

Sustainable Alternative Ceiling Boards using Palm Kernel Shell (PKS) and Balanite Shell (BS)

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Abstract

This paper presents an experimental study to investigate the sustainable alternative ceiling boards using Palm Kernel Shell (PKS) and Balanite Shell (BS). The ceiling boards were prepared by mixing (BS/binder, PKS/binder and PKS/BS/binder) at different ratios of (20/80, 40/60, 60/40 and 80/20) and represented as samples (A¹, A², A³ and A⁴), (B¹, B², B³ and B⁴) and (C¹, C², C³ and C⁴) respectively. The samples were cast by flat press process in rectangular sheet shape mould of 187mm x 125 mm x 3mm. The samples were cut into specimen sizes of 30 mm x 40 mm and tested for dry shrinkage, water absorption, apparent porosity, bulk density, flaking, and hardness properties. Morphology of the samples were examined using SEM. Results of the analysis show that irrespective of the filler loadings the properties of PKS / binder particularly at 20/80 ratio (B¹) displayed better dry shrinkage of 3.7 %; water absorption of 12.4 %; apparent porosity of 15 %; bulk density of 2.3 g/cm³; flaking of 0.05g and hardness of 57.6 Hv which approximates those of the conventional specimen (Control) with a more better physical properties compared to BS / binder at 20/80 ratio (A¹) with dry shrinkage of 6.1 %; water absorption of 33 %; apparent porosity of 35 %; bulk density 1.2 g/cm³; flaking of 0.36g; hardness of 26.2 Hv and PKS / BS / binder at 20/80 ratio (C¹) with dry shrinkage of 9.8 %; water absorption of 30 %; apparent porosity of 32 %; bulk density 1.4 g/cm³; flaking of 0.1g; hardness of 36.7 Hv. These results therefore suggest that PKS could be used as a sustainable alternative in the production of ceiling boards.

1.0 Introduction

A ceiling board is a building material required for ceiling systems in commercial structures, residential, and institutional buildings. When joints and faster heads are covered with a joint treatment system, its design provides a monolithic surface (Madu, Nwankwojike, and Ani 2018). Generally, it is not considered a structural element but a finished surface concealing the underside of the roof structure of a building which reduces heat and solid transmission and sound in the house (Oladele et al. 2009). Of recent, there has been an increase in the growth of the world's population. The need for shelter and structural accessories such as ceiling sheets is in high demand. Studies have shown that Nigeria and other developing countries make use of asbestos and Plaster of Paris (P.O.P) in buildings for covering the upper layer of the internal sections (Ohijeagbon 2014).

In the past, asbestos known as a fibre present in rocks were used for the production of ceiling boards due to its poor heat conductivity and high fire resistance. Ceilings with good quality upper surface and excellent heat insulation are good for hot climates. These fibres such as Amosilte, Crocidolite, and Chrysotile however, results in asbestosis which causes cancerous as well as malignant mesothelioma in humans and tumours in other animals (Kanarek 2011; Yakubu et al. 2017). This has therefore forced researchers increase the drive for locally sourced eco-friendly building materials with the possibility of utilizing agricultural waste for ceiling board production in the nearest future (Yakubu et al. 2017).

Palm kernel shell (PKS) as an agricultural by-product is generally regarded as waste from palm oil processing. They are obtained after extraction of the palm oil, the nuts are broken and the kernels are removed with the shells mostly left as waste (Edmund, Christopher, and Pascal 2014). The hard stony endocarp (PKS) surrounding the kernel and shell consists of pyroligneous liquor (45 %), charcoal (33 %) and combustible gas (21 %). PKS can be seen in varied shapes and sizes (Dagwa, Builders, and Achebo 2012; Okly 1987). Several types of research are being carried out towards the use of PKS and some areas where PKS are considered are: on roads to improve vehicular traction where there are no tarred roads, combustion processes for electricity and heat generation, etc. (Yusoff 2006; Obam 2012).

Balanite aegyptiaca also known in English as “desert date” can be sourced in different kinds of habitat, and tolerates a wide variety of soil types, from sand to heavy clay and climate moisture levels, from acid to sub-humid. This species of tree which is up to 12 m high is classified either as a member of the Zygophyllaceae or the Balanitaceae (Sanjay and Yogesha 2016). The fruit is an ellipsoid drupe, about 2.5–4 cm long and 1.2 cm in diameter which turns yellow and glabrous when mature and are edible. Though this fruit attracts numerous insects and an emulsion made from the fruit is used as molluscoid and fish poison since though the saponin becomes rapidly inert so that fish killed this way are edible. The treatment of liver and spleen diseases and the elimination of schistosomiasis and bilharzias flukes carrying snail can be achieved with the fruit. Interestingly, a refreshing drink can be obtained from this fruit too, but will ferment with time becoming an alcoholic drink (Moustapha et al. 2014; Oyekan and Kamiyo 2008). The best way of checkmating waste nuisance is to channel it into an important and profitable purposes. The significance of this study is to explore the potential of using PKS and Balanite shell as a sustainable alternative filler for the production of ceiling boards.

