Study of thermal insulation and some mechanical properties for hybrid composites (cement – wood sawdust)

Sanaa A. Hafed

Abstract— **The aim of the research is to study thermal conductivity and some physical and mechanical properties of hybrid composites which consist of (cement mortar and sawdust) to use these materials in thermal insulation according to the parts of the building and economic standards. The use of materials such as ordinary Portland cement, natural sand and sawdust "jawy", and water is a common and tradition for construction applications in Iraq. However, the hybrid composites materials are still rare employment.**

For the preparation of thermal conductivity samples compressive strength adopted the standard specifications of America. The thermal behavior of materials used such as cement is of great relevance in the application and use of the buildings as insulation for walls, and other structures. The high specific heat value is desirable due to the ability of cement associated to retain heat where this act is changing up content of sawdust used because of its qualities insulation. Also, the devaluation of the thermal conductivity is desirable in order to provide thermal insulation is required. The complexes cured in water for (1-28 days), the resistors value mechanical increased directly proportional to the increase sawdust content, which leads to an improvement in mechanical properties and a decrease in density and thermal conductivity, which makes high thermal insulation complexes concrete, and that achieves the objective of this research.

***Index Terms*— composites (cement mortar + wood sawdust), thermal conductivity, density compressive.**

I. Introduction

Iraq is characterized by extreme climatic conditions, it is cold winter and hot, hard with moderate relative humidity, moderate winds and high dust storms [1]. Perhaps the most important cause of this extreme climate is climate change in the region, which requires a change in the human activities that brought this to the point [2, 3]. Most of the pollutants emitted to the atmosphere are from burning fossil fuels in power plants and in transport [4]. So, the main cause of pollution in Iraq is the bad use of fossil fuels in energy production [5]. Therefore, any action that reduces the energy consumption will reduce and rationalize the energy consuming. Especially if we know that Iraq as an exporter of oil has been affected a lot by the volatility of oil prices in recent years [6].

Composite materials are engineering materials from many compounds that combine to give manufactured products and can be from two or more materials [7]. These composite products have been used to provide design solutions not provided by raw materials. That there are many materials today, and even become commonplace and the most common materials are polymers enhanced by fiber [8]. The use of composite materials instead of traditional building materials is usually to provide a great value of weight [9]. The good properties and durability of these engineered materials are to withstand high loads and work as heat insulators [10]. In addition to the low weight of individual components, these materials are desirable in ordinary construction and even in buildings with very special purposes such as shelters and private laboratories [11].

The enhancement in the composite material increases and improves the mechanical properties of the product. All fibers used in the composite are of different types possess different properties, and thus the characteristics of the compound added to the composite affect the product in different ways [12]. Fiber-reinforced plastic is a composite material made of polymeric fiber reinforced materials, usually glass fiber, carbon or aramid. Other fibers, such as paper, wood or asbestos can be used and sometimes used for some applications [13].

The use of composite materials has many advantages [14]:

1 - Accuracy of dimensions and the need for narrow emphases when using repeated templates.

2- High resistance to chemical compounds.

3 - Can be made parts of a unified specific application specific.

4. High resistance to corrosion, whether physical or chemical.

5. High durability and at the same time gives flexibility in design.

6 - Flexural high coefficient to carry the required loads and high-impact force at high temperatures.

The wooden fibers as reinforcing materials are used in a construction and structural composite materials have been distinguished. In spite of wooden fibers have week mechanical properties compared with artificial fibers. Also they characterized by the benefit of low density, low energy consumed through manufacturing process, and low cost. Different types of usable matrix materials become famous and Portland cement has been selected for the characterization and investigation [15]. Detection was made to the effect of the pulping technique selected to prepare the wooden fibers on the strength of the composite material and on the stability of the fibers in the matrix made from cement. A thermos mechanical, chemically pretreated at elevated temperature pulp manufactured by the Kraft process were choice for future study. The influence of the (w/c) ratio of the matrix material and the fiber weight in the composite material on the strength of the composite material some of mechanical properties are reported and studied for composite material containing these pulps [16]. Ref. [17] examined the possibility of developing new building materials called wood Crete, using wood sawdust, waste paper, and traditional lime. For this purpose, advanced processing techniques were used to take into account the characteristics of the wood of Crete. The results showed that the reliability of the developed vehicle is of low weight and has good insulation properties of heat with a density of 356 to 713 kg / m 3 and

