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Mechanical properties and microstructure of alkali activated mortar containing unexpanded clay

I.F. Nasser [a], M.A. Ali [b], M.J. Kadhim [b,*]
[a] Institute of Technology, Middle Technical University, Baghdad, Iraq
[b] Materials Engineering Department, Al-Mustansiriayah University, Baghdad, Iraq
* Corresponding e-mail address: dr.mohammedjkadhim@yahoo.com
ORCID identifier: https://orcid.org/0000-0002-7783-2927 (M.J.K.)

ABSTRACT

Purpose: In building constructions, due to the decrease of local raw materials and for sustainability purpose, beside the need of light pieces to be used in roofing and false ceiling; an alkali-activated mortar is the new development where pozzolanic material is used instead of cement and activated by an alkaline solution. Therefore, in this research, alkali-activated mortar containing unexpanded clay as a fine aggregate with a dry density of 1652 kg/m^3, compressive strength of 3.2 MPa, and thermal conductivity of 0.4 (W/m.K) was produced ,also boards were performed in a dimension of 305×152×12 mm as to use them in false ceiling, and reinforced with 0.25 and 0.5% steel fibre to improve their toughness by 370.8% and 1146.1% compared with reference boards, which made them good choice to used them in roofing and secondary ceiling.

Design/methodology/approach: For preparation of alkali-activated mortar, low calcium fly ash (FA) was used as a source binder material. In addition, super-plasticizer and unexpanded clay as a fine aggregate (produce from the crushed artificial aggregate) in the ratio of 1:2.75 fly ash/fine aggregate. The paste was prepared by mixing fly ash with an alkali silicate solution, in a solid-to-liquid ratio of 0.4. Alkali silicate activator was prepared by mixing the NaOH and Na_2SiO_3 solutions at the mass ratios of 2.5. The concentrations of the NaOH was the same molarity of (14M).To improve the mechanical properties of the reference mortar mixture ,steel fibre with 0.25 and 0.5% content were added to the mix .The specimens were tested for water absorption, dry density, compressive strength, flexural strengths, flexural toughness, and thermal conductivity, in addition to the Scanning Electron Microscope test (SEM) for all mortar mixes. Alkali-activated mortar boards with (305×152×12 mm) were prepared and tested for flexural strength and toughness.

Findings: The results indicated that the modulus of rupture for mortar boards reinforced with 0.25 and 0.5% steel fibre exhibits an increase of (3.68-12.10)%. In comparison, the toughness is increased by about 370.8% and 1146.1%, respectively, as compared with the reference mortar (without fibre) which made them resistance to accident, in addition to use them in roofing due to their thermal insulation.

Research limitations/implications: Further research is needed to make a similar board using another sustainable material. We can examine the thermal insulation that we can get from these board, especially in the building in Iraq which the weather faces high temperatures.

Practical implications: There is a by-product that we could get from the electricity station in Iraq. We must study how we get rid of it.

Originality/value: This paper investigate how to produce a new light board using artificial aggregate made from unexpanded clay, which has many benefits in building insulation roofing.

Keywords: Alkali-activated mortar, Pozzolanic material, Unexpanded clay, Flexural toughness, Scanning Electron Microscope, Thermal insulation