2.0 Experimental

2.1 Materials

The materials used for this investigation are thus presented. Palm Kernel Shell (PKS) (obtained from Umuodom village, Isiala Mbano, Imo – state, Nigeria). Distilled water, 88 Universal Mold Release Wax (Meguiar’s Mirror Glaze), Balanite Shell (BS) (got from Monday village, Kaduna) and Ordinary Portland Cement (OPC) (manufactured by Dangote Cement).

2.2 Methods

2.2.1 Materials preparation

300g of PKS was stirred in 3 Litres of water and left for 72 Hrs to remove extraneous organic matters. The clarified water was decanted leaving a cleaner PKS. The shell (PKS) (Fig. 1(a)) was sun dried for 3 days, ground and sieved through a BSS 36 sieve to obtain fine particles. The process was repeated for the (BS) (Fig. 1(b)). The filler obtained (PKS or BS) were mixed with OPC in a ratio of (20/80, 40/60, 60/40 and 80/20) represented as samples (A¹, A², A³ and A⁴), (B¹, B², B³ and B⁴) and (C¹, C², C³ and C⁴)

respectively. The mix were moulded to desired shape using a corresponding mould and were sun-dried for 14 days preparatory to the test to be carried out.

2.2.2 Test procedures

The dry shrinkage (DS) was determined by weighing a 30 mm x 40 mm of each dried specimen as (L_d) and later as (L_o) after over drying at 150⁰ C for 90 minutes. The DS was calculated using eq. (1):

$$\%DS = \left(\frac{L_d - L_o}{L_d} \right) \times 100 \quad (1)$$

Where L_d = Initial dried weight

L_o = Final weight

The water absorption (WA) was determined by immersing a dried 30 mm x 40 mm weighed specimen (W_d) in 250 ml beaker of water for 45 minutes. After which they were taken out, wiped with a clean cloth, weighed (W_w) and recorded according to BS EN1097-6:2000. The WA was calculated using eq. (2).

$$\%WA = \left(\frac{W_w - W_d}{W_d} \right) \times 100 \quad (2)$$

Where W_d = Initial dried weight

W_w = Final weight

Apparent porosity (AP) and Bulk density (BD) was determined using BS EN1097-6:2000 by weighing a 30mm x 40mm dried specimen (W_d) of each filler ratio. The specimens were soaked in water for 45 minutes and the wet weight of the specimens taken as (W_w). Finally, the specimens were weighed as (W_s) when suspended in water. The AP was calculated using eq. (3) while the BD was determined with eq. (4) where ρ_w is the density of water.

$$\%AP = \left(\frac{W_w - W_d}{W_w - W_s} \right) \times 100 \quad (3)$$

$$\%BD = \left(\frac{W_d * \rho_w}{W_w - W_s} \right) \left| \frac{g}{cm^3} \right| \quad (4)$$

A dried specimen board 30 mm x 40 mm was weighed (W_1). A hard shoe brush was used to make 20 strokes of forward and backward movements each against the two surfaces of the board. Thereafter, the board was weighed (W_2). The F_t was calculated using eq. (5) (Obam 2012).

$$F_t = \left(\frac{W_1 - W_2}{W_1} \right) \quad (5)$$

Where F_t = Flake test

W_1 = Initial dried weight

W_2 = Final weight

The micro – hardness (MH) was determined by placing a specimen in a Leitz Hardnes (OS-2H) tester. This tester had a diamond indenter, in the form of a right pyramid with a square base and an angle 136° between opposite faces under a load of 3 N in accordance with ASTM E384-17.

The scanning electron microscope (SEM) was determined by placing a small piece of the dried compacted specimens in a PHENOM G2 Pro SEM machine to access the morphology of the specimen on the monitor screen using 15.0 KV.

3.0 Results And Discussion

3.1 Dry shrinkage

Across the various filler ratios in Fig. 6, the control specimen had the least percentage rate of 0.5 % seconded by 3.7 % of 20/80 ratio of PKS (B^1). This could be as a result of the interactions in the network as well as low strain of expansion and contraction on account of constituents in the board within the particles and binder in the board compare to other ratios.

3.2 Water absorption

The control specimen in Fig. 7 shows the least absorption rate of 4.3 % followed by 12.4 % of 20/80 ratio of PKS (B^1). This is probably due to the increased closure of internal pores which ensures that there is reduced space for water to percolate through the specimen. The water rate can be taken as a measure of resistance of board to liquid penetration. A very poor resistance to liquid penetration is an indication of a very high water absorption rate (Opuada Ameh, Tijani Isa, and Sanusi 2015).

3.3 Apparent porosity

The apparent porosity of the ceiling board had a unique property relative to that of water absorption. However, the control specimen displayed the least apparent porosity percentage rate of 1.5 % due to a better closing up of voids within its particles. Amongst other ratios, the 20/80 ratio also shows the least apparent porosity rate of 15 % for PKS (B^1). This is most likely due to better interlocking of the particles and binder as shown in Fig. 8. The mechanism prevailing in apparent porosity is related to water absorption rate (Kadir, Sarani, and Kadir 2017).

