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Development of Insulating Masonry Bricks from Wood Fiber and Varying Milled Glass Proportion

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Abstract: Thermal efficient sandcrete bricks are masonry units with good thermal insulating properties. Wood fiber (WF) possesses low thermal conductivity, hence, its incorporation in mortar mix results in thermal efficient masonry units. Milled glass (MG) could be added for strength enhancement. This study incorporated WF into mortar mix at a constant dosage of 5 wt.%, with varying MG proportions of 0, 5, 10, 15 and 20 wt.% and cured for 7, 14 and 28 days. The results obtained showed minimization of porosity and water absorption at increasing MG content. Density and compressive strength were enhanced as MG content increased. Flexural and splitting tensile strengths appreciated and peaked at 15 wt.% MG. Thermal performance measured demonstrated progressive appreciation in thermal conductivity while specific heat capacity followed a downtrend as MG dosage increased. The study revealed that the collage of 5 wt. % wood fiber and 15 wt. % MG yielded optimum result. The study, therefore, concludes that the addition of milled glass and wood fiber positively and significantly affected the properties of sandcrete bricks. 15 wt.% of milled glass and 5% wood fiber inclusion in sandcrete bricks are recommended for use by construction practitioners.
Keywords: Milled glass; Properties; Sandcrete bricks; Wood fiber.

1. Introduction

Demand for structures keeps rising on account of various reasons like population growth, technological advancement and structural modification in cities. This in turn places demands on construction materials. One of the well-known approaches in this field is the use of waste for building materials production [1-4]. Concrete bricks are essential structural units for construction and are experiencing price hikes based on the high cost of component materials like sand and cement. Over time, structural materials developers are devising means of lowering the cost of these bricks by incorporating some waste materials like agricultural and industrial wastes into the sand/clay-cement mix [5–9]. Most of the wastes are being employed as cement replacement or aggregate replacement either partially or fully [10]. Such wastes include rice husk and its ash [11], coconut shell ash [12], eggshell [13], palm kernel shell [14] and agro fibers [15, 16]. The essence of adding waste is for a low cost without compromising strength [17–20] in fact in some cases, strengths are enhanced due to initiation of pozzolanic reaction as a result of silica content present in these wastes [21–23].

To achieve bricks with good thermal insulation properties, the inclusion of additives with lower thermal conductivity in cement bricks results in a decrease in thermal conductivity of the bricks effect of which reduces thermal exchange in buildings [24, 25]. A study carried out by Awang et al. [26] shows that the addition of polypropylene fiber (thermal conductivity value of 0.11 W/mK) in concrete mix resulted in a decrease in thermal conductivity of cement composite brick developed. Ashour et al. [27] showcased how thermal insulation was enhanced in brick by infusion of wheat straw and barley straw. Another agro-waste material is wood fiber also known as wood sawdust which has an average thermal conductivity of 0.061 W/mK [28]. As compared with the higher thermal conductivity of concrete bricks [29], the presence of sawdust in concrete initiates the lowering of the thermal conductivity of bricks. Hafed [30] studied thermal insulation in cement-wood sawdust concrete composite and observed progressive depreciation in thermal conductivity of concrete with sawdust proportion at 10, 20 and 30 wt.%. 85% reduction in thermal conductivity was achieved when 30 wt.% sawdust was incorporated. A similar investigation was conducted in [31] where the effect of rubber cuttings and wood sawdust on the properties of lightweight bricks was probed. The outcome realized showed a considerable reduction in thermal conductivity. Comparable results reflected 42.8% and 66.7% reduction in thermal conductivity for rubber cuttings and wood dust respectively on the infusion of 20 wt.% additives; depicting the fact that sawdust is more potent in lessening thermal conductivity than rubber cuttings. Therefore, the use of wood dust in concrete brick mixture depicts the fact that insulating concrete bricks are good for use in the present time of global warming which has brought about increased temperature.

Conversely, despite the effectiveness of sawdust in the thermal insulation of bricks, its presence is detrimental to the strength of the bricks. Investigation revealed an increasing proportion of sawdust in the concrete samples reflected reduction in density, compressive and flexural strengths. A close assessment investigated the effect of wood sawdust on strength of cement composite [32]; the result indicated a reduction in compressive strength as sawdust was used for the replacement of sand up to 50 wt.%. The same experience as with compressive strength was noted in [33]. Awal et al. [34] scrutinized properties of sawdust concrete and concluded that the presence of sawdust has a diminishing effect on compressive strength. From the reports, it can be inferred that the use of sawdust in concrete amounts to an improvement in insulating properties, however, strength is compromised.

A way of addressing the challenge is by the inclusion of strength-enhancing additives. Milled glass or glass powder which is obtained mostly from waste glass via grinding, milling and sieving has been reported to enhance strength in bricks [35, 36]. The waste glass was reported to have a pozzolanic effect on concrete due to silica content, hence it's been employed in concrete. This material was deduced to improve compressive, flexural and split tensile strength in the findings of [37, 38]. 20 wt.% waste glass inclusion in 38 gave an optimum 15% rise in 28th day compressive strength. Inclusion of 15 wt.% glass powder amounted to a 24.4% rise in compressive strength reported in [39] while 37% improvement in tensile strength was equally observed on account of 15 wt.% waste glass inclusion. In the light of these aforementioned observations and onto strength optimization of wood fiber-mortar bricks, milled glass at varying proportions of 5, 10, 15, 20 and 25 wt.% are employed as partial replacement of fine sand while wood dust is incorporated at 5 wt.% constant proportion of the concrete mix.

2. Materials and methods

2.1 Materials

The materials production process involved at the first stage, the acquisition of glass waste, cement, sawdust (wood fiber) and sand aggregate. The physical properties of the materials are shown in Table 1. Broken windows glass was collected, cleaned, crushed and grounded. The grounded glass was further milled in a ball mill and sieved to -150 µm. Sample of the milled glass was tested for chemical composition (Table 2) and properties such as specific gravity, density, fineness modulus and water absorption were assessed in consonance with [40, 41]. Ordinary Portland cement (OPC) of grade 43 conforming to [42, 43] required prescriptions was procured from a local merchant and tested for specific gravity [44] and fineness [45]. Initial and final setting time [46] at varying milled glass content of 0, 5, 10, 15, 20 and 25 wt.% and consistency [47] were also assessed. The chemical composition of milled glass and OPC was probed as par [48] specifications using X-ray fluorescence (XRF) and the result is presented in Table 2. The wood fiber was collected from a local sawmill sieved to -300 µm and prepared by soaking in water for 24 hours to reduce impurities and water sugar content sequel to 48 hours' sun drying. The study incorporated wood fiber at 5 wt.% constant proportion of the concrete mix as was recommended in previous study [49]. Natural sand (max size 1 mm) used was collected from a riverbank, washed and oven-dried at 110 °C for 24 hours prepared and graded in line with [50].