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PROPERTIES

1. Introduction

Concrete is in great demand on using Portland cement, led to emissions high volume of carbon dioxide and logical imbalance as a result of natural resources consumption [1]. For the last years, numerous researches have been carried out to produce high-performance concrete with high strength and durability by using mineral additives. The use of mineral additives such as pozzolana has increased over recent years because when used correctly in a certain percentage, it can improve the fresh and hardened properties of concrete like strength, durability, and permeability of concrete. Also, incorporating mineral admixtures with Portland cement improves different properties of concrete, such as lowering water temperature, increasing water resistance, reducing aggregate alkali reaction, and enhancing resistance to sulphate soils attack [2]. Fly ash as a mineral admixture is a by-product of burning coals of the electrical power plant, which is available in abundance, but it creates a disposal problem, and much of it is required to get rid of it. Fly ash is lightweight and easy to fly, which creates extreme health problems like asthma, bronchitis, etc. [3]. Using of fly ash to produce cementless concrete gain extra attention by numerous researchers all over the world. This is because fly ash is one of the cheapest aluminium silicate materials rich in silica (SiO_2 40%-70% by weight) and alumina (Al_2O_3 15%-30% by weight) [4]. In the world, the total production of fly ash is about 780 million tons per year. Also, using a ton of fly ash instead of Portland cement can save emissions to the air [3]. The mortar or concrete containing fly ash is eco-friendly, and it can produce high volume fly ash concrete with 50% fly ash replacement by weight of cement [5]. The alkali-activated mortar was one of many potential ideas mooted in the preliminary concept study in the last decays. The materials were placed forward because they replaced Portland cement, which has a high carbon/energy footprint in produce, and is activated by alkaline solution. Yang et al. [6] investigated the properties of twelve alkali-activated mortars activated by sodium silicate in addition to reference mortar containing Portland cement. Sodium oxide in sodium silicate is used for evaluating alkali-activated mortars properties. Ground granulated blast-furnace slag (GGBS) and fly ash were used as a source material. For various mortars, the sodium oxide/source material was in the range of (0.038-0.164). The researchers measured the compressive strength, flexural strength and shrinkage strain of different mortars. They concluded that the alkali quality coefficient affect significantly on the compressive strength. For alkali-activated mortar containing GGBS, a higher development in compressive strength occurred at early age, while in alkali-activated mortar with fly ash the higher development in strength occurred at long-term age. Hardjito et al. [7] studied, the effect of different factors on the fresh and hardened properties of low-calcium fly ash cementitious mortar. The factors include the concentration of sodium hydroxide solution, the ratio of alkaline activator solution/fly ash, and the ratio of water/solids. Tests were carried out on 50 mm cubes mortar specimens. For curing, the specimens were put in an oven at an elevated temperature of 65ºC, 70ºC, and 80ºC for 24 hours. Then, they remoulded and put to cool at ambient temperature before being tested. Fourteen mixes cast with different morality, with (sodium silicate/sodium hydroxide solution) of 2.5. The researchers concluded that the compressive strength increases with increasing the concentration of alkaline activator. Also, the compressive strength of mortar decreases as increasing the water/solids ratio, and the samples cured for one day at 65ºC have the highest compressive strength, which ranges between (1.6-20) MPa at 28 days age, Medri et al. [8] produced different mixes of lightweight composite panels containing alkali-activated metakaolin as binder with different binders compositions (metakaolin or alumina-based) and using expanded vermiculite as aggregate in two sizes. The researchers studied the mechanical and thermal properties of the produced composites. They obtained lightweight composite panels with densities between (700-900) kg/m^3 and an average strength of 2 MPa. Alkali-activated concrete is different from the conventional concrete which consists of hydraulic cement as a binder. An alkali-activated mineral admixture as a binding medium holding an inert aggregate to form a compact mass. The concrete can provide several benefits: high early strength [2], high temperature resistance [3]. Furthermore, perfect durability for aggressiveness environments compared with the normal concrete. Mechanical properties and data analysis for the prediction of different mechanical properties of alkali-activated concrete were investigated [9]. fly ash (FA) based cementless mortar has better compressive strength (81% more for natural sand and 89% more for crushed sand) than the general OPC mortar [10]. Cementless concrete with acceptable σc values obtain using FA as source binder materials. The σc of FA-BGPC raise whenever SS/SH reach around 2.5, at this point the reduction begin. The molarity of NaOH in the range of 10-16 M to produce a mixtures with acceptable σc behaviourism, was suggested to use. The curing method; It was suggested to use the oven curing temperatures in around 50-80°C for about 24 h to get an effective polymerization process to reach accepted σc [4]. Based on research by Ahmed et al., studied the eco-efficient fly ash-based cementless concrete for 510 researches, they concluded that it can participate in sustainable development because it is non-cement concrete and uses industrial ash or by-product as a binder. These properties of the mixture lead to a reduction in the proportion of carbon dioxide in the air, energy consumption, as well as the disposal of waste and the cost of construction [11].

2. Materials

The fly ash used is the main component of cement substitute, it's a grey powder consisting mostly of spherical particles. The amount of SiO_2, Al_2O_3 and Fe_2O_3 more than 75, CaO is 2.25, which indicate the type of fly ash is F [12]. Unexpanded clay as a fine aggregate (UECFa) is used in this investigation [13]. The gradation of unexpanded clay aggregate is prepared depending on the Iraq Standard under the number 5 of the year 1984 [14], and its properties within ASTM C330 specification [15]. For the alkaline activators, the solutions of sodium silicate and sodium hydroxide are used by mixing the NaOH and Na_2SiO_3 solutions at the mass ratios of 2.5. The concentrations of the NaOH was 14 in molarity [16] in addition to superplasticizer DARACEM 19CFMQ is used which complies with the ASTM C494-2005 Types F [17], crimped steel fibres of about (1000 MPa) ultimate tensile strength with aspect ratio (l/d) of 55 were used. The properties of artificial lightweight fine aggregate used in this investigation was of about 17 for absorption, 1.69 for specific gravity and 1180 (kg/m^3) for dry density.

3. Preparing, casting, and curing of cementless alkali-activated mortar

Many trial mixes were investigated to prepare alkali-activated mortar. Low calcium fly ash (FA) was used as source binder material with variable water contain ratio (b/w), and super-plasticizer, and the fine aggregate used was unexpanded clay. After many trials, one mortar mix (MOR0) was adopted, and to enhance the mechanicals properties, steel fibre in two percentages (0.25 and 0.5%) were added to the selected mortar mix and produced (MOR0.25 and MOR 0.5) mixes, respectively. Table 1 shows the details of various alkali-activated mortar containing unexpanded clay (AAUC) mortar. For all mortar mixes, water to binder ratio (W/FA) of 0.4% and a binder to the fine aggregate ratio (FA/Fa) of 1:2.75 were used. Through the preparation of the paste, the fly ash was mixed with alkali solution in a ratio of (solid/liquid) equal to 0.4. The preparation of the alkali activator includes mixing the NaOH and Na_2SiO_3 solutions at the mass ratios of 2.5. The concentration of the NaOH was 14 M. Alkali-activated mortars were produced by mixing the alkali-activated paste with crushed unexpanded clay, as shown in Figure 1. The prepared mixtures were tested for workability with flow test; then they were cast into standard prism moulds of (40×40×160) mm and wooden boards with dimensions

Table 1.
Details of AAUC mortar mixes

Mix Design.	FA kg/m^3	UECFa kg/m^3	W/FA	Fibre kg/m^3
MOR0	500	1375	0.4	-
MOR0.25	500	1375	0.4	19.5
MOR0.5	500	1375	0.4	39

Note 1: FA= fly ash, A=activator, W= water, A/FA= 0.4.
Note 2: Superplasticizer dosage =2% by weight of fly ash, molarity of NaOH=14.

