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DATE PITS AND DATE PALM WOOD-BASED HEAT INSULATOR COMPOSITES

Basim Abu-Jdayil[*], Abdel-Hamid Mourad[†], Atif Hussain[‡]

[*]Chemical & Petroleum Engineering Department, UAEU, Al Ain, UAE
babujdayil@uaeu.ac.ae

[†]Mechanical Engineering Department, UAEU, Al Ain, UAE
ahmourad@uaeu.ac.ae

[‡]Chemical & Petroleum Engineering Department, UAEU, Al Ain, UAE
ahussain@uaeu.ac.ae

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Summary: *A composite material made of unsaturated polyester and date-pits or date palm wood as filler was fabricated to serve as an insulating material. Unsaturated polyester liquid blended with fillers with 0 – 60% as a polymer/filler ratio was transformed into solid upon thermo-set process. The composite characterization was performed by testing the compressive strength, thermal conductivity, and water retention. The results indicated that increasing the date pits, in general, causes a slight increase in thermal conductivity coefficient. This may be due to the higher conductivity of the filler. On the other hand, the date wood based composites showed decrease in the thermal conductivity with increasing filler content. However, the thermal conductivity of both composite materials is very promising and comparable with the commercial thermal insulators. Although compressive strength tests showed a decrease in strength with increasing the filler content, the prepared composites presented superior mechanical strengths (35 – 108 MPa) when compared with the commonly used insulating materials. Generally, composites containing date wood showed better mechanical, physical and thermal properties than that containing date pits. From the experimental work performed on these composite materials, we arrive at the conclusion that the date-pits and date wood can be utilized to manufacture stable and compatible composite materials. One would say that date wood based composites show good characteristics in terms of thermal conductivity(<0.11 W/m.K), water retention (< 2.5%) and mechanical strength (72 – 108 MPa) and with such cheap and abundant fillers from natural resources, they show a promising thermal insulating material both for domestic and industrial applications.*

1 INTRODUCTION

The UAE is a major oil producing country. Nonetheless, there are serious moves under way to reduce energy utilization leading to carbon emission and development of alternatives to carbon-based fuels for power and cooling. Recent reports concerning energy consumption in the region have said that 25 per cent of Gulf water has been consumed, with one-fifth of it being used for electricity. The reports also said that the UAE would need $10 billion (Dhs 36.7 bn) to satisfy energy demand for the next 10 years, due to developments and projects that are increasing by 12 per cent each year. The UAE has one of the highest levels of energy consumption per capita in the world [1]. Therefore, there is an ongoing search for finding the proper alternatives to preserve energy and minimize energy losses. Our country, like other countries, highly appreciates all forms of energy saving. Subsequently, heat insulators, part of building materials and some industrial hardware, are steadily getting their importance as a means of saving energy. On average, space heating and cooling accounts for 50–70% of the energy use of a US home [2]. This percentage could be higher in other parts of the world with harsher climatic conditions and less energy efficient buildings, for example in the Gulf region. Thermal insulators, as part of building materials and some industrial hardware, are therefore steadily gaining importance as a means of saving energy. Thermal insulation serves in reducing energy losses during the whole year by maximizing the efficiency of both cooling and heating systems. Savings in energy consumption will reduce both costs and carbon emissions.

Thermal insulation materials available in the Gulf region are relatively expensive and until now are infrequently used by local contractors. In addition, the typical insulation materials; polyurethane, polystyrene, and mineral wool [3] suffer from poor mechanical properties, which limit their application in the construction process. Consequently, there is a necessity to develop a thermal insulation material that possesses excellent mechanical and physical properties as far as energy saving, water resistance, ease of handling and machining are concerned. At the same time, it should be relatively cheap so that it may be used extensively.

Many presently available insulating materials are made of polymer materials, fillers, and other additives, i.e. they are composite materials. Polymers are generally known to be good insulating materials due to their stable physical and chemical properties. Mechanical properties, however, can be further improved or modified with the addition of fillers as demonstrated by the increase in the strength of the composite [4]. Many kinds of clay minerals such as bentonite, kaolin, talc, mica, etc. have been used as inorganic fillers for the conventional polymer composites to reduce the cost or to give them special properties such as modulus, hardness, thermal stability, electrical insulation, thickening, opacity and brightness [5-9].