The specific gravity of input materials; milled glass, cement and sand are 2.71, 3.12 and 2.59, respectively while densities are 1.62, 3.08 and 1.38 g/cm^3, respectively, from which it is deduced that cement is the heaviest. It is also noted; milled glass is heavier than sand used, hence, partial replacement of the sand by milled glass powder in the composite mix could contribute to the densities of the bricks. The finest of the input materials is cement (fineness modulus of 1.22) which gives a view of a large surface area for reaction. The milled glass is also finer than the sand implying a large reactive surface area.

Table 2 reflects the chemical content of the input materials. As expected, cement is high in calcium oxide while sand and MG have a high content of silica. The presence of the two compounds effectuates the formation of calcium silicate hydrate (CSH) in the presence of cement and water thereby strengthening the composite matrix. Figure 1a illustrates the scanning electron image of the sand which pictures the presence of a distribution of grains of the sand (x500 magnification). Figure. 1b reflects the elemental composition of the sand pinpointing silicon as the predominant element confirming the result of the chemical composition of silica (Table 2).

Table 1. Physical properties of input materials

Property	Material values		
	Milled glass	Cement	Sand
Specific gravity	2.71	3.12	2.59
Density, g/cc	1.62	3.08	1.38
Fineness modulus	2.11	1.22	2.57
Water intake tendency (%)	0.12	-	1.9
Consistency (%)	-	28	-

Table 2: Chemical properties of milled glass and Ordinary Portland Cement

Compound	Content in Milled glass (wt.%)	Content in Cement (wt.%)	Content in Sand (wt.%)
CaO	5.32	62.7	1.3
SiO_2	73.41	19.4	78.8
Al_2O_3	3.52	5.7	8.4
Fe_2O_3	0.71	1.2	2.3
MgO	1.64	2	0.2
Na_2O	12.52	0.8	3.3
K_2O	0.22	0.3	3.0
SO_3	0.16	1.0	2.7
Others	2.50		
	Bogue's Compound		
	C_3S	52.8	
	C_2S	17.5	
	C_3A	11.2	
	C_4AF	7.6	

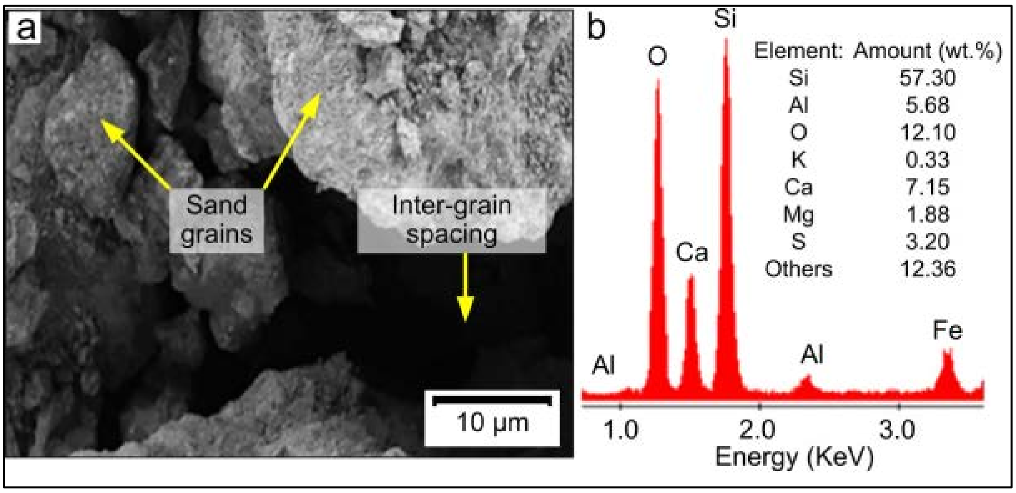

Figure 1. Properties of sand (a) morphological features (b) elemental composition

2.2 Sample preparation

Natural sand excavated from a riverbank was packed in a container and transported to the laboratory. Water was added to the sand, stirred manually and the mixture was allowed to settle for 24 hours. Afterward, the supernate was poured away and the process repeated two more times for the removal of impurities. The leftover sand was spread in the open and allowed to dry after which collected sand was oven-dried at 110 °C for 24 hours. Waste sawdust (wood fiber) was collected from a sawmill in Akure, Nigeria and soaked in water maintained at 40 °C for 24 hours to dissolve impurities and sugar content. The supernate was poured off and the process repeated two more times. The wood fiber was then spread in the open and allowed to dry after which they were transferred into an autoclave maintained at 100 °C and 5 bar pressure for 20 min. The dried wood fiber was mixed with cement, sand and water according to the mix proportion stipulated in Table 3. Mixing was carried out at room temperature (27 ± 2 °C) at a water-cement ratio of 0.52. Slump test and setting time test (in line with [51, 52] and [46, 53], respectively) were carried out at varying mix proportions to evaluate the effect of MG on the workability of the concrete mix. The mix was transferred into prism moulds of size 400 x 100 x 100 mm and 190 x 90 x 90 mm in dimension, cube mould of 100 mm and cylindrical mould of diameter 100 mm and height 200 mm (Figure 2). Vibratory compaction was utilized in compacting the mix at 500 vibrations/min. Samples were demolded after 24 hours and cured for 7, 14, and 28 days by air curing method. At an interval of 24 hours, water was sprayed on the samples in the open air to maintain humidity. Cured samples were tested and results evaluated.