Fig. 1. Production of AAUC mortar

measured 305 mm in length and 152 mm in width with 12 mm thickness; also cubic specimens of 50 mm and 100 mm were cast. Then covered with polyethylene sheets and left for one day. After that the specimens were put in a Kline at 90°C for 48 hours. Then, the samples were left to cool down and rest at room temperature. The specimens were tested for water absorption, dry density, compressive strength, flexural strengths, flexural toughness, and thermal conductivity. In addition, Scanning Electron Microscope test (SEM) was done as one of the most important microstructural test.

4. Experimental tests for alkali-activated mortar

The following tests were carried out to investigate the properties of AAUC mortar.

4.1. Workability

Flow test on mortar was carried out according to ASTM C-1437-2015 [18], as shown in Figure 2. The value of flow is the average of mortar diameters spread in disc, measured in two perpendicular directions.

Fig. 2. Flow test of the AAUC mortar

4.2. Dry density

This test was determined to depend on ASTM C642 [19], using cubes with dimensions of 100 mm and the average of three specimens represented the value of dry density at the age of 28 days.

4.3. Water absorption

The test was carried out depending on ASTM C642 [19] where three cubes of 100 mm for each mix at 28 days of age were taken to determine their water absorption.

4.4. Compressive strength

The mortar specimens used were 50 mm cubes. They were tested at the age of 28 days according to ASTM c109/c109M [20] by a digital compression machine with a capacity of 2000 kN, see Figure 3. For each mix, the average result of three specimens was recorded.

Fig. 3. Compressive strength test of AAUC

4.5. Flexural strength and flexural toughness

This test was done according to ASTM C348 [21] using prisms of dimensions (40×40×160) mm. The specimens were simply supported throughout 120 mm and load data displacement rate of 0.5 mm/min (which was conducted in a displacement controlled mode). The test data were recorded using computer-controlled data acquisition system as shown in Figure 4. The load-deflection curves are characterized by flexural strength, and toughness (total area under the load-deflection curve). The average of three tested specimens represents the value of the flexural strength for each mix. Flexural strength was calculated from the simple beam bending formula according to ASTM C348/2015.

Fig. 4. Flexural test machine

4.6. Thermal conductivity

The test includes preparing the specimens with dimensions of (4x4x2) cm, and their thermal conductivity was calculated at room temperature by the hot disk instrument. This test is carried out in the Materials Department at the University of Technology.

4.7. Scanning Electron Microscope (SEM) of AAUC mortar matrix

For obtaining the fracture surface texture of samples, the SEM (Model: TESCAN-VEGA/USA) with detector (X-Flasb 5030) and tungsten source is used which contain a magnification ranges between (10-80,000). The work distance is ranged between (1-12 mm) and operates with a voltage of (1-20 kV). The dimensions of the tested samples were (1x1x1 cm) and vacuum dried before taking the SEM images to prevent the build-up of electric charge when the electron beam scans the specimen.

4.8. Flexural strength and flexural toughness for AAUC boards

Flexural tests of AAUC boards were performed at 28 days according to ASTM C1185-12 [22] using special wooden moulds of dimensions 305 mm in length 152 mm in width with 12 mm thickness. The specimens were simply supported throughout (255 mm) and loaded at a displacement rate of 0.5 mm/min (conducted in a displacement-controlled mode). The test data were recorded using a computer-controlled data acquisition system. The load-deflection curves were determined by flexural strength and toughness (the total area under load deflection curve). The average of three tested specimens was used for each flexural strength value. The flexural strength was calculated from the simple beam bending formula according to ASTM C1185-12 [22].

5. Results and discussion

In order to evaluate the properties of boards, all the results were discussed in detail to show if these light boards with stand the purpose which produce for (lightweight, good thermal conductivity, magnifies flexural strength and toughness).

5.1. Properties of AAUC mortar

Flow ability is the ability of a fresh mortar mix to fill the mould properly with the desired work without any reduction in the concrete quality. In this investigation, the main factor that affected on the workability of mortar mixes is the fibre content. The test results show that the flow value deceases whenever the percentage of steel fibre increased, as shown in Table 2 and presented in Figure 5. This is due to the increment in the mixtures viscosity as a result of the large surface area of fibres [23].

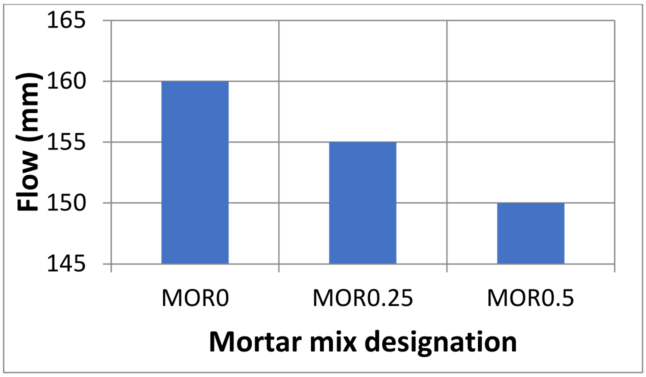

Fig. 5. Flow of AAUC mortar

5.2. Dry density

The densities of (AAUC) mixes are presented in Table 2 and shown in Figure 6. The range of density is between (1625-1750) kg/m^3, which is lower than that of traditional concrete or mortar (with normal weight). This is due to the using of unexpanded clay that has lower specific gravity compared with natural sand. The incorporation of fibre to mix (MOR 0.25 and MOR 0.5) causes an increase in density to about (4.12% and 6%), respectively compared with the control mix (MOR0), and that is due to the high specific gravity of the used fibre.

