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Determining Properties of a Lightweight Papercrete Containing Paper Sludge, Pumice Cementious Material and Pumice Aggregate for Sustainable Construction

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In this study, a lightweight paper and mortar composite called *papercrete* was examined. Traditionally, *papercrete* is produced by mixing wastepaper with cement and sand. This study assessed the impact of using pumice as an ingredient in the production of *papercrete*. For the control specimens, *papercrete* was produced using waste paper, sand and OPC. These specimens were labelled 'Sample A'. In the next set of specimens, *papercrete* specimens were produced using crushed pumice as fine aggregate to totally replace sand. These samples were labelled 'Sample B'. In another set of specimens, pumice was used to completely replace sand as fine aggregate and to replace 10% of OPC. These were labelled 'Sample C'. The three specimens were then examined on the following tests; density, water absorption, strength, thermal conductivity and fire reaction. For the density test, it was discovered that at 28 days, Sample B with a density of 563Kg/m^3 and Sample C with a density 564Kg/m^3 had higher densities than Sample A with a density of 536Kg/m^3. For the compressive strength test at 28 days, Sample B had a strength of 3.86N/mm^2 and while Sample C had a strength of 2.70N/mm^2. The compressive strength of Samples A and B were significantly greater than that of Sample A which had a strength of 1.74N/mm^2. Similar increases were noted for tensile strength. Test for thermal conductivity revealed decreases for Sample B recorded a thermal conductivity of 0.631W/m°K while Sample C recorded a thermal conductivity of 0.631W/m°K. The thermal conductivities recorded for the samples were both less than that of Sample A which was 0.657W/m°K. All samples had good reaction to fire as there was no ignition upon impingement by flame. Also, all samples were highly water absorbent. It was concluded that producing *papercrete* with pumice significantly improves strength while maintaining low thermal conductivity and density.

Keywords: Compressive strength, *Papercrete*, Pumice, Pozzolana, Lightweight

Introduction

As sustainability has emerged as the most serious environmental issue at present the trend is now towards the use of recycled materials to supplement or even substitute some materials in concrete. Naik and Moriconi (2005) pointed that about eleven billion tonnes of aggregate comprising sand, gravel and crushed rock is used in concrete production annually whilst Moriconi (2007) added that two billion tonnes of Portland cement is consumed annually which during production contributes significantly to the release of green-house gases (GHG) leading to global warming.

Furthermore, there is a quest for materials with specific properties such as low density, low thermal conductivity, ductility, fire resistance, high strength etc. Consequently, other materials are used to substitute or complement other ingredients in concrete. One such effort is the use of lightweight aggregates such as pumice to produce concrete with low density. Another is the use of supplementary cementitious materials called pozzolan or pozzolana to supplement cement. These materials react with calcium hydroxide from hydrated cement to produce other compounds with cementitious properties (Chindaprasirt, Jaturapitakkul, and Sinsiri 2004; Rogers, 2011). Some of these materials include; fly ash, silica fume, metakaolin, pumice, crushed burnt bricks. Another effort is the use of recycled aggregates from demolition waste such as recycled concrete aggregate and crushed brick or the use of lightweight aggregates such as pumice and scoria to produce concrete with low density.

Currently, waste papers are used to produce a paper-mortar composite called *papercrete*. To produce *papercrete*, waste paper is mixed with Portland cement and sand (Mohammed, 2009; McElroy, Thompson & Williams, 2010). The result is a material like concrete which is lightweight. Mohammed (2009) reported a papercrete density of 650Kg/m^3 at 28 days. Furthermore, papercrete provides an environmentally friendly way of disposing the massive amount of waste papers generated. The Bureau for International Recycling (BIR) in 2012 estimated that over 400 million tonnes of paper is produced and consumed annually with only about 50% recovered. In Nigeria, the Food and Agriculture Organization (FAO) in 2012 estimated that 19,000 tonnes of paper and paperboard was produced and a further 570,000 tonnes imported with only 8000 tonnes recovered. The remaining is either thrown away or goes into landfill thus constituting a substantial portion of solid waste. The International Institute for Environment and Development (IIED) revealed that when paper rots or composts, it emits methane gas which is twenty five times more toxic than CO_2. In addition to being lightweight, papercrete has good heat and sound insulating properties. Sangrutsamee, Srichandr, and Poolthong (2012) obtained thermal conductivity values ranging from 0.289 to 0.625W/m°K. Masjuki, Mohammed, and Al-Mattameh (2008) reported a noise reduction coefficient of 1 for papercrete thus indicating that *papercrete* has great sound absorbance.