resistance to pressure from 0.06 to 0.80 MPa, which makes it a good building material. The properties resulting from the addition of wood have increased their efficiency by adding waste paper and this effect has been shown in the strength and thermal conductivity.

Ref. [18] made products from lightweight composite materials, with sawdust and perlite as a block, using extruding process. After investigating the physical properties, the tanning and mechanical properties of these compounds, it was found that the dry densities identified for the wood cement compounds were close to 1.0 and were nailed as solid natural wood. By increasing the temperature of these substances, their flexural strength was decreased. When 50% sawdust was replaced with perlite, the resulting compound was resistant to higher temperatures than the first product.

Ref. [19] investigated the physical and mechanical properties of experimental polymer panels are made from single-walled carbon nanotubes and wood flour. Researchers used a ratio of the exact mass of wood to 50/50 lb (w / w) in all compounds. Wood-flour details with water were uptake, fish swelling, bending properties, impact strength, and morphological properties of manufactured compounds. The results showed that the mechanical properties of the composite compounds could be significantly enhanced with increasing percentage of maleic anhydride grafted polyethylene (MAB) content, which showed that carbon nanotubes could fill the spaces of wooden plastic compounds.

The present study aims to evaluate the thermal conductivity and the physical and mechanical properties of hybrid compounds consisting of cement mortar and sawdust to test the possibility of using these materials in thermal insulation in line with building parts and economic standards. The use of materials such as ordinary Portland cement, natural sand, "Jawy" sawdust and water is a common tradition of construction applications in Iraq. However, hybrid composite materials are still rarely used.

II. EXPERIMENTAL METHODOLOGY

A- Materials

The materials used included ordinary Portland cement, natural sand sawdust of wood called "jawy" and, water.

1- Ordinary Portland cement:

Iraqi Cement called “Kbessat” specific gravity of this type (3.15) and the water to cement ratio is (W/C =0.3)

2 - Sawdust of wood:

Wood sawdust using of jaweey tree ,has specific gravity of wood (1.25-1.55),density 750-800 kg/m^3,ultimet tensile strength of wood 1500 N/m^2 , elastic modulus of wood 10-17 Mpa ,moisture absorb of wood 7-9%,water absorb of wood 40-50% ,using two particles sizes larger than 5mm ,and less than 1.4 mm.

B- Methods:

The mixing process was allowed to run for about 10 minutes to allow thorough mixing by hand. It was not possible to monitor the quantity of water used with the different mixes firstly because the moisture content of the materials varied, and secondly because the “feel” method was used to indicate appropriate amounts of water to be added by trial and error. In any case, all excess water was expelled.

C- Measuring Details

1- Thermal conductivity:

Lee's disc manufactured by (Griffen and George Company/ England) Lee's disc instrument is used to calculate thermal conductivity of the samples under test, this instrument consists of three discs of brass and heater. The heat transfers from the heater to the next two disc then to the third disc across the samples. The temperatures of the discs (TA, YB, TC) can be measured with the thermometers which are located in them. The surfaces of these discs should be clean and well touched to obtain the optimum heat transfer through them. After supplying (6volt) by the power supply to the heater, the current value through the electrical circuit is about (0.25A), and then the temperatures of the discs are recorded after reaching the thermal equilibrium (nearly after 45 min).

$$IV=\pi r^2 e(T_A+T_B)+2\pi re[d_A T_A+d_S(\frac{1}{2})(T_A+T_B)+d_B T_B+d_C T_C] \quad (1)$$

Where: I: Is the current value through the electrical circuit.