Table 2.
Some properties of AAUC mortar

Mortar mix design	Flow, mm	Density, kg/m^3	Comp. strength, MPa	Water absorption, %	Thermal conductivity, W/m. K
MOR0	160	1652	3.2	14.0	0.487
MOR0.25	155	1720	3.4	12.9	0.560
MOR0.5	150	1750	4.2	12.0	0.620

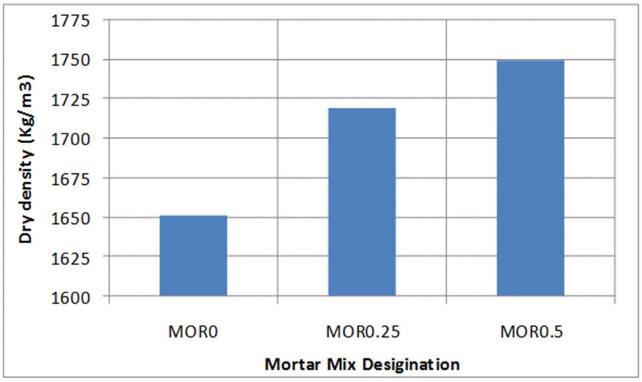

Fig. 6. The dry density of AAUC mortar

5.3. Water absorption

The test results are apparent in Table 2 and shown in Figure 7 and Figure 8. The water absorption of reference (AAUC) mix was (14%), and this is due to the high absorption of unexpanded clay aggregate used (17%). At the same time, the incorporation of steel fibre with 0.25 and 0.5% volume fraction causes a reduction in water absorption to 12.9 and 12%, respectively, due to the increase in the continuous interaction products over the steel fibre closing the pores.

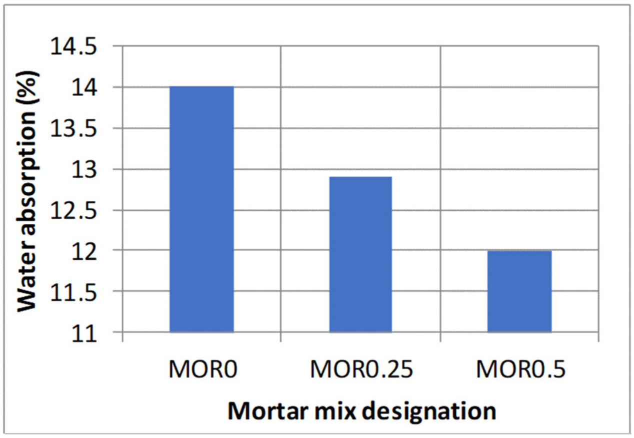

Fig. 7. Water absorption of AAUC mortar

5.4. Compressive strength

The mechanical properties of (AAUC) mortar are of primary importance regardless of possible applications in civil engineering. A satisfactory strength is considered one of the primary conditions for the possibility of using cementless concrete in construction [24]. The test is performed using three specimens per mortar mix.