Literature Review

Papercrete also called fibrous concrete or fibercrete is a generic term used to describe a mixture of cement, sand, paper and water (Titzman, 2006; Mohammed, 2009; McElroy, Thompson & Williams, 2010; Chung *et al*., 2015). *Papercrete* is primarily produced by mixing shredded paper with cement, sand and water to make paper-mache slurry that can be cast into block units (Lyons, 2007). Beneficially, where papercrete blocks are used in construction, the same material can be used as the mortar. The resulting material desiccates to a grey colour and is highly water-absorbent. However, as a result of its lightweight it has good insulating properties and the cement content significantly increases its resistance to fire. Each of the ingredients in *papercrete* plays a different role in the mix. The cement is responsible for the strength of the material as it binds other ingredients together (Lyon, 2007; Kokkinos, 2010). Sand adds thermal mass, makes the mix stronger and less water absorbent (Kokkinos, 2010). The fibres on the other hand are responsible for low density, low strength and low thermal conduction (Sangrutsamee *et al*., 2012).

Studies on the use of waste paper as concrete composite indicate varying strengths of *papercrete*. In the study by Sangrutsamee *et al*., (2012), compressive strength of over 6MPa was achieved by varying the pulp content. Mohammed (2009) obtained a 28 day compressive and flexural strength of 5.56N/mm^2 and 1.43N/mm^2 respectively at a *papercrete* density of 650kg/m^3. *Papercrete* also has good insulation properties. Kokkinos (2010) reported that *papercrete* has a low thermal conductivity coefficient and high thermal diffusivity which means even though *papercrete* changes temperature quickly, it doesn't transmit much heat. This has been collaborated by other researchers. Studies by Masjuki *et al*. (2008) obtained thermal conductivity K, for *papercrete* of 0.85W/m°K. Sangrutsamee *et al*., (2012) investigated properties of *papercrete* containing different paper types and varying pulp content and obtained thermal conductivity values ranging between 0.2890 and 0.6250W/m°K. Titzman (2006) obtained thermal conductivity as low as 0.10 W/m°K. In addition to its low thermal conduction, *papercrete* has been reported to have good sound insulating properties. In the study by Masjuki, Mohammed, and Al-Mattameh (2008) and Mohammed (2009) a noise reduction coefficient (NRC) of 1 was obtained for *papercrete*. NRC measures how well materials stop sound from reflecting i.e. how much sound they can absorb. According to Neville (1998), the NRC for conventional concrete is 0.27 and 0.45 for concrete with expanded shale aggregate. This means conventional concrete only absorbs 27% of the sound hitting it while 73% is reflected. *Papercrete* is however highly water absorbent, behaving like a sponge when exposed to water (Titzman, 2006). Suganya (2012) obtained water absorption values as high as 74%.

Pumice is a term that is used to describe a variety of porous vesicular materials produced during volcanic eruptions. Pumice has a very low density and often floats on water (Kilic *et al*., 2009) and thus used as lightweight aggregate in concrete production. Lightweight aggregates can be divided into structural and nonstructural. The structural lightweight aggregates are defined by ASTM C330 and C331. The nonstructural lightweight aggregate are defined by ASTM C332. Nonstructural lightweight aggregates are used in insulating concretes for soundproofing and nonstructural floor toppings. These lightweight aggregates according to ASTM C332 should produce concrete with density less than 800 Kg/m^3 and strength between 0.7 and 7 MPa. Pumice is a well-known lightweight concrete aggregate used for both structural and nonstructural concrete. When used to produce concrete, they produce a lightweight thermal and sound insulating, fire resistant lightweight concrete (Failla, Mancuso and Miragha, 1997; Gunduz, 2008). The compressive strength of pumice is low, between 5 and 7 MPa for pumice of standard gradation (Ugur, 2003). Additionally, smaller particles of pumice tend to have a higher density than larger particles i.e. smaller sizes of particles cause an increase in density as a result of collapsed voids which makes the aggregates more compact and dense. Conversely, increasing the particle size of pumice aggregates increases the porosities in the aggregate which results in a decrease in density.