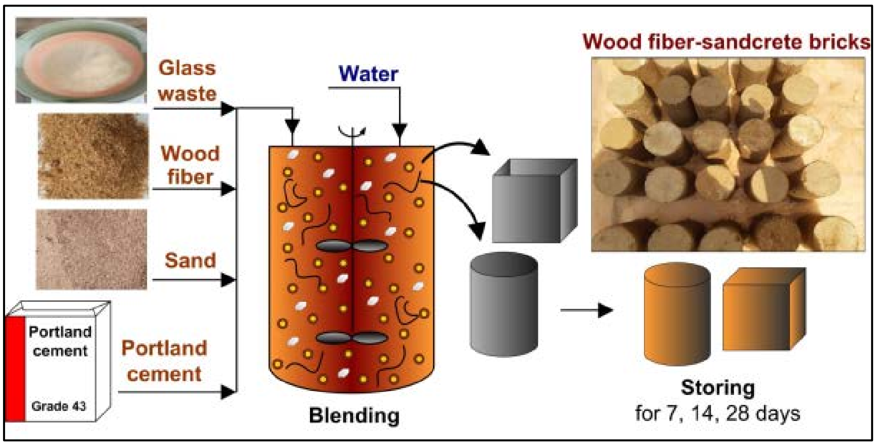

Figure 2. Scheme for wood fiber-sandcrete bricks preparation

Table 3. Mix proportion of bricks

Mix	Milled glass (wt. %)	Cement (wt. %)	Wood fiber (wt. %)	Sand (wt. %)
Mix-0	0	20	5	75
Mix-1	5	20	5	70
Mix-2	10	20	5	65
Mix-3	15	20	5	60
Mix-4	20	20	5	55
Mix-5	25	20	5	50

2.3 Test methods

Porosity, water absorption and dry density were assessed on concrete samples of dimension 190 x 90 x 90 mm and carried out after curing days of 7, 14, and 28 as stipulated in [54]. Samples were oven-dried at 110 °C for 12 hours after which they were weighed (M1). Sequel to this, the samples were immersed and soaked in water for 24 hours; soaked mass in air was recorded to be M2 while soaked mass when suspended in water was measured as M3. The properties were evaluated applying equations 1, 2, 3. Evaluation of thermal properties entailed test for thermal conductivity employing hot plate method in line with [55] and specific heat capacity using flow meter apparatus [56]. Compressive strength was carried out on sets of cubes (100 mm) samples in line with ASTM C 39 2016 using a universal testing machine (Instron 3369 Series) at 2000 N/s. Flexural strength test was conducted on samples of dimension 400 x 100 x 100 mm as per [57] under 3-point loading test. Cylindrical samples produced were utilized in evaluating split tensile strength according to [58] using the testing machine.

$$\text{Dry density} = M_1/(M_2-M_3) \quad (1)$$

$$\text{Porosity} = (M_2-M_1)/(M_2-M_3) \quad (2)$$

$$\text{Water absorption} = (M_2-M_1)/(M_1) \quad (3)$$

3. Results and discussion

3.1 Setting time and slump variation with varying milled glass content

Initial and final setting time for the mortar mix at increasing MG proportion reflected an upward trend as depicted in Figure 3a, which is attributable to a longer time of setting owing to the larger surface area as MG portion increased. Glass particles have very low water absorption tendency, therefore require more time for water to permeate the particles for chemical reaction to be initiated.

The slump in this study was reduced from 119 mm obtained at 0 wt.% milled glass addition to 65 mm obtainable on account of 25 wt.% MG addition as shown in Figure 3b. As MG proportion increased, the surface area increased and by extension, volume, requiring more water for mixing. Also linked to poor cohesion existing between MG particles and cement. Since water content for mix remains constant, a higher proportion of MG lowers workability. Slump in [59–61] demonstrated depreciation and downward trend as glass powder increased in proportion; buttressing observations in this study. Relationship between slump and MG portion is illustrated as inversely linear with coefficient of determination of 0.9847 depicting a significant effect of MG on slump (Figure 3b).

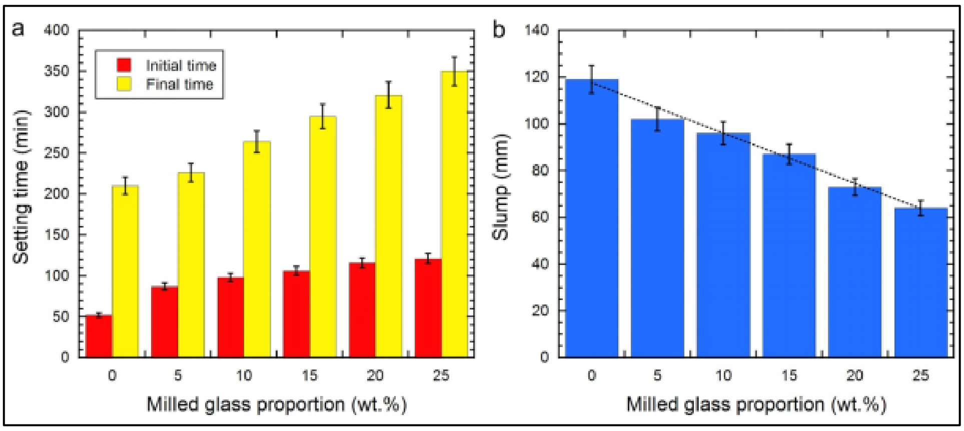

Figure 3. Variation in (a) setting time and (b) slump as milled glass proportion increased in the mix

3.2 Properties of bricks

3.2.1 Total porosity

It can be observed from Figure 4a that the porosity of the sandcrete bricks reduced with increased proportions of MG. Porosity relates to a void fraction within a material; in this case sandcrete bricks. Porosity plays role in determining the properties and durability performance of bricks; in fact, previous studies linked the strength of cementitious composites to porosity [62–64]. Pores are sites for entrapped air, water and gas (O_2 and CO_2) ingression into concrete bricks which in turn affects durability. [65–67] claimed and affirmed that high porosity in concrete reduces durability in concrete, due to the high diffusivity of gases and moisture transmission within the structure. Therefore, the reduction of pores in sandcrete bricks is expedient. As observed in Fig. 4a, porosity is reduced with milled glass loading. MG sieved to -150 µm serve as filler, filling in voids within the brick samples. The fineness of the MG initiates a higher surface area for pozzolanic reaction. As these MG increased, accretion in the pozzolanic reaction is engendered, the outcome of which produces C-S-H gel [68]. The gel further filled up pores leading to a reduction of porosity.