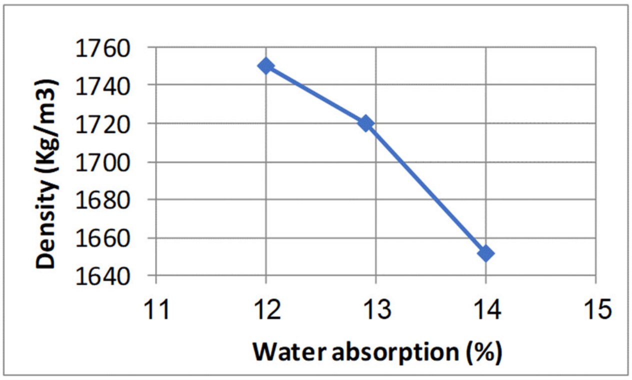

Fig. 8. Relationship between density and water absorption for AAUC mortar

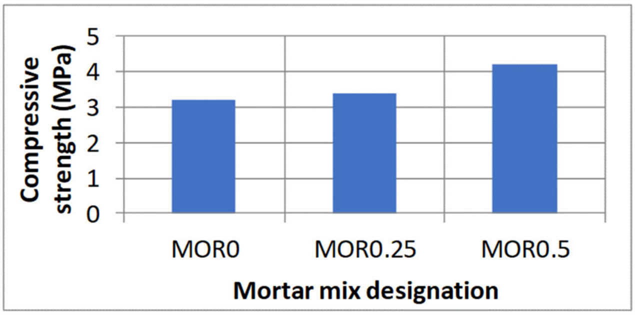

Fig. 9. Compressive strength of AAUC mortar

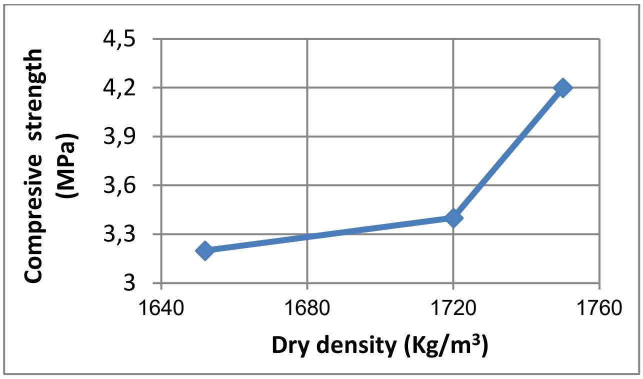

Fig. 10. Dry density and compressive strength of AAUC mortar

The compressive strength of the produced mortar is 3.2 MPa at 28 days with a density of 1652 kg/m^3 which could be used for insulation purposes, as shown in Figure 9 and Figure 10, which shows lower strength compared to compressive strength value due to the use of unexpanded clay as a fine aggregate than natural sand due to losses of hardened particle component. On the other hand, Hardjito [7] obtained a compressive strength ranging between (1.6 MPa-20 MPa)

Table 3.
Flexural strength and toughness on AAUC mortar prism

Mortar mix design.	Flexural strength, MPa	Increase in strength, %	Toughness, N.m	Increase in toughness, %
MOR0	1.215	0.0	0.0617	-
MOR0.25	1.924	58.4	0.554	798
MOR0.5	2.707	122.8	0.936	1417

using normal sand. The fibre content effect on the compressive strength of (AAUC) mortar, the compressive strength was raised to 6.25% and 23% respectively as the fibre content increases from 0.25% to 0.5%, concerning the control mix. This is due to the higher gained bond between fibres-paste interfaces, in addition to the fibre effect in restricting the growth of microcracks, which lead to higher strength of the composite.

5.5. Flexural toughness and flexural strength

The flexural toughness and strength of AAUC mortar are displayed in Table 3. Figure 11 shows (AAUC) mortar reinforced with 0.25% and 0.5% steel fibre mixes exhibit increment in flexural strength of 58% and 122% respectively relative to the plain AAUC mortar specimens. Significant enhancements in load capacity and toughness were observed with higher content of fibres.

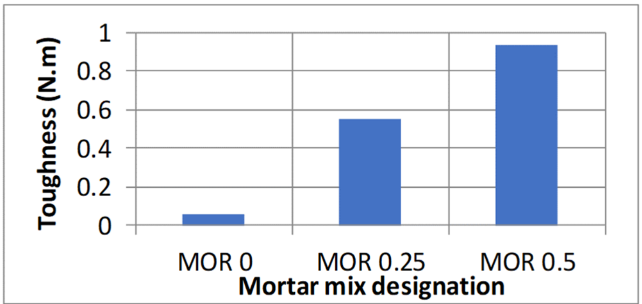

Fig. 11. Toughness of AAUC mortar

The load-deflection curves of (AAUC) mortar specimens are shown in Figure 12, at the age of 28 days. This confirmed that specimens with no fibre have a rectilinear load-deflection relationship with no post-crack response when defeated at the peak load. On the contrary, the specimens reinforced (AAUC) mortar demonstration significant enhancement. When the load above the point of variation increases, the first crack begins. Later, the stresses of the matrix are transported to the fibres and increase deflection slightly up leading to specimens' failure due to de-bonding. The results indicated that the fibrous specimens show better flexural performance also, load-deflection relationship significantly improved related to plain specimen. This is because steel fibre offers better toughness and strength properties. In addition, there is a superior flexural performance compare to non-fibre reinforced specimens because of the fibres effect and the fine particles from unexpanded clay that made a good inter lock in the paste. The results show that incorporating steel fibre improves the flexural strength and toughness of AAUC mortar significantly. Its percentage increase in flexural is 58.4%, 122.8% for the steel fibre specimens of 0.25% and 0.5% respectively comparative to specimens without fibre.

The percentages increase in toughness for AAUC mortar reinforced with 0.25% and 0.5% fibre is 798-1417% respectively, compared to reference mortar. The fibrous AAUC mortar shows advances after the cracking behaviour of alternative mortar. Improvement in the flexural fracture of AAUC reinforced with fibres is attributing to the increase of energy required to breakage due to the crack arresting procedure. The fibres operate as crack eliminators or walls, increasing the tortuosities of an expanding crack [25]. Micro cracks and crack formation have been identified by Häkkinen [25] earlier in the matrix due to generalized shrinkage caused by the chemical reaction that regulates hydration and stiffening in the alkaline matrix, and this is faster than the conservative hydrolysis process in typical concrete. The interfacial zone between the fibres and hardened matrix) is the area in which cracks could be located. Fibre splitting during load transfer to the main composite fracture allows to demonstrate the typical stiffening behaviour achieved with enhanced matrix fracture [26].

5.6. Thermal conductivity

Thermal conductivity for material is the quantity of heat It pass through the unit thickness in a vertical direction to the surface of a unit area, due to the unit temperature gradient below it certain conditions. Thermal conductivity in Table 2 and Figure 13 show very low value of 0.487 W/m.K for the control mix (MOR0) which make it suitable as insulation construction material. The superior thermal resistance related to conventional materials would permit this concrete