A pozzolan is a material that contains silica and/or alumina that will react with lime to form hydraulic compounds similar to those found in natural hydraulic limes (Rogers, 2011). Hence the term supplementary cementitious materials (SCM) or cement supplement is used to describe pozzolans. Pumice belongs to the class of naturally occurring pozzolan. Ilter (2010) stated that naturally occurring aggregates such as pumice act as active pozzolanic material when used as fine aggregate. Although Rogers (2011) pointed that their reactivity is greater when powdered to 75 microns or less. ASTM C618 covers natural pozzolan for use in concrete. These pozzolans are designated Class N pozzolans and include diatomaceous earth, opaline chert and shales, tuffs and volcanic ashes or pumicites. These pozzolans have a minimum requirement of 70% for the sum of the oxides $SiO_2+Al_2O_3+Fe_2O_3$. Mengistu and Fentaw (2003) described pumice as highly vesicular glass and lightly coloured generally composed of 60-70% SiO_2, 12-14% Al_2O_3, 1-2% Fe_2O_3 and other alkali oxides. Pumice can be used as a pozzolan in conjunction with Portland cement to improve the compressive strength and enhance the durability of concrete (ACI, 2001).

As *papercrete* is a relatively new material, most of the studies are dedicated to ascertaining mix proportions and properties of *papercrete*. Fuller, Fafitis, and Santamaria (2006) assessed parameters such as Young's modulus, thermal conductivity, thermal resistance and creep. Siva Prasad et al. (2015) investigated properties such as strength, water absorption, fire resistance and hardness. Mohammed (2009) went further to assess fracture toughness, sound absorbance and transmission. This study goes even further by assessing the impact of using other material in producing *papercrete*. Traditionally *papercrete* is produced by mixing waste paper, cement and sand. For this study, crushed pumice was used as fine aggregate in place of sand. Additionally, powdered pumice was used as a pozzolan to replace a portion of Portland cement. The resulting papercrete will then be examined for density, water absorption, compressive and tensile strength, thermal conductivity and fire reaction in order to assess the suitability of using pumice in producing *papercrete*.

Materials and Methods

Materials

Dangote Portland cement obtained from local dealers in Zaria was used in the study. The cement was assumed to conform to BS EN 197-1 (2000).

River sand was also obtained from local dealers in Zaria. A sample of the river sand was collected and sieve analysis conducted. This was undertaken in accordance to BS 812 – 103.1 (1985). The sieves used were 4.75mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and conformed to BS 410.

Pumice used in the study was sourced from Jos in Plateau State. The pumice was manually crushed and sieved using a 5mm sieve in order to remove large particles and to obtain particles within the fine aggregate limit (i.e. from 4.75mm to 600µm) and pozzolans (75µm and below). Grading of the pumice particles was carried out based on the result of the sieve analysis conducted i.e. the percentage by weight of particles retained on each sieve in the sieve analysis of the river sand was used to grade the crushed pumice. This was done in order to enable comparison between samples containing pumice with samples containing river sand. A sample of the pumice aggregate is shown in 'Figure 1'.

Figure 1: Pumice aggregate

Methods

Chemical analysis of pumice

The chemical composition of pumice was assessed by X-ray fluorescence spectrometry. The test was conducted at the Centre for Energy Research and Training (CERT) ABU, Zaria, using a Mini pal 4 PW 4030 X-ray Spectrometer. The sample for analysis was weighed and grounded in agate mortar. PVC dissolved in Toluene was used as a binder. The binder was added to the sample, carefully mixed and pressed in a hydraulic press into a pellet. The pellet was loaded in the sample chamber of the spectrometer and voltage of 30KV and current of 1mA was applied to produce the X-rays to excite the sample for 10mins. The spectrum from the sample was then analyzed to determine the concentration of the elements in the sample.

Preparation of the paper sludge.

The preparation of the paper sludge involves soaking the paper in water and then grinding. Newspapers were soaked in water until they were soft enough to grind as the grinding was carried out manually using pestle and mortar. The soaked newspapers were then ground until the desired consistency was obtained. The ground paper was left in slurry form until it is needed. Before usage, water is drained from the ground paper which is then assumed to be in saturated surface dry (SSD) condition. This is done in order to use the same quantity of water for all the mixes. Figures 2 to 4 show the sequence for the preparation of the paper sludge.