Date pits and date palm wood are readily available in a number of countries. They have typically been seen as waste product from the preparation of dates and are usually discarded. In the United States, pulverized ground date pits are being used on a small scale, on dirt roads as a type of road base gravel. In the Middle East, it is sometimes used in animal feed. Several investigators have used date-pits to adsorb dye [10], aluminum [11], heavy metals [12], and phenol [13]. On the other hand, Composites formed from polypropylene filled with wood flour are typically used in automotive applications and consumer products [14], and these composites have recently been investigated for use in building applications [15].

The aim of this work is to utilize local waste materials (Date pits and Date wood) in production and development of polymeric thermal insulator material with competitive properties (mechanical and thermal) and cost.

2 MATERIALS AND METHODS

2.1 Materials

The polyester used in this study was obtained from Reichhold Inc., Dubai (UAE) as Polylite 721-800E, an isophthalic polyester resin with styrene content of 44 - 46% and viscosity 280-330 mPa s. It has built in accelerator which gives relatively long gel time, rapid curing combined with relatively low exothermic temperature and short demoulding time.

The date pit filler was obtained from a local date factory in Al-Ain. It was crushed, ground and then screened to ensure a size range of less than 800 µm. The date wood filler was obtained from the UAE University farm located in Al Foah, Al Ain. Large pieces of date palm wood and leaves were crushed and ground using a high energy mill to obtain fibers with various diameters and lengths. It was not easy to perform an accurate separation of fibers solely based on diameter and length. Therefore, sieving of the crushed date palm fibers can give an approximate size characterization and the mesh size can relate to the diameter distribution. The date palm fibers were screened using meshes into two sizes for composite preparation; size #1: fibers having diameter less than 1200 µm and size #2; fibers having diameter less than 600 µm. The results of size # 1 will be presented here.

2.2 Fabrication

The composites were prepared using different date pit and date wood concentrations (0 - 60 vol%) which were added to the unsaturated polyester at room temperature. For the curing process, methyl ethyl ketone peroxide was added as an initiator. The composites were prepared using a high viscosity mixer and the mixture was then poured into suitable mould prepared from stainless steel. Different types of moulds were fabricated to meet the requirements of the tests that were performed on the prepared composites. The produced samples were then subjected to different mechanical, thermal and physical tests according to ASTM standards.

3 RESULTS AND DISCUSSION

A thermal conductivity testing machine, Lasercomp FOX-200 was used to measure the thermal conductivity of the produced composites. The dimensions of the samples were 150 mm×150 mm×20 mm. The measurement conditions follow the standard methods reported by ASTM C1045-01. The thermal conductivity coefficient of unsaturated polyester was experimentally found to be 0.115 W/(m.K). Figure 1 shows the thermal conductivity coefficient of composite material as a function of filler content measured at 25 °C. Increasing the date pit content, in general, caused a slight increase in thermal conductivity coefficient. This may be due to the higher conductivity of the date pit compared to the polyester resin. On the other hand, increasing the date wood content led to decrease slightly the thermal conductivity coefficient. This means that the thermal conductivity of date wood is smaller than that of date pit. The mean value of the thermal conductivity of all date palm samples studied by Agoudjil et al. [16] was 0.083W/m. K. At 60 vol% filler content, the thermal conductivity of date pit composite and date wood composite was 0.166 and 0.110 W/(m.K), respectively. Although an increase in thermal conductivity with filler content has been observed, the thermal conductivity of the prepared composite material is very promising and comparable with the commercial thermal insulators and building materials. On the other hand, the composites prepared in this study present good thermal performance comparing with some composites that can be used as building materials with thermal insulation properties like plaster/wheat fiber (0.33 W/m.K), plaster/barley fiber (0.29 W/m.K) and plaster/wood shaving (0.28 W/m.K) [17].