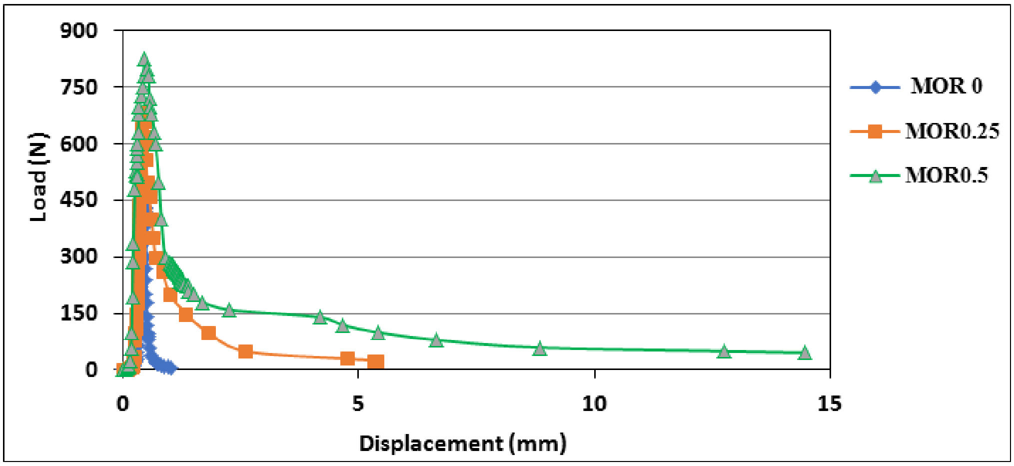

Fig. 12. Load-deflection curves of AAUC prism specimens

to be a feasible material for energy efficiency. The increase in steel fibre volume friction leads to an increase in thermal conductivity as the fibre owns supreme thermal conductivity. Based on the above results, the specimens fall under the category of structural and insulating concrete – Class-II (compressive strength between 3.5 and 15 MPa and the thermal conductivity is less than 0.75 W/m.K).

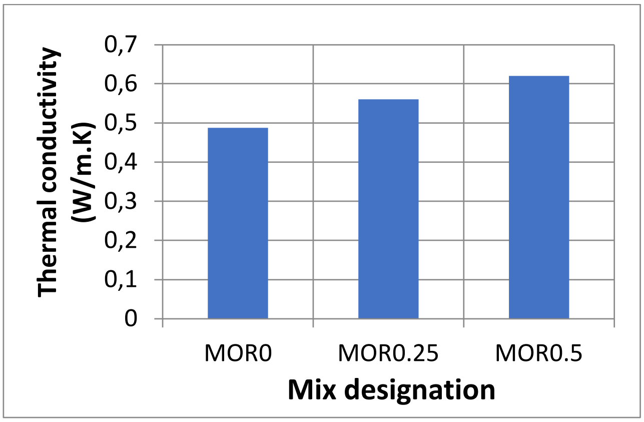

Fig. 13. The thermal conductivity of AAUC mortar

5.7. Scanning Electron Microscope test image of AAUC mortar matrix

The Scanning Electron Microscope test (SEM) images for the AAUC mortar specimens are given in Figure 14. The images show that the matrix is denes in some portions with well-formed crystalline phases, but still heterogeneous portions with the high number of un-hydrated fly ash particles observed in Figure 14a and Figure 14b.

Figure 14c shows the microstructure of zone B that indicated in Figure 14b; the microscopy shows that give a gain in bonding between both the binder of polymeric and residual materials react with supplementary materials. Some fly ash particles react with the alkali-activator solution, covered partially with reaction products. The needle shaped crystals also seen in Figure 14c.

Figure 14d shows the SEM image of AAUC mortar reinforced with steel fibre. It can be considered that the products covered the surface of fibre which is mean that there is an adequate connection between the AAUC matrix and steel fibres; hence the composite would have good mechanical properties.

5.8. Properties of AAUC boards

The (AAUC) boards were prepared in a dimension of 305×152×12 mm, and flexural tests have been used for these boards. The results in Table 4 indicated that the modulus of rupture for (AAUC) boards reinforced with 0.25 and 0.5% steel fibre, exhibit an increase of 3.6 and 12%, respectively, compared to the reference mortar (without fibre), this result related to higher bonding strength between the cement matrix and crimped steel fibre and the high value of fibre tensile strength. The incorporation of fibre considerably improves the toughness of (AAUC) reinforced boards by 370.8% and 1146.1% for boards reinforced with 0.25 and 0.5% steel fibre compared with reference boards (without fibre), as shown in Figure 15. The high result is argued to the modulus of elasticity for the fibres that substantially improve the load capacity, which also significantly increases the toughness values with incorporation of fibre to AAUC mixes. This increase in results was due to the crack width control caused