Porosity was also noted to diminish with lengthened curing days. This trend can be associated with increased hydrates formed over the curing days owing to hydration reaction. It can be inferred that increased MG loading and curing period provoke depreciation in porosity. 28-day curing arose 8.4, 10.9, 12.4, 13.2 and 14.8% reduction for 5, 10, 15, 20 and 25 wt.% MG content, respectively over the control mix. Investigations carried out in [69, 70] affirm the results presented in this study, in which porosity reduced with curing ages. Palankar et al. [71] stipulates < 30% for porosity and it can be noted that all samples had below 30% value hence fit for masonry purposes.

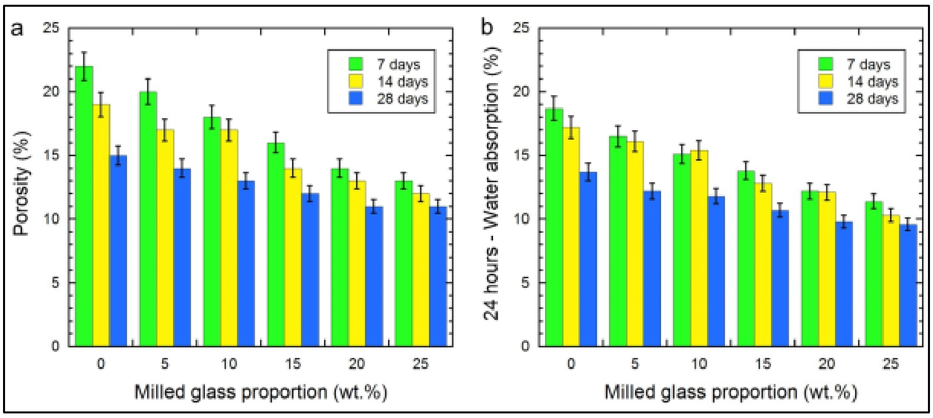

Figure 4. Influence of milled glass proportion and curing period on (a) porosity (b) water absorption

3.2.2 Water absorption by immersion

Though wood fiber presence within the matrix may kind of initiate some setbacks in terms of water uptake since the fibers are cellulose-based, hence hydrophilic. Been that as it may, MG presence and curing age duration presented a very good reduction in water absorption tendencies within the bricks as shown in Figure 4b. Similar to the experience of the outcome on porosity, water absorption (WA) trended downwards both at MG loading and lengthened curing days, affirming a direct link between the two parameters as buttressed in [72]. Increased MG particles prompted void reduction via infilling process effectuating less water intake. Another assisting factor in water absorption reduction is less water uptake tendencies of glass powder [73]. 28-day curing spawned 6.7, 13.3, 18.6, 22.2 and 22.2% reduction for 5, 10, 15, 20 and 25 wt.% MG content, respectively in comparison with the control mix. In effect, the inclusion of MG at the increasing proportion of 5 to 25 wt.% ensued minimization of water uptake potential in wood fiber sandcrete bricks. Curing duration is an effective variable in achieving the results.

Studies carried out in [74] depicted a reduction in water intake as glass powder content increased from 5 wt.% up to 25 wt.%. Similar to observation recorded in this study, the addition of waste glass at varying proportions of 0, 5, 10, 15, 20, 25 and 30 wt.% in sawdust cement brick reported in 74 presented progressive reduction in water absorption tendencies. Up to 22% reduction (relative to the value obtained for control brick) in water absorption capacity was achieved with the inclusion of 30 wt.% waste glass powder [75]. However, this study is contrary to [76] in which the addition of waste glass culminated into an upswing in water intake capacity.

3.2.3 Dry density

With increasing milled glass dosage, density appreciated progressively (Figure 5a). This is attributable to the heavier weight of the milled glass. Another reason for the boast in density can be ascribed to accretion in MG loading effectuating enhanced packing within the matrix. Due to the infilling of pores, there is enhanced packing density instigating an increase in dry density. 76 utilized glass powder in cementitious material at 0, 5, 10, 15, 20, and 25 % weight fraction and observed similar trend.

Evaluation made showed ascension in dry density as waste glass proportion rose. 3.4% density enhancement was reported in the study on incorporation of 25 wt.% waste glass. A similar study in [75] followed the same trend with increasing waste glass. The presence of the waste glass in sawdust cement brick instigated a gradual rise in density from 5 wt.% up to 30 wt.% waste glass at 5 wt.% interval. On the contrary, results presented in this study negates observation made in 37 where a downward trend in density was reported with glass powder loading which was found to be lighter than granite sand used unlike in this study where milled glass is heavier than sand used.

Figure 5b also revealed an uptrend in density with the curing period. Lengthened curing period initiates the formation of more hydrate phases which filled in pores, enhancing densification. The findings showcased in [77] agree with the rise in density discovered in this study. MG loading of 5, 10, 15, 20 and 25 wt.% amounted to density enhancement of 2.3 (insignificant, showing that 5% MG has an insignificant contribution on density of the composite), 5.2, 10.5, 14.5 and 17.4% over control sample at the end of 28 days curing, indicating the efficacy of milled glass in densification in wood fiber sandcrete bricks. In line with [78], density values of 28th day cured bricks lying between 1.75 to 2 g/cm^3 are medium weight bricks, therefore, bricks doped with 0 to 15 wt.% MG are medium bricks. Density above 2 g/cm^3 are classed as normal weight bricks; to that effect, wood fiber sandcrete bricks mixed with 20 and 25 wt.% MG are classed normal weight bricks.

