Sustainable Insulation Materials for Green Strategy in Construction

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Abstract

In the twentyfirst century, there has been remarkable achievements in green material technology by the development of building insulation materials. Using the plant-based materials, waste materials are not only a potential response to the lack of fossil sources in certain regions but also a way of contributing to the environmental protection.

This study was performed to investigate whether the technological wastes manufactured by thermal power station and MCO as renewable material can be used in building insulation material production. The study is significant with regard to the environmental requirement of using wastes that would be dangerous otherwise

Keywords*:* Modified corn oil, fly ash, thermo-mechanical characteristics, insulation material, thermal conductivity, green building

Introduction

Energy is indispensable for improvement of life-quality and socioeconomic development in all countries (ASHRAE, 1990). The renewability challenges relating to the environment protection and energy saving has become a hot topic in both academia and industrial world for decades. The construction industry is considered to be the greatest contributor to bad emissions and energy consumption. According to a view of the energy performance and environmental assessment of buildings, it is vital to progress, an overview of current theoretical perspectives, constraints, trends, and implementations towards the development of environmentally conscious green building designs. With this aim, the development of sustainable bio-based insulation materials will lead to energy efficient and low cost, low maintenance building products (Hoseini et al., 2013). These new materials frequently possess mechanical and thermal characteristics asper or better than those of commonly used technological materials. As such, they may replace petrol-based materials resulting in petrol-based source protection and in waste decline (Kaplan, 1998).

Recently, polymeric composite materials made from renewable sources have attracted a lot of interest. Using plant oils as a source for polymers has many advantages over using petroleum as a source. Plant oils are more abundant than fossil oil. One of the main advantages of these oils is their cheapness. Combining with the low cost of extraction as mentioned above, this abundance makes them an attractive choice for industrial use (Teffera et al., 2016). The plant oils, as a renewable raw material (biodegradable and non toxic), mainly consist of a mixture of unsaturated and saturated fatty acids with many C-C double bonds which can be converted into other reactive groups. (O'Brien et.al., 2004; Güner et.al., 2006; Salunkhe et al., 1991)**.** The epoxy groups in plant oils can easily react with a number of chemicals to create new oleochemicals. The presence of multiple C-C bonds makes plant oils natural and ideal building materials to obtain of a proportion of utlize plastic materials (Eckey, 1954; Wang et. al. 1999; Petrovic et al. 2000). Oil-based plastics and biocomposites have large potency for technological implementations because of the amorphous characteristics and the low cost of oil-based materials (Imai et.al. 2007; Tsujimoto et. al. 2008). Corn oil is extracted from the germ of corn (Perkin et al., 2005). Big production of corn oil made in USA, Brazil, China, Mexico, India, Indonesia, France, South Africa, Ukraine, and Argentina (Saso et al., 2013). Corn oil has a triglyceride composition, with C-C (1-4) double bonds in each of the molecules with side chains of fatty acid. With different monomer types, the unsaturation's proportion in corn oil presents quite much allowing modification of the corn oil. The corn oil's total unsaturated fatty acid composition is approximately 80–90%. Palmitic acid, Linoleic acid, and Oleic acid consist about (8.6– 16.5%), (34–65.6%) and (20–42.2%), respectively (Bist et al., 2007). Inexpensive corn oil has been used commonly for inks, coatings, resins, lubricants, agrochemicals, and plasticizers in addition to their implementations in food industry. Other technological uses of corn oil include salve, paint, soap, textiles, nitroglycerin, rustproofing for metalic materials, insecticides, and biodiesel. It is sometimes used as a capsule for drug molecules in pharmaceutical preparations (Can et.al. 2001; http://tr.wikipedia.org.). It can be seen in the literature that there are many papers concerning polimerization of various modified plant oils and corn oil. For example, Li et al. (2013) prepared the conjugated corn oil and corn oil's cationic copolymerization for thermosetting polymeric materials. By Richard et al. (2007), plastic composites are obtained from Soy/Corn Oil. The resulting composites have shown useful thermal stability and mechanical properties and the very high potential for industrial applications. Tsujimoto et al. (2010) developed a novel group of biodegradable composites from sustainable plant-based oils. These nanocomposites have shown good coating characteristics, thermal stability, and mechanical strength which are fixed by joining the network of silica in natural polymer resin.

The coal-fired energy stations use coal as fuel in their furnaces. As waste, FA creates a primary content (70–90%), and bottom ash ingredient being between 10–30% in this type of power plants (Siddique, 2010). The global production of FA is predicted to exceed the level of 550 Mtyear^{-1}. Some of the countries where main source is coal for electric production such as South Africa (30 Mtyear^{-1}), Russia (50 Mtyear^{-1}), India (80 Mtyear^{-1}), the Canada, USA (83 Mtyear^{-1}), and China (100 Mtyear^{-1}), manufacture significant quantities of FA (Little et al., 2008). Turkey currently manufactures approximately 18 Mtyear^{-1} of FA from 15 coal-fired energy plants (Çavuşoğlu, 2008). Approximately 10% of Turkey FA is recently used as partial substitution in construction material industry, as a replace for crude material in construction material industry for grouting and as a filling material generally and building-construction implemantations (Little et al., 2008). All around the world, the maximal use of FA is seen in building industry (He et al., 2016). The production of construction materials from FA indicates an appealing alternative, this admit of primary technological waste material to be usefully re-used and prevent the usage of organic materials that need subtraction from the surroundings (Little et al., 2008).

