخلطة الثانية T2 تتكون من التربة و المحلول القلوي (AM & NA)؛ الخلطة الثالثة T3 تتكون من التربة و الرماد المتطاير و المحلول القلوي (NS, FA&AM) و الخلطة الرابعة T4 وتتكون من التربة و الرماد المتطاير و البولي انيلين و المحلول القاوي (NS, FA, PA,& AM) . تم دراسة كل من مقاومة الضغط ومعدل تشرب المياه والتغير في الكثافة بالإضافة الي التغير في التركيب البنائي باستخدام الميكروسكوب الالكتروني. وقد لوحظ وجود تأثيرات معنوية في جميع الصفات المدروسة. وقد اظهرت النتائج ما يلي : ان الخليط المكون من (NS, FA, PA,& AM) اعطي اعلي قيمة لكل من مقاومة الضغط والكثافة (٧,٨ نيوتن/مم٢ و٢,٢٨ جم/سم٣، على التوالي). كما اظهر نفس الخليط ادني معدل امتصاص للماء حيث بلغ معدل الامتصاص ٢,٠٢٪ و٣,١١٪ بعد ٢ و٢٤ ساعة من النقع في الماء، على التوالي. كما أظهرت نتائج تحليل البنية المجهرية تحت الميكروسكوب الالكتروني ان الخلطة الرابعة هي أفضل تركيب بنائي مع أقل مسامية.