3.4 Bulk density

The bulk density is a measure of the change in weight of ceiling board with respect to the total volume of ceiling board; where the total volume is the sum of both closed and open pores. From the graph shown in Fig. 9, there was a gradual decrease in bulk density across the filler ratios. The bulk density in the (PKS) ranges between 0.93 and 2.3 g/cm³; in the (BS), it is between 0.85 and 1.2 g/cm³; and in the (PKS / BS) it is between 0.88 and 1.4 g/cm³. This closing up of internal pores reduces the effective volume resulting in increased bulk density for given weight of board. This also means that the specimen from PKS has better bulk density property compare to others. Amongst the various specimens for PKS, 20 /80 ratio (B¹) exhibits maximum bulk density of 2.3 g/cm³ indicating better closing-up of internal pores hereby reducing the penetration of water particulate (Osei and Jackson 2012).

3.5 Flaking

The flaking of the boards at various ratios shown in Fig. 10 shows that 20/80 of the BS specimen (A¹) as well as 80/20 of PKS specimen (B⁴) exhibited higher flaking values of 0.36 g and 0.37 g respectively. This may be as a result of poor fusion as well as cohesive bond within the individual particles in the board. However, the least flake occurred at 20/80 of PKS (B¹) with a value of 0.05 g; at 80/20 of BS (A⁴) with a value of 0.09 g and at 20/80 of PKS / BS (C¹) with a value of 1.0 g. This may be due to a better network structure and stronger bond within the individual particles. Though amongst the various specimen the control stands out with a negligible flake rate. This further indicates that the lesser the inner pores, the denser the specimen, the better, stronger the fusion within the individual particles in the board and the lesser the flake rate (Obam 2012).

3.6 Micro hardness

The micro hardness of the various ratios of the ceiling board is shown in Fig. 11. Across the ratios, the control and 20/80 ratio of PKS (B¹) exhibits the highest hardness value of 88.7 Hv and 57.6 Hv respectively. This could be attributed to increase in solid state fusion compared to others with lower / weak cohesive bond within the individual particles. In other words, it could be described as the denser the specimen, the stronger the bond within the particles in the board (Opuada Ameh, Tijani Isa, and Sanusi 2015).

3.7 Morphology Characteristics

With the magnification of 320 X, Fig. 12 (a) which is the SEM image of the asbestos (Control) sample exhibits tight edge – to – face (EF) and edge – to – edge (EE) flocculation which present increased closed network of structures. Although the surface appears rather rough but the attraction between masses indicates stronger force bonding them resulting to the decrease in flakes and porosity and also increase in hardness and bulk density. Figure 12 (b) shows the morphology of A¹ (BS) of ratio (20/80) % sample. This sample reveal some amount of porosity and de-bonding in many areas which indicates less

connection of the particles, a very weaker bonds and poorly aggregated particles which may readily disaggregate when it come in contact with water. The morphology of B¹ (PKS) of ratio (20/80) % sample in Fig. 12 (c), show a well aggregated particles with high bonding area and coarse surface. With such tight bonds, dispersion is inhibited due to strong force bonding the particles and the tightness also promotes increase in hardness and bulk density as well as decrease in porosity and flakes; which combats dispersive behaviour. Figure 12 (d) reveals the flocs with tight masses for C¹ (PKS/BS) of ratio (20/80) % sample indicating fairly strong bonding with macro-cracks, small discontinuities and a reasonably uniform distribution of particles in some areas with also a moderate non – dispersive appearance.

4.0 Conclusion

From the study, the phase identification as well as the micro structural analysis of the PKS (B¹ (20/80)) exhibits almost the same physical and morphological appearance to that of the conventional (asbestos) ceiling board. Also, the ceiling board produced with PKS aggregates are denser and stronger than that of the BS and PKS/BS ceiling board with acceptable physical and mechanical properties. Finally, the maximum strength of PKS/binder mixture which could be replacement for the conventional ceiling board was attained at (20 / 80) % seconded by PKS / BS / binder at same ratio and could be termed s light weight green building products.

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Tables

Table 1: Chemical analysis of OPC

Parameter	OPC (%)
SiO ₂	23.0
Al ₂ O ₂	3.22
Fe ₂ O ₂	3.85
CaO	65.88
MgO	2.0
Na ₂ O	0.21
K ₂ O	0.30
SO ₃ ²	1.50

Figures



Figure 1

(a) Dried PKS (b) Dried BS (c) Ground PKS (d) Ground BS (e) Ordinary portland cement