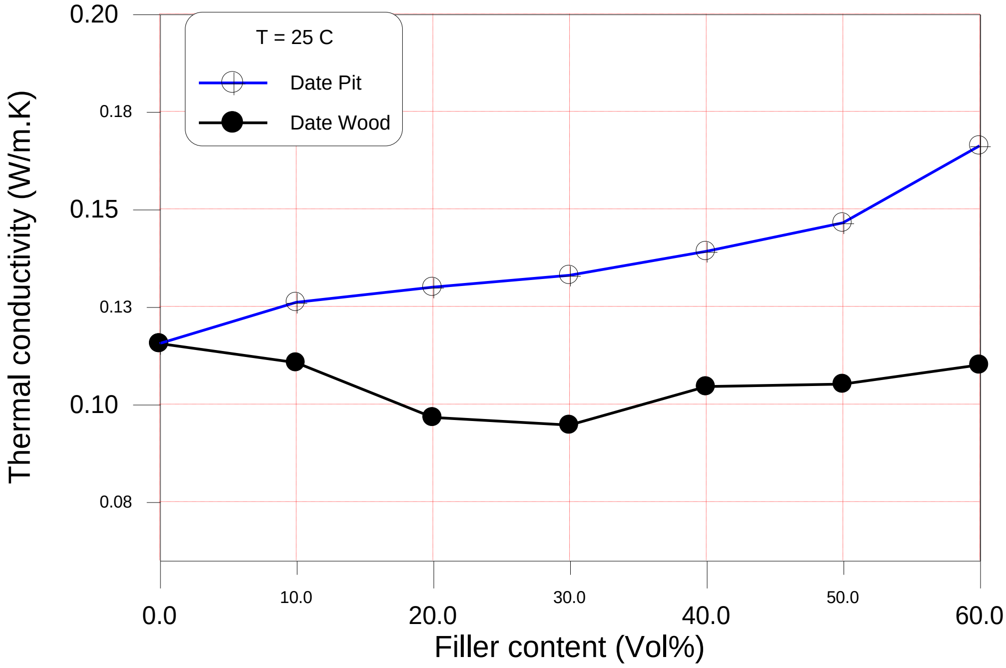

Figure 1: Thermal conductivity of composites.

Compared with building bricks (or cement plaster) which have thermal conductivity of 0.72 W/(m K), with concrete (stone) which has a thermal conductivity of 0.93 W/(m K), and with reinforced concrete with a thermal conductivity of 1.73 W/(m K), Polyester-date-pits composites with 60 wt% date-pits content have thermal conductivity values between 0.166 and 0.170, at 0 and 50 °C, respectively. If an average resistance, using Eq. (1), is taken to the aforementioned materials without incorporating the composite:

$$\frac{1}{k_{average}} = \sum_{i=1}^{n} \frac{w_i}{k_i} = \frac{0.333}{1.73} + \frac{0.333}{0.93} + \frac{0.333}{0.72} \tag{1}$$

where k_i is the thermal conductivity of component i and w_i is the weight fraction of component i, then a $k_{average}$ of 1.0 W/(m K) is obtained. On the other hand, if a wall is built with such building materials (building blocks, concrete and reinforced concrete) while this time the polyester-date-pits composite comprises one-third of the wall thickness while the rest of the wall is made of the previous materials, then

$$\frac{1}{k_{average\ with\ insulation}} = \sum_{i=1}^{n} \frac{w_i}{k_i} = \frac{0.333}{0.168} + \frac{0.67}{1.0} = 2.634 \tag{2}$$

which means that the new value of $k_{average}$ will be 0.3796 W/(m K). Consequently, constructing a wall made of polyester-date pit composite that comprises one-third a wall thickness, the minimum percent relative reduction in overall thermal conductivity will be about 62%. Following the same analysis for the date wood composite, the minimum reduction in overall thermal conductivity will be about 73%.

The water retention test was performed according to ASTM D-570-95. Cylindrical specimens of 30 mm long and 25 mm in diameter were used. Two types of tests were performed on the prepared composites: i) 24 Hour Immersion: The specimen was placed in a container of water at room temperature, and rested at its edge and entirely immersed. At the end of 24 h the sample was removed from water, wiped free of surface moisture with a dry cloth, weighed to the nearest 0.0001 g immediately. ii) Immersion at 50 °C: The specimen was placed in a container of water maintained at a temperature of 50 ± 1 °C, and rested at its edge and entirely immersed. At the end of 48 h the sample was removed from water, wiped free of surface moisture with a dry cloth, weighed to the nearest 0.001 g immediately.

Figure 2 gives the distilled water retention percent in 24 hr and 50 °C tests for the two composites as a function of filler content, which was calculated by the following equation:

$$\boldsymbol{WR}\,\% = \frac{\textbf{wet weight} - \textbf{dry weight}}{\textbf{dry weight}}\ \mathbf{x\,100} \tag{2}$$

In general, WR% value of composite was low and it increased with increasing filler content. It is expected that in the examined conditions, the cross-linking process was efficient, which reduced voids needed for water retention. Below the filler content of 30%, the water retention of both composites was comparable. Above the filler content of 30 vol%, the effect of date-pit on water retention was significant. Increasing the temperature led to remarkable exponential increase in water retention of date pit composites. By increasing the immersion temperature to 50 °C, the water retention percent increased by three times compared to room temperature immersion. In the case of date wood composites, the effects of temperature and filler content were not significant on the water retention. At 60% date wood content, the water retention of the composite in the 50 °C conditions was less than 2.5%.