C is a material widely spreaded on the surface of earth with the useful properties of small size (Cébron et al., 2015). Since it has been a cheap, natural raw material, it was utilized as filler material for plastics for years, but its strengthening capability is poor, thus it can only be used for traditional composites. With polymers and natural monomers, C can be customized to produce the C compounds coherent with chemical reactions (Hasegeva et al, 2006). The reinforcement of natural sourced plastics with C can produce novel value added implementations of sustainable bio-plastics materials worldwide. These biocomposites offer the potency for the application and diversification of polymers because of their ideal characteristics such as high heat dimensional stability, flexion temperature, fixed barrier characteristics, and enhanced physico and thermal-mechanical characteristics (Li et al., 2005).

P is a volcanic glassy rock that becomes a porosic material of eminently less density by heating to 900°C. Because of its high SiO_2, $Al2O_3$ contents, and glassy structure, P is an obvious pozzolan material. The expanded perlite is used in diverse horticultural, constructional (for example; the light building materials' production) and industrial applications (Chandra et al., 2002; Demirboga et al. 2001; Topcu and Isikdag, 2007). Depending on the amount and type, one or more of the following benefits can be supplied through their use: reducing the lower permeability, cement consumption, improved workability, higher strength, higher durability, etc. (Ellerbrock and Mathiak, 1994). Turkey can be considered as a significant P manufacturer in the world. P deposits are too large in the world (6700 Mt) and about 66% of those are in Turkey (TSPO, 2001).

Many researchers have worked on the characteristic structures of the FA-C-P and their usage as building-insulation materials. Ceylan and Ebeoglugil (2002) have used P and C for the production of lightweight construction materials with good thermal isolation and researched the characteristics of the costruction materials. By using boron waste, P, and C, Cobanlı (1993) has obtained light costruction materials with great thermal insulation value. Ayberk (1995) has determined that P is usable in different types in buildings due to its fire resistance and insulation characteristics. Celik (2015) has investigated the technical characteristics of P bricks produced with coal powder, K, Na, and borate. By Queralt et al. (1997), FA and C mixtures were sintered to manufacture ceramical materials appropriate for use as tiling, stoneware, bricks, and paving. Without the addition of non-organic additives or other natural binders, firing, milling, and pressing were used to manufacture dense ceramics from FA by Ilic et al. (2003). The thermal characteristics of brick-construction masonry with FA were investigated by Li et al. (2015). They displayed that the thermal properties of a clay construction block were lesser than that of a recycled block, which was shown lightly better thermal protection. Balo et al. (2007; 2008-June; 2008-October; 2009; 2010-1; 2010-2; 2010-3; 2011; 2013; 2015-January, April-2015) manufactured building-insulation materials with FA-C-different customized bio-based oils (such as sunflower, linseed, olive, soybean, palm, castor, canola, and tall) and analysed the technical properties of these materials. Combining FA and C with modified plant oil to manufacture a potentially useful building-insulation material was shown to be feasible. By increasing the modified plant oil-FA ratio and decreasing the C ratio, high abrasion loss, low thermal conductivity coefficient, and low strength were obtained. Specimens produced at high temperatures have shown lower strength and thermal conductivity coefficients than the specimens produced at low temperature. The building materials' *k* coefficient values with modified plant oil, FA and C are determined between 0.537-0.215 W/mK. The minimal thermal conductivity coefficient (0.215 W/mK) was determined with the specimens including 30% C, 70% FA, 5% pumice powder, 5% perlite, 50% modified castor oil in all the specimens. The tensile and compressive strengths varied from 1.287 to 0.428 MPa and 13.53 to 1.5 MPa, respectively. The best compressive-tensile strength values were observed to be 40% modified soybean oil, 30% FA, and 70% C in all the specimens. Results have shown that compressive-tensile strength of the insulation material decreased when the high C ratio and low modified plant oil ratio used in the production of the insulation material composition. The modified plant oil was not only served as binding material, but also emerged to serve as heat conductor. The C in the specimen not only fixed the compressive strength of the manufacture, but also fixed the abrasion loss. The best specimen characteristics in all the specimens containing modified castor oil/FA/C/ pumice powder/perlite were obtained as follows: thermal conductivity coefficient of 0.215 W/mK, tensile strength of MPa, compressive strength of 6.23 MPa, abrasion resistance of 3.91%, and density of 1.331g/cm^3.

The aim of this study is to investigate the technical characteristics of new building-insulation materials with lesser thermal conductivity to decrease heat conduction into costruction to diminish the fuel demand. The useful green building-insulation materials were manufactured by incorporating MCO, FA, C, and P. The chemical structure of CO and MCO is displayed in Figure 1.