Figure 2: Soaked newspapers

Figure 3: Ground newspapers

Figure 4: Paper sludge

Mixture proportions and casting of specimens

Mix proportion: the experiment started with the determination of the quantity of water to ensure a workable mix. A mix ratio of 1:1:3 (cement: fine aggregate: paper) as suggested by Lyons (2007) and Solberg (1999) was employed with varying quantities of water. The trials established that 2.5g of water per 1g of ground paper at saturated surface dry condition was suitable. Consequently, three sample specimens were prepared and labeled Sample A, B and C. Sample A contained cement, sand as fine aggregate and paper. Sample B contained cement, pumice as fine aggregate and paper. Sample C contained cement, pumice replacing 10% of cement, pumice as fine aggregate, and paper. Details of the components in the samples are presented in table 1.

Casting: the moulds used were 72 x 72 x 72 mm cube moulds for density, water absorption, compression, and thermal conductivity tests. 100 x 200 mm cylinder moulds were used for tensile test and 250 x 75 x 25 mm rectangular moulds were used for fire reaction test. Three samples each were produced per batch for the compressive strength, tensile strength and water absorption tests. A sample per batch was used for the thermal conductivity test. Six samples per batch were used for the reaction to fire test. The samples for strength tests were also used to assess the density of the materials. Plates 4 to 6 show the test specimens.

Table 1: Constituents of Papercrete

Sample	Binder	Fine Aggregate	Paper Sludge
A	OPC	Sand	Paper Sludge
B	OPC	Pumice	Paper Sludge
C	OPC (90%) + Pumice (10%)	Pumice	Paper Sludge

Figure 5: Compression test samples

Figure 6: Tensile test samples

Figure 7: Fire reaction samples

Curing: As *papercrete* is highly water absorbent and takes a significant time to dry, the samples were cured for 7 days by covering with polythene sheets and then the samples were allowed to air-dry.

Test on fresh and hardened *papercrete*

Density: the density of the *papercrete* samples was determined in accordance with BS EN 12390-7: 2009. The samples for each mix were weighed and there volume determined in accordance with section 5.5.5 of the standard.

Water absorption: the water absorption was determined by total immersion in accordance with ASTM C642. The oven dry mass (A) and saturated mass (B) after immersion in water was determined for all the samples. The oven dry mass was determined by weighing the samples and drying in an oven at a temperature of 100°C for 24 h. The saturated mass was determined after final drying, cooling and determination of mass by immersing the samples in water until they achieved a constant mass. This took up to 48 h. The absorption percentage was then calculated using the equation:

Absorption after immersion (%) = $\frac{B-A}{A} \times 100$ ---------------------- Eqn. 1 (ASTM C642, 1997)

Strength test: The compression test was conducted in accordance with BS EN 12390-3: 2009. However, the specimens were oven-dried 24 hours prior to testing as the samples were still significantly wet. The cubes were placed, trowelled face sideways, centrally in the testing machine and loaded. However the loading was stopped once the sample became fractured as it has been established that when *papercrete* is compressed, it has more displacement than concrete and then slowly fractures (Titzman, 2006; Fuller, Fafitis, and Santamaria 2006). The tensile strength was also determined using the same compression machine as in the compression test. Plates 4 and 5 show the set up for the compressive and tensile strength tests.

Figure 8: Samples in oven

Figure 9: Compression test

Figure 10: Tension test

Thermal Conductivity: The apparatus consists of a controller and a hot plate. The power supply is set from the controller. The temperature of the hot plate was then recorded after the readings reached a steady state. The temperature at two points on a sample was then recorded. The thermal conductivity was then computed using Fourier's law:

Q = $\frac{K \times A \times \Delta T}{L}$ ---------------------- Eqn. 2 (Incropera and Dewitt, 2002)

Where: Q = heat transfer; K = thermal conductivity; A = area of the specimen; ΔT =

difference in temperature between two sections (of area A) at a distance L; L = distance between two sections (of area A) at which temperature is taken. Plate 10 shows the set up for the thermal conductivity test.

Figure 11: Thermal conductivity test

Figure 12: Fire reaction test

Fire reaction: The reaction of *papercrete* to fire was assessed in accordance with BS EN 11925-2 (Single Flame Ignitability, SFI test). The samples were fixed in a horizontal position and a filter paper placed underneath the sample as shown in plate 11. A cigarette lighter size flame was placed on the edge and surface of three samples each per mix for 30 seconds. The time to ignition and the time until the flames spread up and reach 150mm above the flame application point are recorded. Also, the ignition or otherwise of the filter paper was noted.