Figure 2

Control sample



Figure 3

Board samples for Balanite shell with binder at various ratios



Figure 4

Board samples for PKS with binder at various ratios

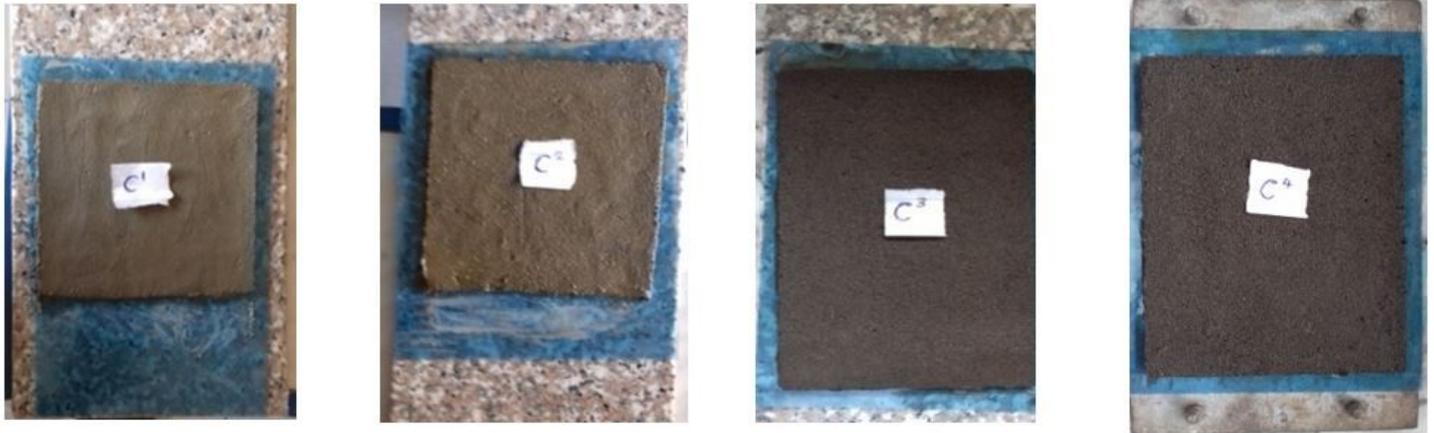


Figure 5