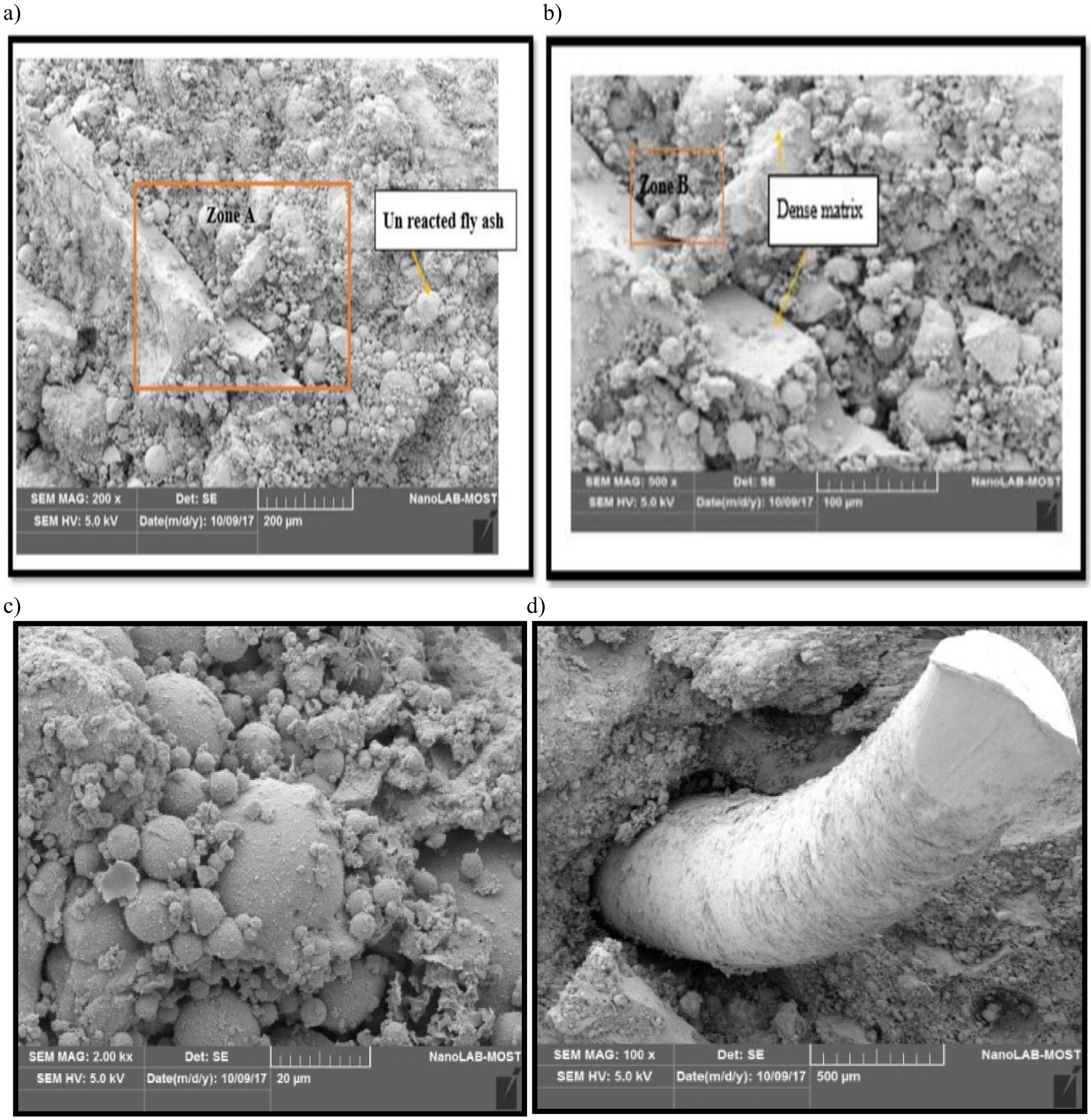

Fig. 14. SEM image of AAUC mortar: matrix (a), zone A (b), zone B (c), reinforced with steel fibre (d)

Table 4.
Flexural strength and toughness of (AAUC) boards

Boards mix design	Load, N	Flexural strength, MPa	Increase in flex strength, %	Toughness, N.m	Increase in toughness, %
BOS0	114	1.90	-	0.089	-
BOS0.25	118	1.97	3.68	0.419	370.8
BOS0.5	128	2.13	12.10	1.109	1146.1

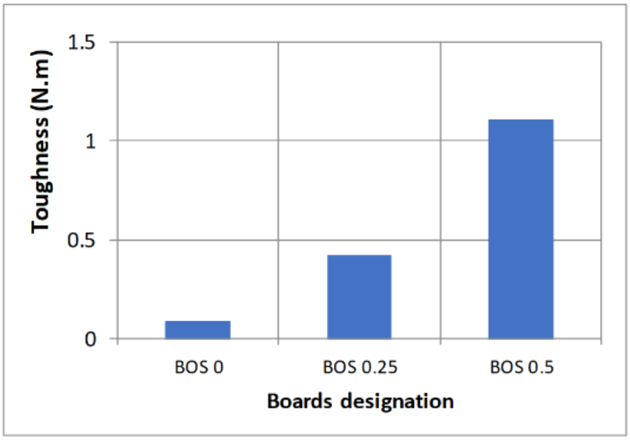

Fig. 15. Flexural toughness on AAUC boards

by the steel fibres, especially at the micro stage. This prevents the propagation of cracks and gathering under load application and transforms the stresses across the cracks preventing its growth till the failure stages when fibre is pulled out [27]. Load-deflection curves of (AAUC) board specimens shown in Figure 16, it's obvious that the behaver show the same as that for Load-deflection curves of (AAUC) prism specimens.

6. Mode of failure for (AAUC) mortar prisms

The steel fibres effect on the ductility of AAUC prism is clear in Figure 17. The specimens with fibres have higher ductility than their corresponded specimens without steel fibre, leading to a great increase in flexural strength in prisms of 58.4, 122.7% compared to the reference mix MOR0 without steel fibres. This increase in results was due to the crack width control caused by the steel fibres, especially at the micro stage [27]. The MOR0 specimens suffer from sudden broken with a loud noise. On the contrary, the MOR0.25, MOR0.5 specimens were much more ductility and it took more time to fail. The length of fibres start to bridge the macro cracks until failure [28].