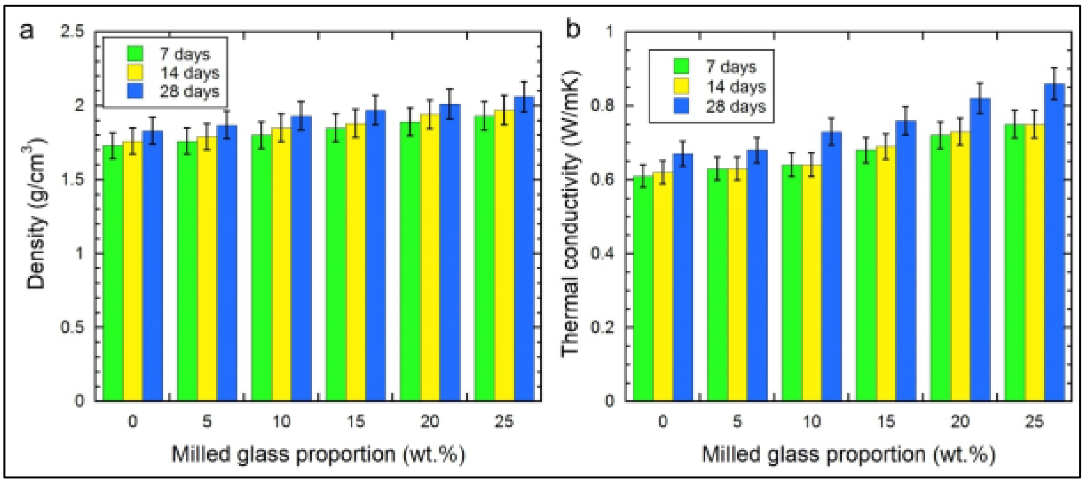

Figure 5. Influence of milled glass proportion and curing period on (a) dry density (b) thermal conductivity

3.2.4 Thermal conductivity

Thermal conductivity refers to heat energy transfer within a medium from one end of the medium to the other end. Insulating masonry bricks are of importance nowadays owing to the effect of climate change causing large heat exposure in buildings and structures. Improving thermal insulation in bricks is an area of research in structural material development. As observed in Figure 5b, thermal conductivity trended upward as MG content increased. This can be linked to reduced porosity with milled glass addition. Depreciation in porosity and voids amounted to the reduced inter-particle distance which begets enhanced cohesion and inter-particle interaction. Therefore, under thermal excitation, particles easily transfer energy from one to another. Also, the thermal conductivity of waste glass is higher when compared with other material input which made up the brick, delineating a reason for appreciation in thermal conductivity at increasing MG loading. Likewise, a higher curing period ensued a gradual rise in conductivity based on enhanced packing, [79] shown the relationship between thermal conductivity and bulk density. It was presented that the thermal conductivity of bricks; was boasted with an upswing in bulk density. Such a relationship is showcased in the present study (Figure 5b) as thermal conductivity trended upward with an increment in bulk density.

As analyzed in [80] bulk density has an inverse relationship with porosity; the same observation is repeated in this study (Figure 5b). Infusion of 5, 10 and 15 wt. % MG showed a marginal rise in thermal conductivity under 7, and 14 days. A significant increase was observed when 20 and 25 wt. % MG was incorporated in the bricks. Incorporation of 5, 10 and 15 wt.% MG had a significant effect on the property at 28 days curing offering 5.5, 8.9, 13.4, 18.9 and 23.4% enhancement in the property. Results in [81] which agrees with the outcome of this study presented 27 and 57.5% rise in thermal conductivity at 25 wt.% and 50 wt.% waste porcelain inclusion respectively for concrete samples cured for 60 days. At 25 wt.% MG under curing age of 56 days, 29.5% increment was observed with wood fiber-concrete bricks sample, a value close to ones realized in [81]. Conversely, reports of [82, 83] depicted a gradual reduction in thermal conductivity as waste glass proportion increased in the concrete mix. Krastev [84] dictated ≤1 W/m2K requirement for standard bricks for the public building of which all brick samples produced met the requirement.

3.2.5 Specific heat capacity

Specific heat capacity is the quantity of heat needed to raise the temperature of a unit mass of a substance by 1 K [85]. A higher heat capacity coefficient is necessary for insulating bricks. A study carried out in [83] presented increasing specific heat capacity of concrete with an increasing proportion of fly ash. Specific heat capacity remained constant for control brick (0 wt.% MG) cured for 7 and 14 days. Addition of 5, 10, wt.% MG brought no significant change in the value (Figure 6a), howbeit, incorporation of 15, 20 and 25 wt.% MG resulted in a progressive reduction in the property value under 14 days. It is observed that between 7 and 14 days there was a marginal reduction in specific heat. Under 28 days, there was a significant reduction in specific heat capacity as 5, 10, 15, 20 and 25 wt.% MG led to 7.7, 8.0, 8.0, 16.6 and 21.7% reduction, respectively. To maintain high specific heat capacity needed for masonry bricks, MG proportion between 0 and 15 wt.% seems to suffice. Results of He et al. [86] tallies with observations noted in this study as specific heat capacity reduced with increasing additives. 25 wt.% of ground rubber gave a 30% reduction in 28-day specific heat.

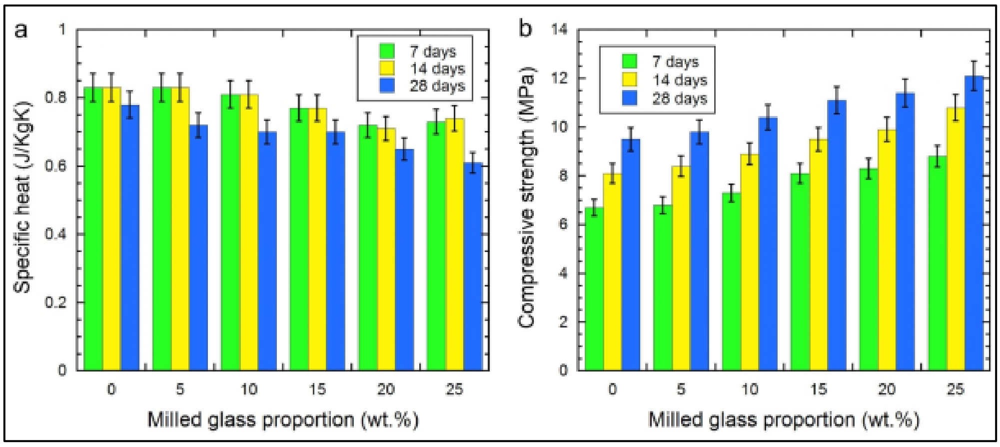

Figure 6. Influence of milled glass proportion and curing period on (a) specific heat capacity (b) compressive strength

3.2.6 Compressive strength

One important mechanical property which affects the performance of bricks is compressive strength. This property is affected by compaction and porosity. Higher compaction impels enhanced densification giving rise to lower porosity. In effect, compressive strength is improved. Figure 6b reveals improvement in compressive strength as MG content increased from 5 to 25 wt.% for all curing days. Glass powder inclusion in the sandcrete bricks at 5, 10, 15, 20 and 25 wt.%, respectively showed 11.9, 17.6, 26.9, 32.4 and 35.8% improvement in compressive strength relative to control mix over 28 days, buttressed in Sakale et al. [87]. Comparably, a study by Rajaiah et al. [88] presents an upswing in compressive strength from 0 to 20 wt.% glass powder input. Sandcrete brick samples were cured for 7, 14 and 28 days and it was revealed that the compressive strength appreciated to 28.25, 39.42 and 43.80 MPa, respectively effectuating enhancement of 24.5, 24.6 and 24.6% over the control bricks respectively.