V: supplied voltage (volute) , r: radius of disc (mm)

TA, TB& TC: temperatures of the brass disk A, B & C respectively.

dA, dB & dC: thicknesses of the brass discs A, B & C respectively ds is the thickness of the specimen. From the equation (3-1), the value of (e) is calculated which represents the quality of heat flows through the cross sectional area of the specimen per unit time (W/ m2C0).

$$k(\frac{T_B - T_A}{d_S}) = e[T_A + \frac{2}{r}(d_A(\frac{1}{4}d_S))T_A + (\frac{1}{2r})d_S T_B] \quad (2)$$

Where:

k: the thermal conductivity coefficient (W/ m. Co).Fig.(3-1) shows Lee's disc instrument.

2-The compressive strength test was determined according to BS1881: part 116:1989[13]. This test was measured on 100 mm cubes using an electrical testing machine with a capacity of 2000 kN, at loading rate of 5 MPa per minute. The average of three cubes was adopted for each test. The test was conducted at age of 28 days after curing with tap water, and at ages exposure to aggressive solution.

Compression =force / area (3)

Compression: [MPa]. Force: [N]. Area: [mm^2].

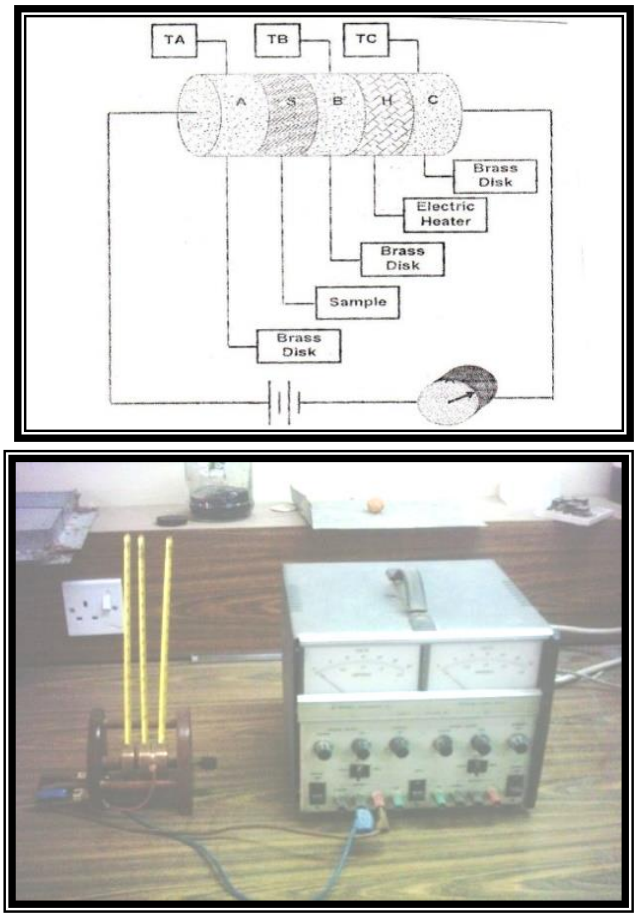

Figure (1): Lee's disc instrument [18].

III. RESULT AND DISCUSSION

A- Thermal Conductivity

The thermal behavior of cement-based materials is relevant to the use of these materials for buildings as walls, and other structures. In particular, a high value of the specific heat is desirable due to the associated ability to retain heat. Moreover, a low value of the thermal conductivity is desirable due to the associated ability to provide thermal insulation. On the other hand, a high value of the thermal conductivity can be desirable due to the associated ability to reduce the temperature gradient, and hence the thermal stress, in a structure. So, Fig. (2) shows the relationships between thermal conductivity values and sawdust of wood ratio (mixed as chopped fibers and flours) with two particles size, less even 2% sawdust ratio weight then more complex even 10% where the addition sawdust of wood have particle size large than 5mm reduce the values of thermal conductivity than mortars' values, more than fine sawdust have particles size less than 1.4mm, because of agglomerated fine particles when mixed with past of cement. The addition of natural sand losses specific heat and higher the thermal conductivity, so the thermal conductivity increase because of sand addition larger mass with sawdust present. While the thermal conductivity decrease because of sawdust of wood percent was much less when sand present [20, 21, 22, 23, 24, 25].