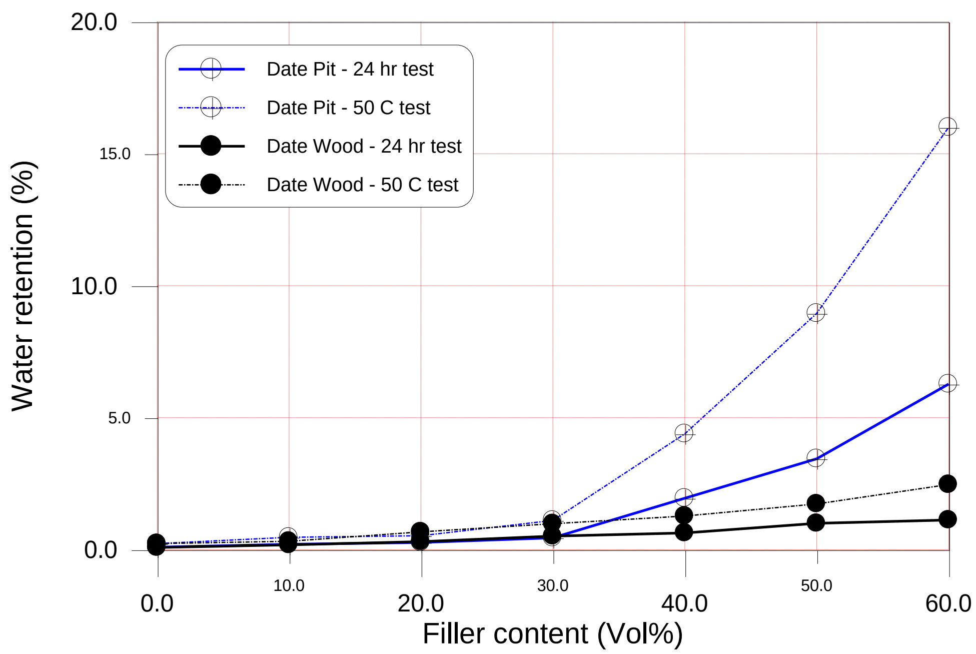

Figure 2: Water retention of composites.

The compressive tests were conducted using universal testing machine (MTS Model MH/20 and capacity 100 kN). The dimensions of the specimens used in compressive test were 30 mm in length and 25mm in diameter. The test specimens were held between two platforms of the machine and load was applied over 25 mm span length at a constant strain rate of 10 mm/min.The average of three tests has been reported for all samples. The pure polyester samples have been observed to flatten (look like a pan cake) without failure up to the 25 mm overhead displacement has achieved, however the composite samples fracture before the 25 mm contraction has been achieved. Figure 3 shows the stress-strain curves for composites containing 10 and 60% filler. It is clear that the increasing filler content not only reduced the strength but also changed the stress-strain behavior of the composite.

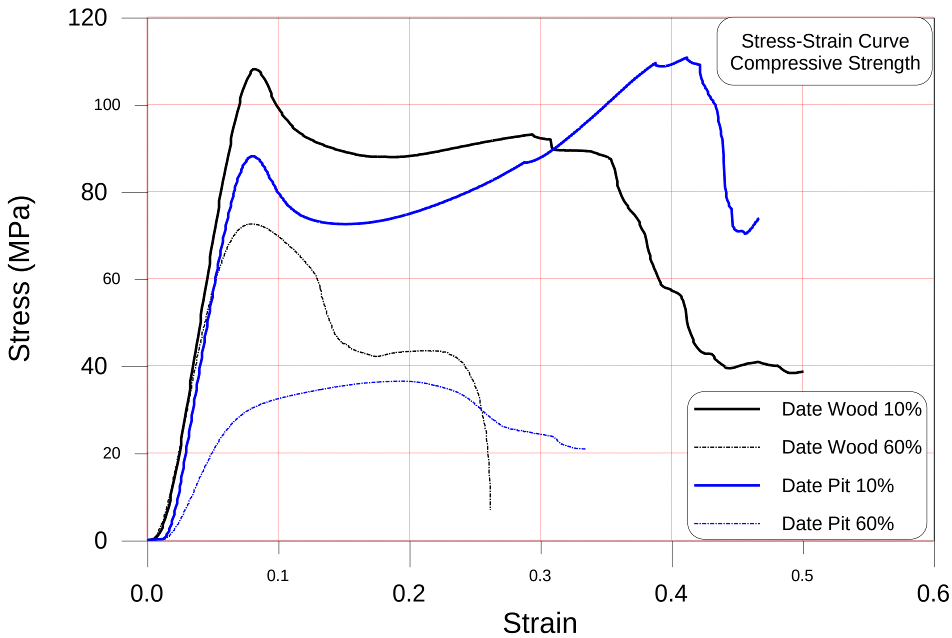

Figure 3: Stress-strain curve for composites, compressive strength test.