In the present investigation, at 28th day curing, 25 wt.% milled glass powder brought about 48.3% improvement in strength over values obtained when cured for 7 days. This showcased importance of curing on strength boost. Utilization of waste glass (size between 150 and 75 μm) as partial replacement of cement and sand in Eme and Nwaobakata [89] exhibited an improvement of 42.2% boast in 28th day-compressive strength compared with 7-day strength on the incorporation of 20 wt.% waste glass powder. There was 24.3 and 41.2% increase in strength under 7 and 28 days respectively. Maximum 7 and 28-day cube compressive strength are 8.8 and 12.1 MPa. Fig. 7b pinpoints rise in compressive strength with concrete ages relative to control brick further affirmed in [67, 90, 91].

Curing promotes the hydration process accumulating hydrates within the matrix which enhances bond strength thereby precipitating strength improvement. Further studies [92–94] affirms the influence of curing in enhancing strength. In line with [95–98] all samples cured for 28 days met the standard for masonry bricks.

3.2.7 Flexural strength

Flexural strength as indicated in Figure 7a increased with consecutive MG dose up to 15 wt.% attributable to enhanced bond strength based on pozzolanic reaction. Flexural strength increased with curing ages on the dint of strong bond between matrix and additives from 5 to 20 wt.% for all curing days of 7, and 5 to 15 wt.% for 14 and 28 days similar to the outcome of 93, 99. It was further revealed that MG dosage beyond 20 wt.% for days 7 and 15 wt.% for days 14 and 28 kindled progressive reduction in strength. This observation is attributed to the hardened matrix as the hardened matrix reduces bending resistance in bricks [99, 100]. Also linked to the incohesive nature of the particles lowering resultant resistance to bending stress by the matrix. Investigations in [94, 101] revealed an increase in flexural strength up to 15 wt.% waste glass before the decline at a further rise in waste glass presence. Going by [98] requirement of ≥ 0.65 MPa and [102], the value of ≥ 0.25 MPa for masonry bricks, all samples met the requirement.

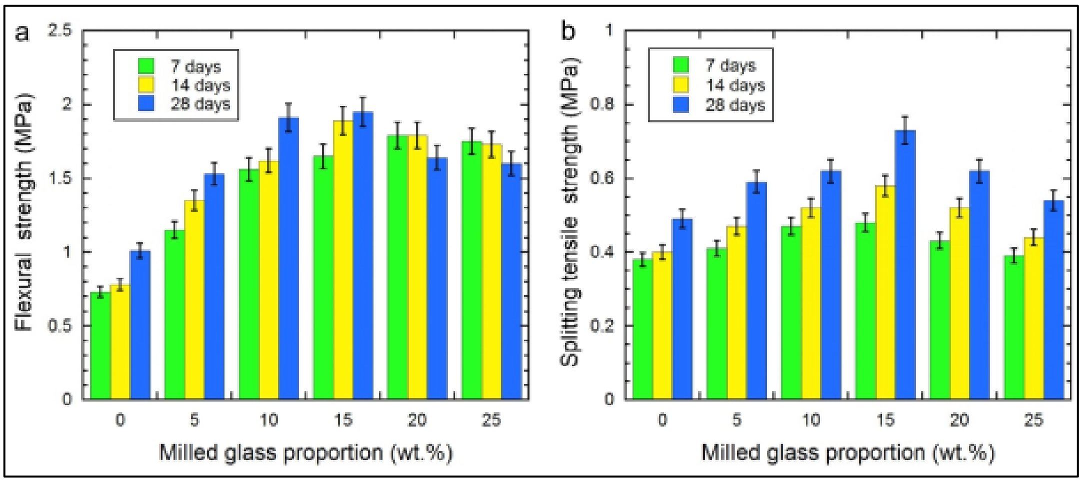

Figure 7. Influence of milled glass proportion and curing period on (a) flexural strength (b) Splitting tensile strength

3.2.8 Splitting tensile strength

Response of cylindrical samples of glass-reinforced wood fiber sandcrete bricks to split tensile test is as reflected in Figure 7b. Similar to observations elucidated in [103], splitting tensile appreciated up to 15 wt.% MG presence under each curing age and reduced on the incorporation of 20 and 25 wt.% MG. Incorporation of 15 wt.% resulted in 9.4% and 19% enhancement under 7 and 28 days split tensile strength respectively in 103. In this study, 15 wt.% improved splitting tensile by 7.6, 10.8% and 13.8% under 7, 14 and 28 days accordingly as compared with values of control bricks under same days. Inclusion of 20 and 25 wt.% presented a progressive decrease in strength when compared with values obtained on in the mix of 15 wt.% MG, which may be as a result of in-cohesiveness of wood fiber particles within the matrix and possible segregation.

Comparable research conducted by [104] demonstrated 13% rise in split tensile at 10 wt.% glass powder addition relative to control (0 wt.%) similar to the outcome present in this investigation. Furthermore, 20, 30 and 40 wt.% glass powder resulted in 5%, 13% and 20% respective reduction in the strength value in contrast to the peak strength value of specimen containing 10 wt.% glass powder. The present study showcased strength reductions of 4.5 and 11 % relative to the value of 15 wt.% under 7 days respectively for 20 and 25 wt.% MG, 5.7 and 15.3% reduction as in the case of 14 days for 20 and 25 wt.% MG, respectively. In the case of 28 days, infusion of 15 and 20 wt.% MG amounted to 9.4 and 19.0% reduction. Progressive enhancement in strength associated with consecutive addition of 5, 10 and 15 wt.% MG can be associated with the enhanced bond strength and within matrix while reduction exhibited on account of 20 and 25 wt.% inclusion for all curing ages is linked to brittleness within the matrix under hardening and possible segregation caused by incohesive wood fiber particles. Other reasons may be on the dint of possible crack formation and increased residual strength induced.