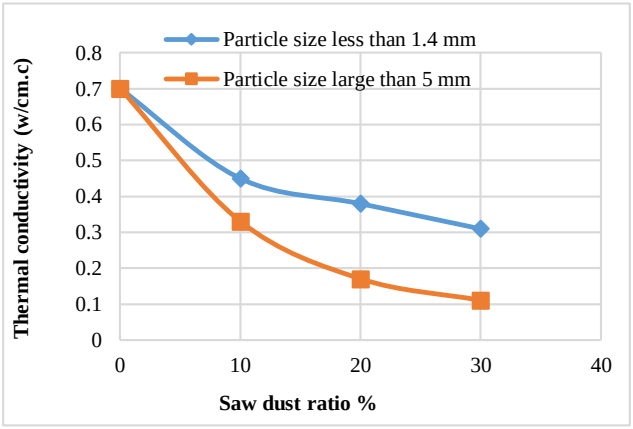

Figure (2): Relationship between thermal conductivity and wood sawdust ratio.

The other hand ,the effect of curing time in water, that effect show the excepted behavior ,where during the curing periods (1day to 28 days), the decreased the values of thermal conductivity because of, the porosity saturated with water during times of immersed samples. As shown in figs. (3 & 4).

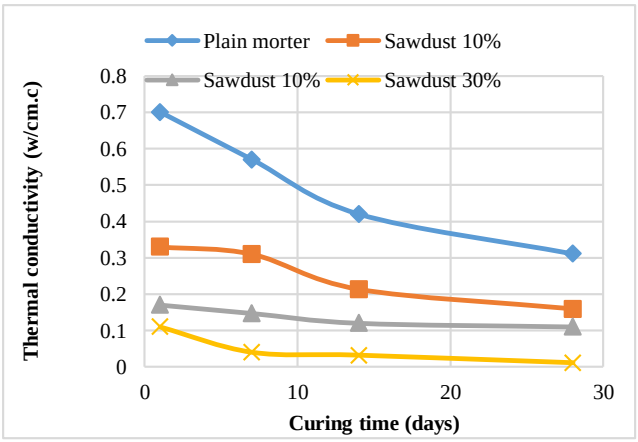

Figure (3): Relationship between thermal conductivity and Curing time in water of samples reinforced with particle size large than 5mm.

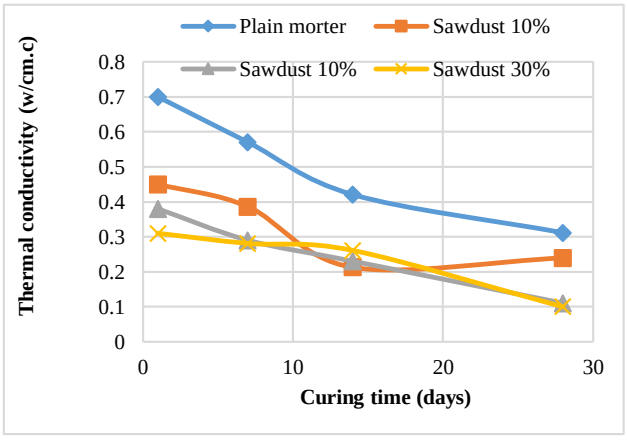

Figure (4): Relationship between thermal conductivity and Curing time in water of samples reinforced with particle size less than 1.4mm.