The effect of filler content on the compressive strength of the composites is shown in figure 4. The results showed clear decrease in strength with increasing both the date-pit and date wood content. This behavior is due to the increase of filler content that leads to introduce voids into the composite. Thus, the decrease in compressive strength is related to the increase of the porosity in the polymer matrix due to air entrainment and the poor filler/polymer matrix adhesion properties. The decrease in the mechanical strength due to inclusion of filler into the polymer matrix may be related to the anticipated coarse morphology of the composites evolved during the mixing of polymers, with date pits and wood in the absence of an appropriate coupling agent system. However, beyond 40% filler content, the decrease in mechanical strength of composites was insignificant. On the other hand, the date wood based composites showed better compressive strength than the composites contain date pit. Although compressive strength test showed a decrease in strength with increasing the filler content, the prepared composites showed greater mechanical strengths (108 – 35 MPa) when compared with the commonly used insulating materials, stone masonry (20–30 MPa) [18] and other composites composed of cement, sand and fiber of waste from coconut and durian (2.4–3.3 MPa) [19].

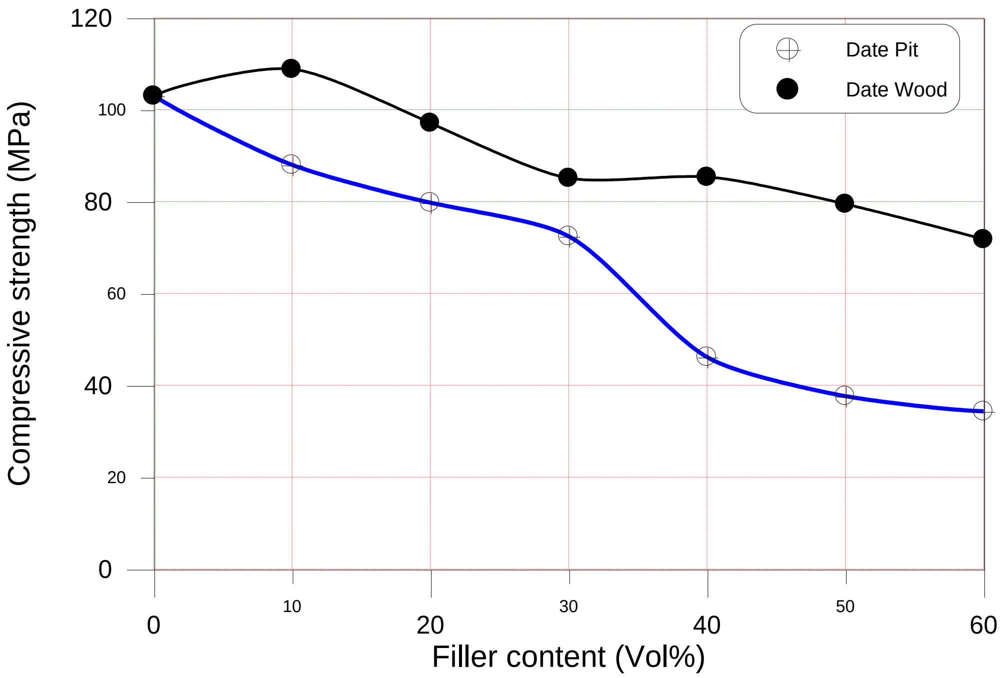

Figure 4: Compressive strength of date pit and date wood composites.

4 CONCLUSIONS

The main objective of this study was to investigate the thermal and mechanical properties of date pit and date palm wood reinforced polyester composites. From the experimental work performed on those composite materials, we arrive at the conclusion that the date pits and date wood can be utilized to manufacture stable and compatible composite materials. The prepared composite materials showed low values of thermal conductivity which were comparable with the commercial insulations. Generally, the date wood based composites showed better performance than that of date pit composites. Consequently, one would say that date wood based composites show good characteristics in terms of thermal conductivity, water retention and mechanical strength and with such cheap and abundant fillers from natural resources, they show a promising thermal insulating material both for domestic and industrial applications. On the other hand, the level of thermal and mechanical properties achieved, indicates to the both composites potential to be used in several types of applications.

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