Table 4. ANOVA Result

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Porosity					
Model	4	349.924	87.481	247.99	0.000
Linear	2	338.996	169.498	480.49	0.000
Milled Glass	1	136.002	136.002	385.54	0.000
Curing Age	1	202.993	202.993	575.45	0.000
Water absorption					
Model	5	354.753	70.951	118.65	0.000
Linear	2	320.279	160.140	267.81	0.000
Milled Glass	1	96.952	96.952	162.14	0.000
Curing Age	1	223.328	223.328	373.48	0.000
Dry density					
Model	5	0.131542	0.026308	668.97	0.000
Linear	2	0.109773	0.054887	1395.66	0.000
Milled Glass	1	0.059731	0.059731	1518.85	0.000
Curing Age	1	0.050042	0.050042	1272.46	0.000
Thermal conductivity					
Model	5	0.276205	0.055241	73.02	0.000
Linear	2	0.252609	0.126305	166.96	0.000
Milled Glass	1	0.120331	0.120331	159.06	0.000
Curing Age	1	0.132278	0.132278	174.85	0.000
Specific heat capacity					
Model	5	0.240478	0.048096	138.15	0.000
Linear	2	0.219150	0.109575	314.74	0.000
Milled Glass	1	0.141422	0.141422	406.22	0.000
Curing Age	1	0.077728	0.077728	223.27	0.000
Flexural strength					
Model	5	4.3687	0.87375	72.18	0.000
Linear	2	1.5379	0.76897	63.52	0.000
Milled Glass	1	1.2140	1.21404	100.29	0.000
Curing Age	1	0.3239	0.32391	26.76	0.000
Compressive strength					
Model	5	71.5543	14.3109	347.50	0.000
Linear	2	59.2156	29.6078	718.95	0.000
Milled Glass	1	25.9652	25.9652	630.50	0.000
Curing Age	1	33.2504	33.2504	807.40	0.000
Split tensile strength					
Model	5	0.143982	0.028796	42.31	0.000
Linear	2	0.030883	0.015441	22.69	0.000
Milled Glass	1	0.027585	0.027585	40.53	0.000
Curing Age	1	0.003298	0.003298	4.85	0.036

3.3 Statistical analysis

Table 4 illustrates ANOVA results of porosity, water absorption, dry shrinkage, dry density, thermal conductivity, specific heat capacity, flexural, compressive and split tensile strengths. Two major factors considered are milled glass proportion and curing age. Table 4 presents a p-value of < 0.05 for all models of the properties considered, depicting the significance of the model of each property. Similarly, the p-value for milled glass and curing age factors at 95% confidence level for each of the properties is significant (since p-value < 0.05). Therefore, milled glass and curing age significantly affected the experimental results of the property of the sandcrete bricks.

The idea behind F-test is that higher f-value highlights the significant effect of the factors on the outcome of results. In that case, as for properties like porosity, water absorption, dry shrinkage, thermal conductivity and compressive strength, curing age shows the higher impact on the properties (with the highest impact on compressive strength) over MG proportion while in the case of dry density, specific heat capacity, thermal diffusivity, flexural strength and split tensile strength, MG proportion has higher influence with the highest influence on dry density.

3.4 Morphological analysis

The microstructure of the samples examined based on varying mix proportions of MG can be represented in Figure 8. As represented in the images, wood fiber can be identified in the sand matrix. Figure 8a reveals the microstructure of control brick (0 wt.% MG) with a lower volume of C-S-H phases as compared with the counterpart which contained milled glass. Fig. 8 b, c, d, e and f pictures the morphology of the samples containing 5, 10, 15, and 20 wt.% MG. The presence of this milled glass promoted more C-S-H phases in the structure, which pinpoint the fact that there was a pozzolanic reaction within the matrix (since they all contained the same proportion of cement). A higher proportion of this milled glass evoked more C-S-H phases in the structure depicting the fact that more MG proportion promoted increased C-S-H phases. The consequence of the feat amounted to improved properties of wood fiber-concrete bricks leading to reduced porosity and water absorption, enhanced densification, rise in thermal conductivity and lessening of heat capacity. Strength-wise, there was an overall enhancement of compressive, flexural and split tensile strengths.