Board samples for PKS and Balanite shell with binder at various ratios

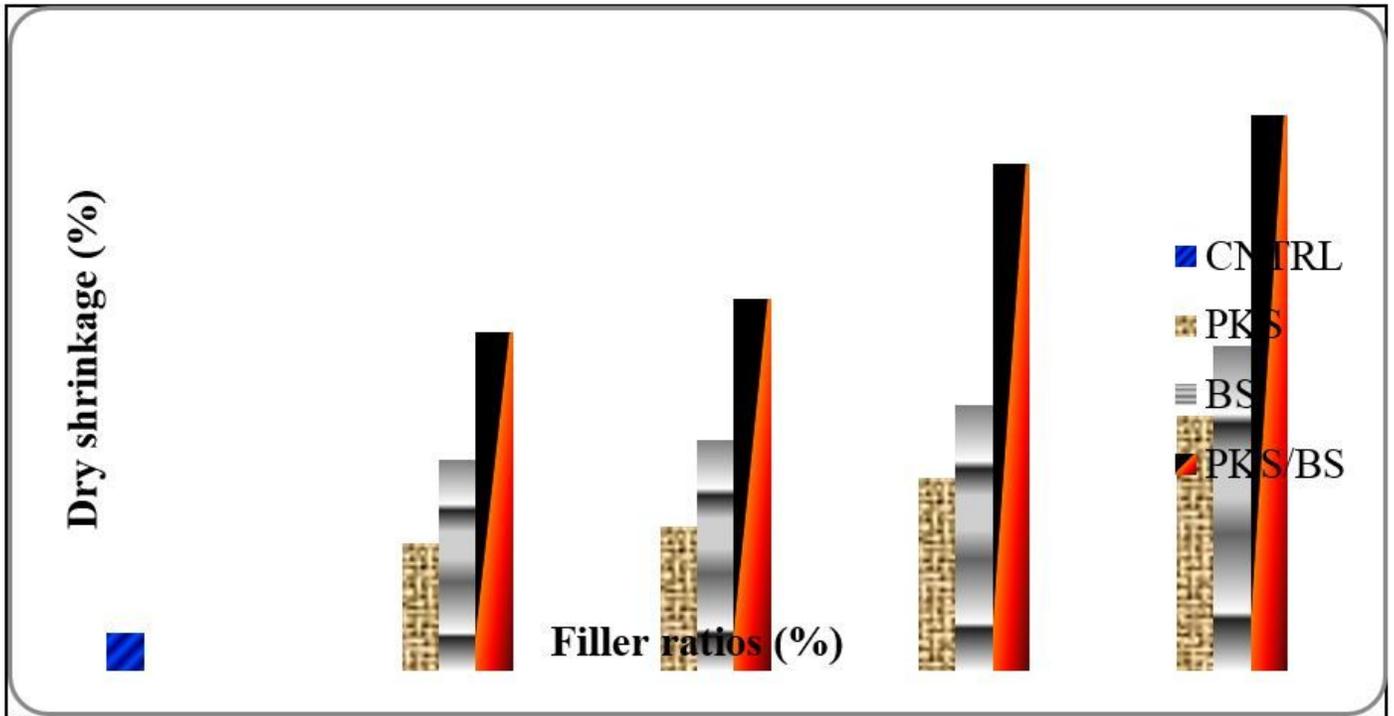


Figure 6

Dry shrinkage of ceiling board specimens at various filler ratios

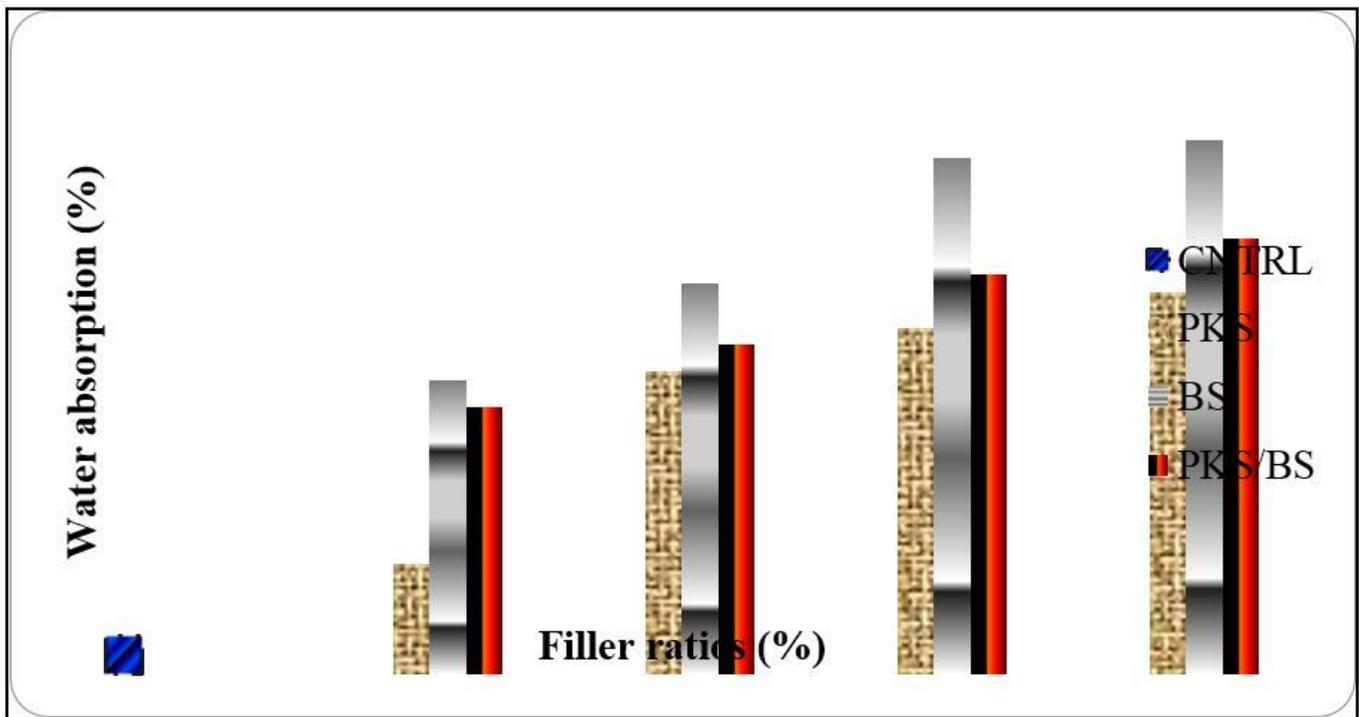


Figure 7

Water absorption of ceiling board specimens at various filler ratios