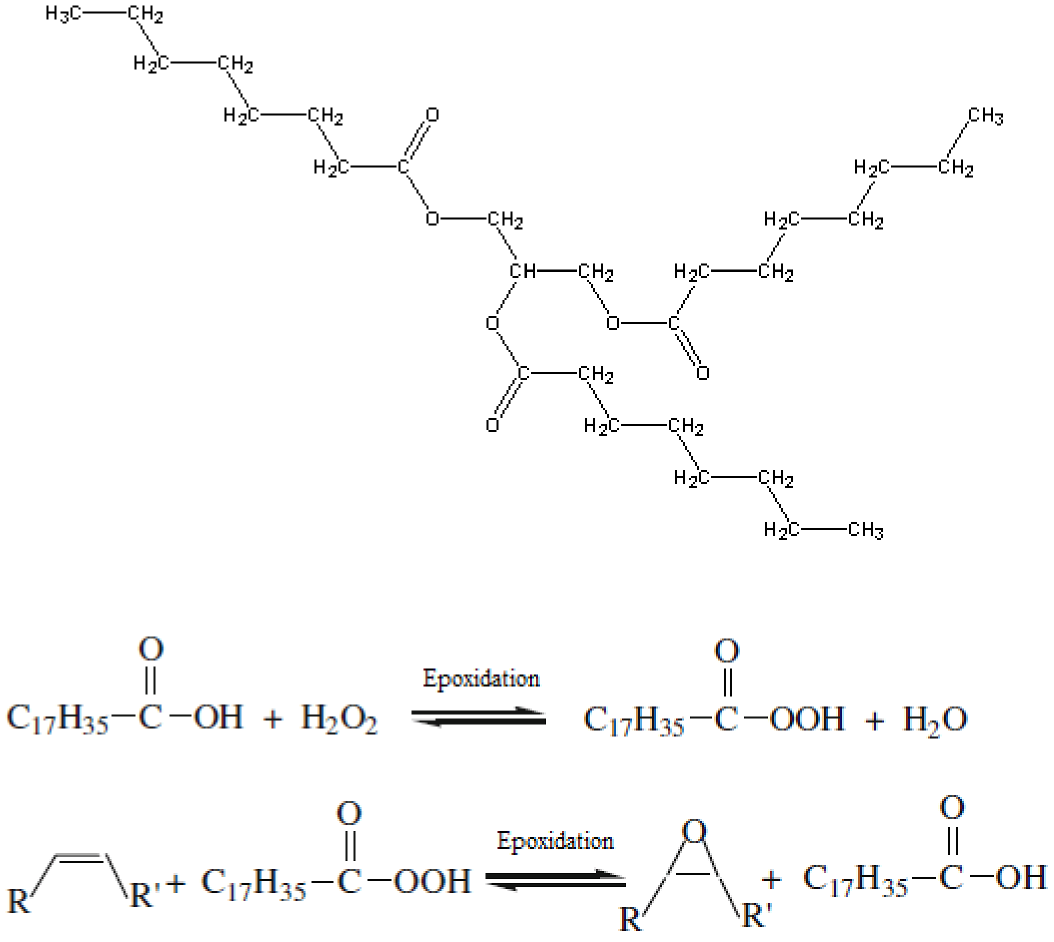

Fig. 1 Chemical structure of CO and MCO

The chemical and general properties of the CO are displayed in Table 1.

Table 1. Fatty Acid composition of CO

Fatty acid composition	Number of carbons/Number of double bonds	Linseed oil (% of total)
Myristic	14:0	0.1
Myristoleic	14:1	0.0
Palmitic acid	16:0	10.9
Palmitoleic	16:1	0.2
Margaric	17:0	0.1
Margaroleic	17:1	0.0
Stearic acid	18:0	2.0
Oleic acid	18:1	25.4
Linoleic acid	18:2	59.6
Linolenic acid	18:3	1.2
Arachidic	20:0	0.4
Gadoleic	20:1	0.0
Eicosadienoic	20:2	0.0
Behenic	22:0	0.1
Erucic	22:1	0.0
Lignoceric	24:0	0.0
Average number of double bonds per triglyceride		4.5

The thermal conductivity coefficient, the compressive-tensile strength and the abrasion loss of specimens are tested. This type of renewable insulation materials will contribute to the energy efficient building as well as green building initiatives through the development of materials from natural and waste resources.

Conclusions

This experimental study was performed to investigate whether the technological wastes manufactured by thermal power station and MCO as renewable material can be used in building insulation material production. The study is significant with regard to the environmental requirement of using wastes that would be dangerous otherwise. The financial feasibility of using these solid wastes is also of significant as the elimination of the solid wastes would desire substantial expenses to stock them and to take gauges to preserve from their harmful impacts. The naturally renewable materials support the trio of energy, economy, and environment because as a local resource it has many positive impacts on employment and provides activity to the economy of the country.

Under the conditions laid down in this search, the conclusions can be obtained as below:

The small thermal conductivity of specimens will help hindering the thermal transfer into the buildings and save energy.

The addition of FA and MCO into insulation material composition diminishes the thermal conductivity and tensile-compressive strength values.

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