B- Compressive Strength

The analysis of compressive strength values for composites appearance larger values than plain cement as shown in fig. (5 & 6) for particles sizes large than (5mm),and less than (1.4mm) respectively: Effect of sawdust content on strength, the difference of strength as a references of sawdust percent for composites immersed time at (1-28 days) the compressive strength lessees with the increase in saw dust content [26].
This is leads to porosity produced by chopped fibers and flours. The maximum is reached around 30 % sawdust content. The compressive strength with fibers (smaller size) is slightly better than coarse sizes. The sawdust is complicated and made weaker zone and that agreement with Several authors reports [27] that in fracture process of fiber-reinforced concrete, the situated illustrated in figure (5 & 6) for fiber content ranged between 0 and 30%. This results of compressive strength agreement with other researcher results values in concrete when adding different insulations materials as while as with Mustafa [28] and Amenah [29] because of the type of physical bonding and the nature of sawdust fiber and flour which leads the cement to weakness of compressive strength values.

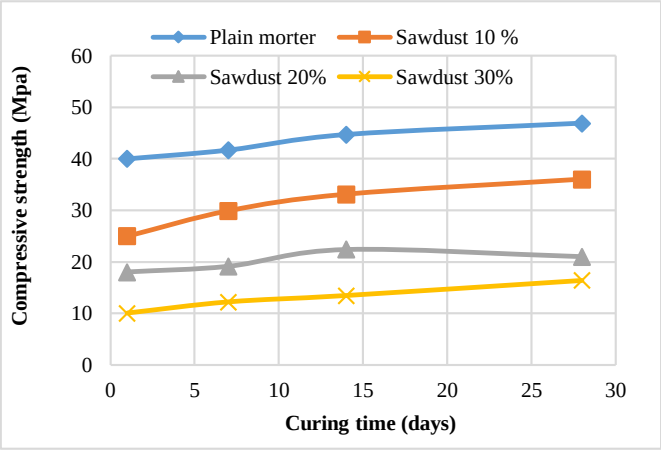

Figure (5): Relationship between compressive strength and Curing time in water of samples reinforced with particle size large than 5mm.

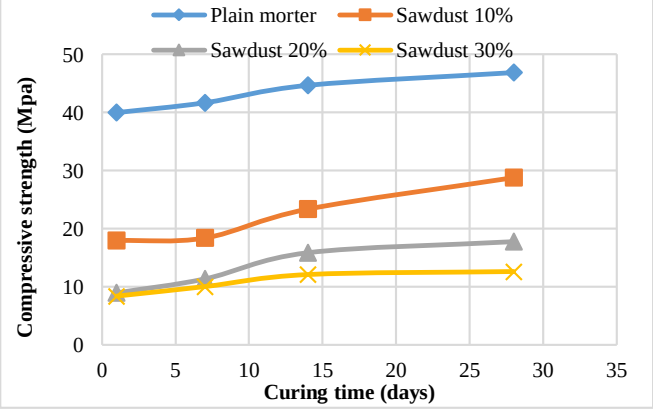

Figure (6): Relationship between compressive strength and Curing time in water of samples reinforced with particle size less than 1.4 mm.

IV. CONCLUSIONS

In this study, the thermal conductivity and some physical and mechanical properties of a hybrid compound consisting of cement mortar and sawdust were studied for use in thermal insulation according to economic and applied standards in Iraq. The study used commonly used materials available in local markets such as normal Portland cement, natural sand, "jaw" and water. The study result can be concluded in the following points:

1. The using of sawdust ratio between (10-30%) give the composites (cement-sawdust) light wighet .
2. Those ratio give higher tharmal insulation by decresing conductivity.
3. Compressive strength valuse have no larger valuesthan the plain cement paste.
4. Using sawdust less cost like recicle peapers.

REFRENCESES

[1] M. T. Chaichan, H. A. Kazem, A. A. Kazem, K. I. Abaas, K. A. Al-Asadi, "The effect of environmental conditions on concentrated solar system in desertec weathers," International Journal of Scientific and Engineering Research, vol. 6, No. 5, pp. 850-856, 2015.

[2] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Climate change: the game changer in the GCC region," Renewable and Sustainable Energy Reviews, vol. 76, pp. 555-576, 2017. http://dx.doi.org/10.1016/j.rser.2017.03.048.