Results and Discussion

Chemical Properties of Pumice

Table 2 presents the composition of major oxides in pumice. The table demonstrates that the pumice used mainly comprises SiO_2, Fe_2O_3, Al_2O_3 and CaO. These four oxides constitute approximately 93% of the oxides in the pumice used. Table 3 on the other hand presents the composition of oxides in the pumice in relation to the requirements for class N pozzolana. It can be seen from table 2 that the sum of silica, alumina and iron oxide in pumice exceeds the 70% minimum recommended by ASTM C618. The sulphur trioxide (SO_3) content was also less than the maximum 4% required by the standard. Also, the analysis revealed no traces of magnesia (MgO) while the sum of minor oxides was less than 5%. Hence based on the oxide composition the pumice used in the study has the potential to undergo pozzolanic reaction.

Table 2: Chemical Composition of Pumice

	Concentration, %								
Compound	**Al_2O_3**	**SiO_2**	**Fe_2O_3**	**CaO**	**SO_3**	**MgO**	**Na_2O**	**K_2O**	**TiO_2**
Pumice	15.50	40.10	22.45	14.88	0.59	–	–	0.77	4.07

Table 3: Chemical Requirements of Class N Pozzolana

S/No.	Properties	Recommendation for Class N Pozzolana	Pumice
1	Silica (SiO_2) + Alumina (Al_2O_3) + Iron oxide (Fe_2O_3)	70 (min %)	78.05%
2	Sulphur trioxide (SO_3)	4 (max %)	0.59
3	Magnesia (MgO) +		–
4	Free alkali e.g. Na_2O, K_2O	5 (max %)	0.77

Properties of *Papercrete* Samples

Density

Table 4 presents the density of the *papercrete* samples at 14 and 28 days. The densities ranged from 541kg/m^3 to 564Kg/m^3. In a similar study by Birhane, Mesfin and Koshe (2017) *papercrete* densities ranging from 655Kg/m^3 to 774Kg/m^3 were obtained. Samples containing pumice had higher densities than the control at both ages. Samples B and C recorded 3% increase in density over Sample A. At 28 days, there was a 5% increase in density of Samples B and C over Sample A. This increase in density could be as a result of the pozzolanic effect of very fine pumice particles which reduce the amount of calcium hydroxide thus improving densification. Another reason could be due to the phenomenon known as ball bearing effect. Mindess, Darwin, and Young (2003) and Joy (2005) pointed that regardless of the reactivity of pozzolanic particles, if they are very fine they will be able to fit into cement grains thus resulting in more efficient paste packing and more rounded particles hence the terminology ball bearing effect. This lowers the mean capillary size and reduces bleeding and hence results in a denser microstructure (Joy, 2005).

Water Absorption

The result of the water absorption test indicates that all samples are highly water absorbent. The differences between the control and samples containing pumice were marginal. For all samples, water absorption at 28 days was higher than those recorded at 14 days. Similarly in an earlier study by Suganya (2012), water absorption values as high as 74.78% was recorded for *papercrete* bricks containing rice husk ash. The high water absorption recorded in this study could be attributed to the high content of paper used in the mix. Titzman (2006) noted that dried *papercrete* behaves like a sponge when exposed to water unless some kind of water resistant treatment is applied. This point is further buttressed in researches by Anusuya and Makesh (2017) and Momin and Sayyad (2017).

Compressive and Tensile Strength

The result of the compressive strength test is presented in Table 4. At 14 days, samples B and C (containing pumice) recorded a significant increase (approximately 39%) over sample A (the control). This massive increase in strength could be attributed to the pozzolanic action of fine pumice particles. Lin, Wu, Shie, Hwang, and Cheng (2010) pointed that the primary effect of pozzolans is the reduction of calcium hydroxide (CH) from the hydrating cement paste. When cement hydrates, calcium silicate hydrate (C-S-H) accounts for a major proportion of the hydrated cement paste while about 25% of the resulting paste is CH. C-S-H is the main cementitious compound (adhesive) that gives concrete its strength. C-S-H reduces permeability and improves resistance to chemical attack. CH on the other hand is a compound that is soluble and susceptible to chemical attack. Pozzolanic reaction however converts the soluble CH to C-S-H resulting in additional cement gel thus improving strength. At 28 days, Sample C recorded the same strength as at 14 days while Sample B recorded an even greater strength (45% increase) over the control. This could be due to enhanced hydration as a result of internal curing. According to Ugur (2003), lightweight aggregates such as pumice tend to absorb water within their pores which is slowly released for continuous hydration of the binder. Additionally, the result is similar to 3.80 N/mm^2 obtained by Siva Prasad et al. (2015) using a very strong mix of 1:1:1 i.e. one part cement to one part sand to one part paper. Suganya (2012) obtained compressive strengths of 3.675 N/mm^2 and 3.108 N/mm^2 in a papercrete mix containing rice husk ash in different proportions. The tensile strength of all the samples was low. However, samples containing pumice still recorded much higher tensile strengths than the control. At 14 days, Samples B and C recorded 44% and 46% increases respectively over Sample A while at 28 days, the increases where 50% and 57% for Samples B and C respectively.