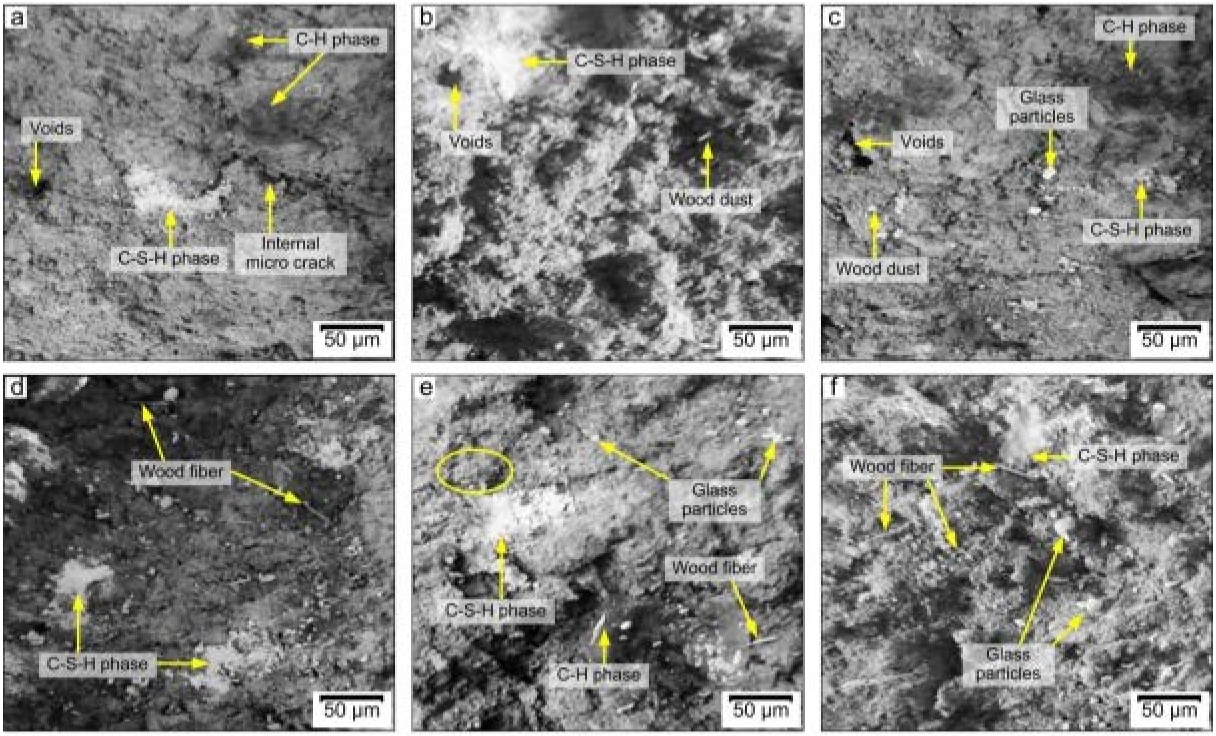

Figure 8. Microstructural images of 28 days cured samples containing (a) 0 wt.% MG (b) 5 wt.% MG (c) 10 wt.% MG (d) 15 wt.% MG (e) 20 wt.% MG (f) 25 wt.% MG

Figure 9 presents morphological images of selected samples by high magnification fluorescence microscope. The images based on high magnification reflect the internal structure at x2000 magnification. As observed in the images, the presence of unreactive glass particles which were could not partake in the pozzolanic reaction. These particles fill or cover micro pores thereby reducing porosity consequent of which evoked reduction in water absorption. Owing to lower porosity, thermal conductivity is slightly enhanced through the presence of wood fiber eventually compliments. With increasing MG replacement of cement, more unreactive glass particles are noted filling up pores. Another feature observed is wood fiber clearly pictured; as it is present in all samples. The in-cohesiveness of the fibers makes it look as if it is dispersed with the matrix. It is observed that hydrate phases are identified in the matrix binding the sand matrix with other components.

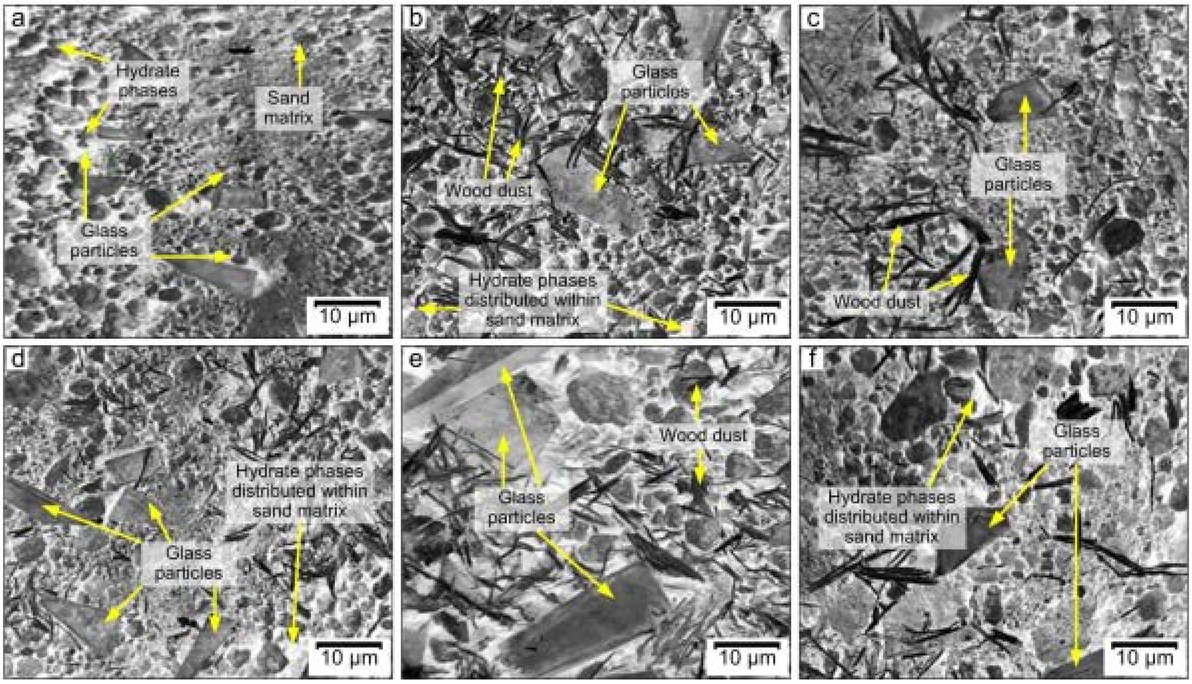

Figure 9. High magnification (x2000) fluorescence microstructural images of 28 days cured samples containing (a) 0 wt.% MG (b) 5 wt.% MG (c) 10 wt.% MG (d) 15 wt.% MG (e) 20 wt.% MG (f) 25 wt.% MG

4. Conclusion

In this study, milled glass proportion of 0, 5, 10, 15, 20 and 25 wt.% and 5% fixed proportion of wood fiber was mixed with cement and sand in the production of low thermal capacity bricks. From the results obtained the following deduction are made:

1) MG addition reduced porosity and water absorption across all curing ages.

2) The specific heat capacity was constant within the first 14 days for all proportions of MG, while the 28th day period led to a decrease in the value.

3) MG addition led to enhancement of density, thermal conductivity and compressive strength.

4) Curing ages enhanced flexural and splitting tensile strength while optimum values were realized on the infusion of 15 wt.% MG proportion for both properties.

The study, therefore, concludes that the addition of milled glass and wood fiber positively and significantly affected the properties of sandcrete bricks. 15 wt.% of milled glass and 5% wood fiber inclusion in sandcrete bricks are recommended for use by construction practitioners.

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