7. Mode of failure for (AAUC) boards

The optimum value of stiffness that is given to improve the ductility and cracking behaviour of concrete reinforcement [27,29]. Plain boards specimens achieved toughness at 0.089 J. The incorporation of steel fibres to mixes increases their toughness and ductility values. Failure of plain board specimens is a sudden broken state as shown in Figures 18(a-c), while Figures 18(d-f), show a ductile broken state for board reinforced with 0.25% steel fibre specimens, and board specimens reinforced with 0.5% steel fibre show more ductile broken state. Boards reinforced with steel fibre are not separated into two parts. This is due to the fact that, the fibre bridges the micro cracks through its ability transferring loads that increase the maximum applied load and also increase the ductility of reinforced specimens that do not break directly in accordance with the first notch is begin.

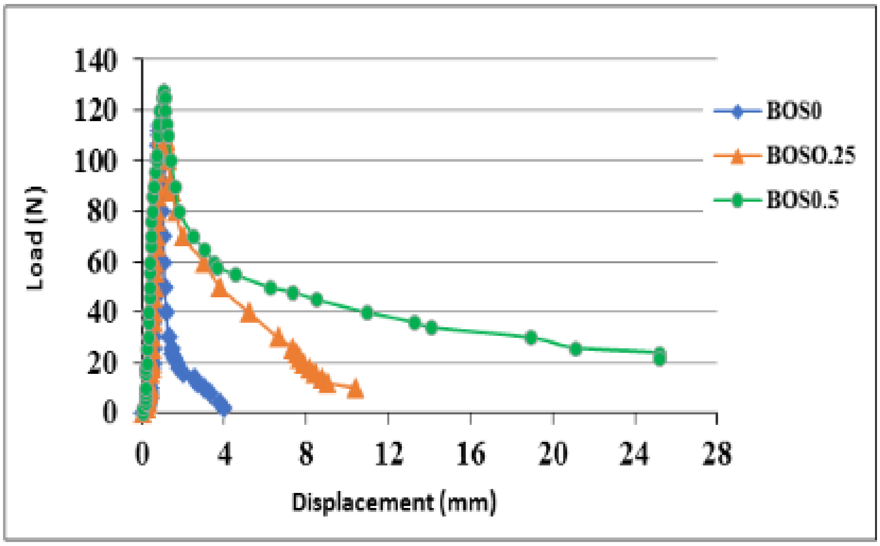

Fig. 16. Load-deflection curves of AAUC board specimens

Fig. 17. Mode of failure for AAUC mortar specimens

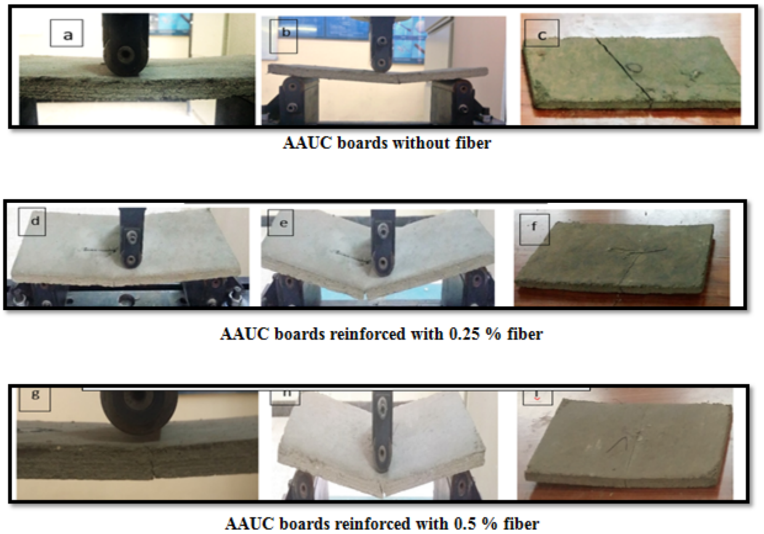

Fig. 18. Mode of failure for AAUC boards

8. Conclusions

This research focused on the development of mechanical properties and thermal insulating of lightweight cementless concrete using locally available waste materials for sustainable development.

1. Cementless alkali-activated mortar containing unexpanded clay (AAUC) with a dry density of 1652 kg/m^3 and compressive strength of 3.2 MPa, the flexural strength of 1.215 MPa, and its thermal conductivity is 0.487 W/m.K at 28 days is produced in this investigation.
2. The inclusion of 0.25 and 0.5% steel fibre in (AAUC) mortar increases the dry density values from 1652 kg/m^3 to 1720 and 1750 kg/m^3, respectively, while thermal conductivity increases from 0.487 to 0.560 and 0.62 W/m. K, respectively.
3. Cementless alkali-activated mortar (AAUC) mortar with 0.25% and 0.5% steel fibre have an increment in the modulus of rupture in the range of 58.3% and 122.7% relative to a plain one. While the percentages of increase in toughness are 798% and 1417%, respectively, compared to plain mortar specimens.
4. The modulus of rupture for (AAUC) boards reinforced with 0.25 and 0.5% steel fibre exhibit an increase in the range of 370.8 and 1146.1% compared to reference mortar (without fibre).

5. The plain specimens (AAUC) mortar show without a post crack responding, the linear relationship between load and deflection behaviour failed at the maximum load.

9. Recommendations/suggestions

1. Conducting more experiments to replace fly ash with local material like "Metakaolin".
2. Replace the unexpanded clay with another local light fine aggregate like "Atablecite" which is available in Iraq.

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