Table 4: Properties of *Papercrete* Samples

	14 days				28 days			
Sample	**Density (Kg/m^3)**	**Water Absorption (%)**	**Compression (N/mm^2)**	**Tension (N/mm^2)**	**Density (Kg/m^3)**	**Water Absorption (%)**	**Compression (N/mm^2)**	**Tension (N/mm^2)**
A	541	83	1.06	0.26	536	89	1.74	0.29
B	555	80	2.70	0.57	563	88	3.86	0.58
C	553	80	2.70	0.59	564	88	2.70	0.67

Table 5: Thermal Conductivity Values of Papercrete Samples

Sample	Thermal Conductivity, W/m °K
A	0.657
B	0.631
C	0.631

Table 5 presents the thermal conductivity of the *papercrete* samples. Samples B and C obtained the same thermal conductivity. Also, the thermal conductivity of Samples B and C were (4%) lower than that of Sample A. In addition to exhibiting similar thermal conductivity as the control, values of thermal conductivity of samples containing pumice were also in tandem with previous studies. Earlier studies by Masjuki et al., (2008) recorded a thermal conductivity of 0.85W/m°K, while Sangrutsamee et.al (2012) obtained values ranging from 0.289W/m °K to 0.625W/m°K for different mixes of *papercrete*. Furthermore, Samples B and C both containing pumice exhibited similar and good reaction to fire just as the control. The samples did not ignite upon application of flame. All the samples begin to smoulder upon application of flame but never ignited. Also the filter paper did not ignite as there were no flaming droplets.

Key findings

i. The bulk density of the samples ranged from 536Kg/m^3 to 564 Kg/m^3. Also, all samples containing pumice had greater density than the control at both ages
ii. Results of the water absorption test reveal a very high absorption rate for all mix. The minimum water absorption recorded was 80%.
iii. At 28 days, the compressive strength for the samples ranged from 1.74 N/mm^2 to 3.86 N/mm^2. Also, samples containing pumice recorded greater compressive strength than the control at both ages.
iv. The tensile strength of the samples at 28 days ranged from 0.29 N/mm^2 to 0.67 N/mm^2. Also, samples containing pumice had higher tensile strength than the control at both ages.
v. All samples recorded low thermal conductivities with values ranging from 0.631W/m °K to 0.657 W/m°K.
vi. All samples have good reaction to fire as no sample ignited on application of flame.

Conclusion and Recommendation

The use of pumice as fine aggregate in *papercrete* results in increases (up to 5%) in density. Regardless, the density of pumice *papercrete* just as normal papercrete still falls below the maximum 800 Kg/m^3 stipulated by ASTM C 332 – 99 for insulating concrete. Still, the use of pumice as fine aggregate in *papercrete* significantly increases the compressive and tensile strength of papercrete (up to 45% at 28 days). Additionally, *papercrete* produced using pumice as fine aggregate satisfies the requirement for lightweight insulation concrete according to ASTM C 332 – 99 which ranges between 0.7 and 7 MPa just as the control. Furthermore, *papercrete* containing pumice has low thermal conductivity (0.631 W/m°K max) just as the control (0.657 W/m°K). Likewise, *papercrete* containing pumice exhibited good and similar reaction to fire just as the control. Also, *papercrete* samples containing pumice where highly as water absorbent as the control. Overall, *papercrete* containing pumice as aggregate display comparable properties to normal *papercrete*. However, the differences between *papercrete* containing pumice as fine aggregate and those containing *papercrete* as aggregate/cement supplement where marginal. It is recommended that *papercrete* be produced with pumice as based on this study, *papercrete* produced with pumice has a great prospect to improve compressive strength while yet retaining desirable properties such as light weight and low thermal conductivity.

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