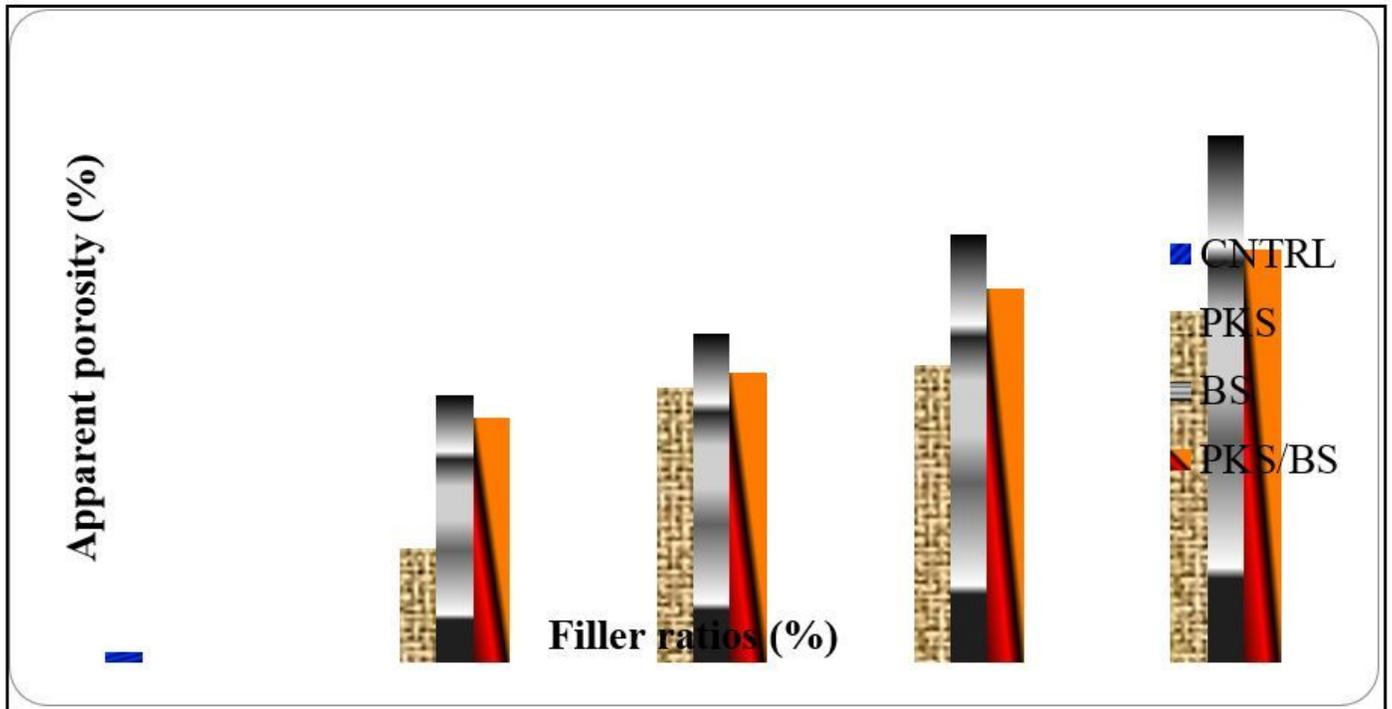


Figure 8

Apparent porosity of ceiling board specimens at various filler ratios

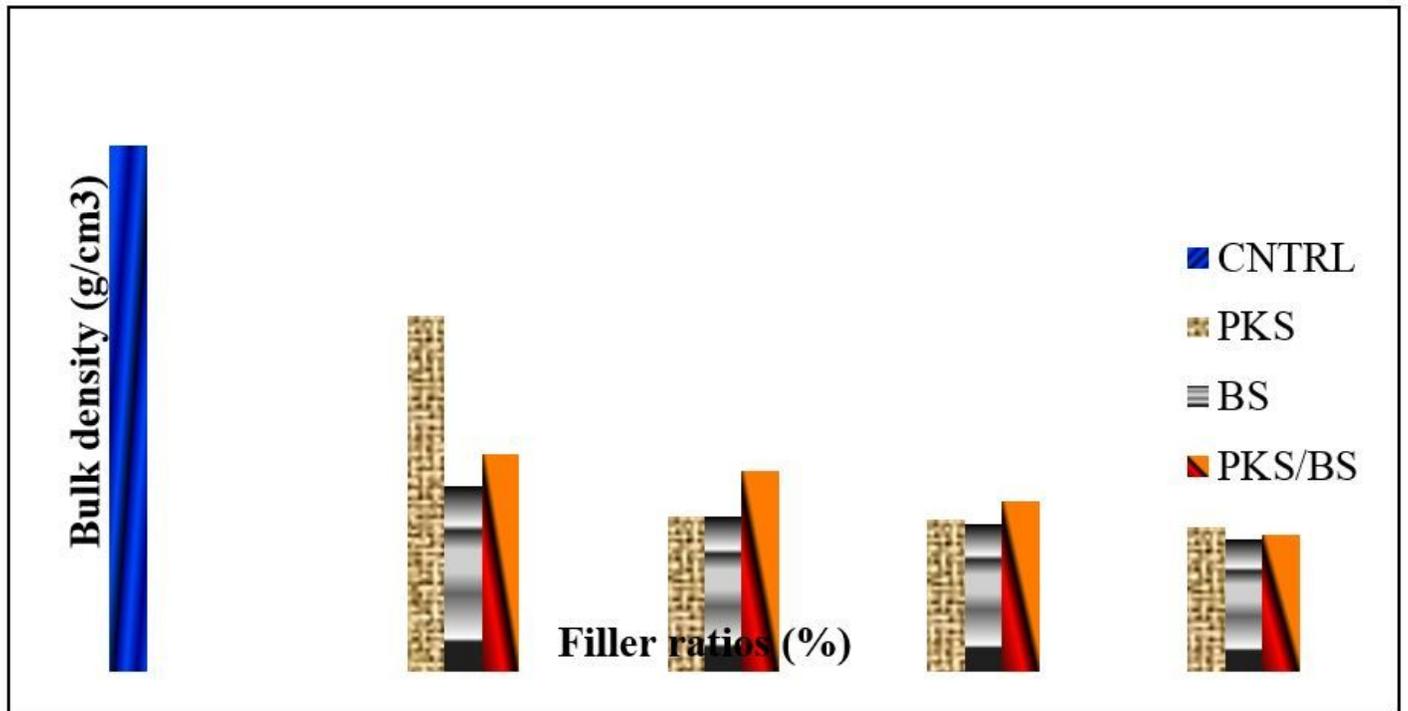


Figure 9

Bulk density of ceiling board specimens at various filler ratios

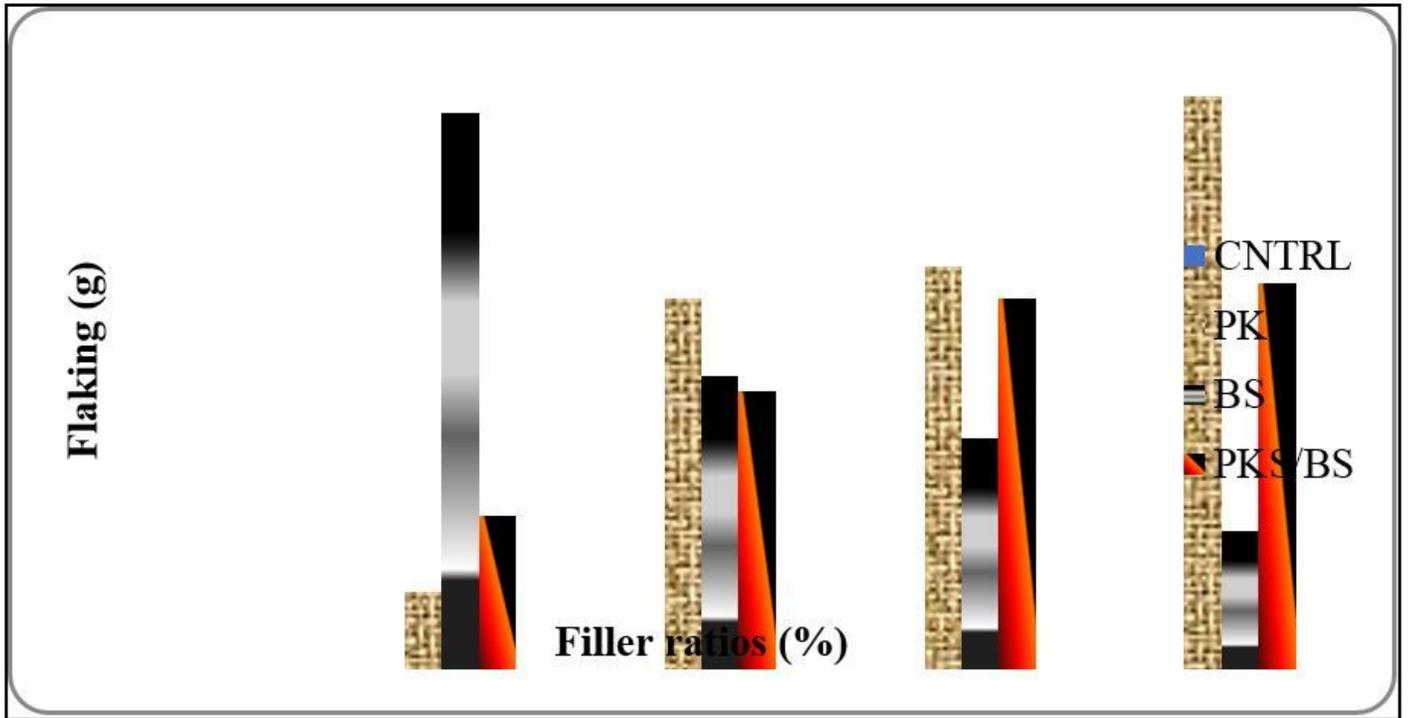


Figure 10

Flaking of ceiling board specimens at various filler ratios

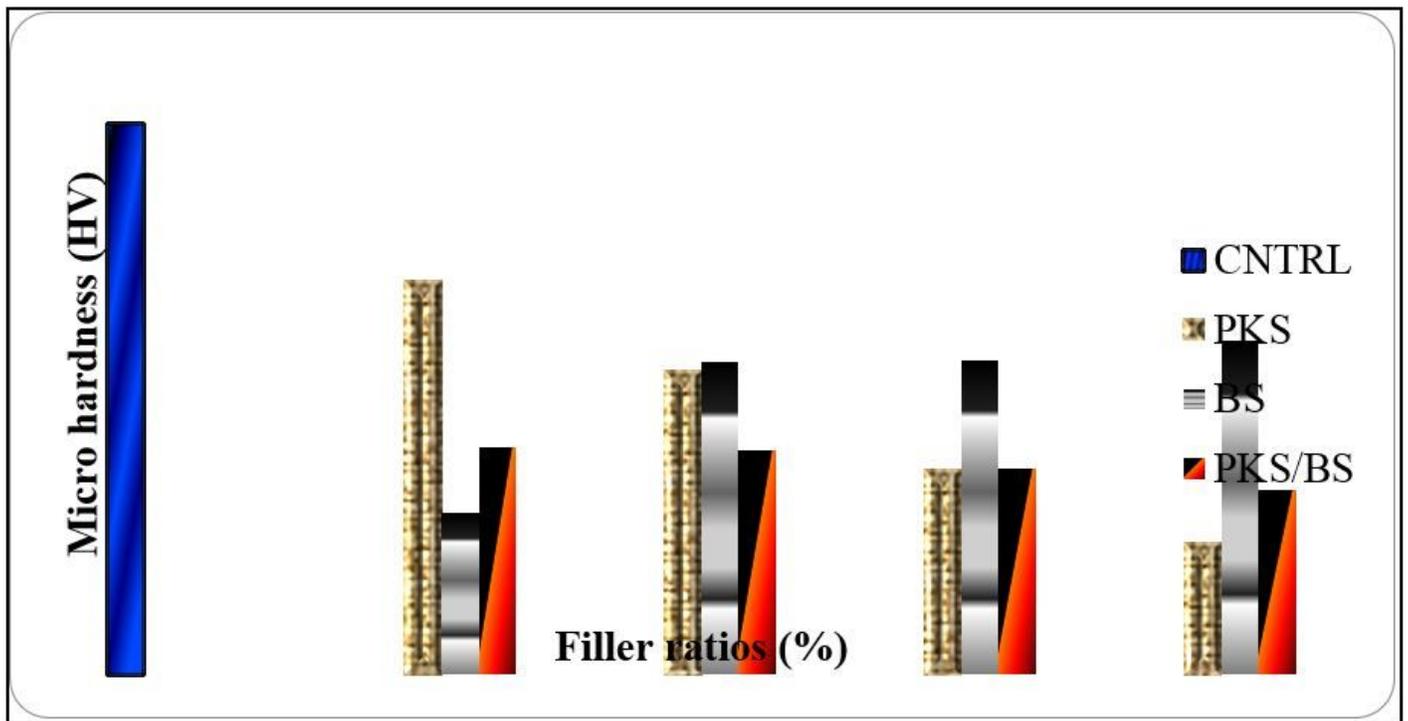


Figure 11

Micro hardness of ceiling board specimens at various filler ratios

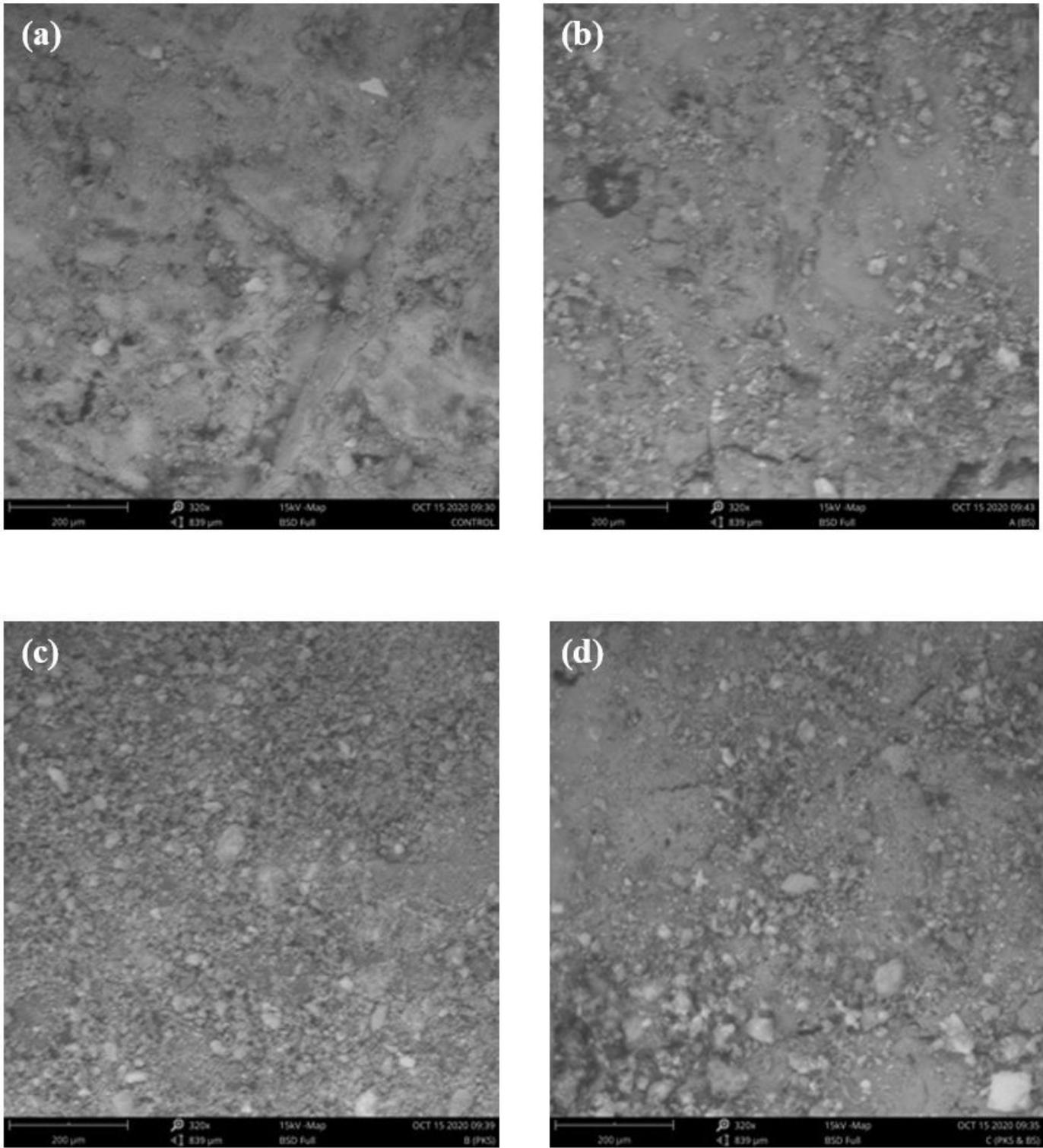


Figure 12

(a) SEM image of asbestos (control) sample (b) SEM image of A1 (BS) of ratio (20/80) % sample (c) SEM image of B1 (PKS) of ratio (20/80) % sample (d) SEM image of C1 (PKS/ BS) of ratio (20/80) % sample