[3] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "Changing the energy profile of the GCC States: A review," International Journal of Applied Engineering Research (IJAER), vol. 11, No. 3, pp. 1980-1988, 2016.

[4] M. T. Chaichan, H. A. Kazem, T. A. Abid, "The environmental impact of transportation in Baghdad, Iraq," Environment, Development and Sustainability, 2016. DOI: 10.1007/s10668-016-9900-x.

[5] A. A. Al-Waeely, S. D. Salman, W. K. Abdol-Reza, M. T. Chaichan, H. A. Kazem and H. S. Al-Jibori, "Evaluation of the spatial distribution of shared electrical generators and their environmental effects at Al-Sader City-Baghdad-Iraq," International Journal of Engineering & Technology IJET-IJENS, vol. 14, No. 2, pp. 16-23, 2014.

[6] H. M. S. Al-Maamary, H. A. Kazem, M. T. Chaichan, "The impact of the oil price fluctuations on common renewable energies in GCC countries," Renewable and Sustainable Energy Reviews, vol. 75, pp. 989-1007, 2017.

[7] M. T. Chaichan, S. H. Kamel & A. N. M. Al-Ajeely, "Thermal conductivity enhancement by using nano-material in phase change material for latent heat thermal energy storage systems," SAUSSUREA, vol. 5, No. 6, pp. 48-55, 2015.

[8] Y. M. Daud, K. Hussin, A. F. Osman, C. M. Ghazali, M. M. Al-Bakri, A. V. Sandu, "Dynamic mechanical properties of hybrid layered silicates/kaolin geopolymer filler in epoxy composites," Materiale Plastice, vol. 54, No. 3, 543-548, 2017.

[9] F. K. Liew, S. Hamdan, M. R. Rahman, J. Lai, "The effects of nanoclay and tin (IV) oxide nanopowder on morphological, thermo-mechanical properties of hexamethylene diisocyanate treated jute/bamboo/polyethylene hybrid composites," Journal of Vinyl and Additive Technology, September 2017. DOI: 10.1002/vnl.21600

[10] D. Bootkul, T. Butkul, S. Intrasiri, "Physical and mechanical properties of wood plastic composites from teak wood sawdust and high density polyethylene (HDPE)," Key Engineering Materials, vol. 751, pp. 277-282, August 2017. DOI: 10.4028/www.scientific.net/KEM.751.277

[11] R. Panneer, "Effect of composition of fibers on properties of hybrid composites," International Journal of Manufacturing, vol. 7, No. 4, pp. 28-43, October 2017. DOI: 10.4018/ijmmme.2017100103

[12] J. Jyoti, A. S. Babal, S. Sharma, B. P. Singh, "Significant improvement in static and dynamic mechanical properties of graphene oxide- carbon

nanotube acrylonitrile butadiene styrene hybrid composites," Journal of Materials Science, September 2017. DOI: 10.1007/s10853-017-1592-6

[13] M. S. Bodur, M. Bakkal, K. Englund, "Glass fiber/waste cotton fabric reinforced hybrid composites: mechanical investigations," Solid State Phenomena, vol. 263, pp. 179-183, September 2017. DOI: 10.4028/www.scientific.net/ssp.263.179

[13] M. Mohammed, A R. Rozyanty, T. Adam, B. O. Betar, "Study of the weathering effect in a natural environment on the hybrid kenaf bast/glass fiber-filled unsaturated polyester composite," 3rd Electronic and Green Materials International Conference 2017 (EGM 2017) Proceedings, vol. 1885, No. 1, pp. 020201, September 2017.

[14] A. K. Bledzki, J. Gassan, "Composites reinforced with cellulose based fibers," Progress in Polymer Science, vol. 24, No. 2, pp. 221-274, 1999. https://doi.org/10.1016/S0079-6700(98)00018-5

[15] F. A. Olutoge, "Investigations on sawdust and palm kernel shells aggregate replacement," ARPN Journal of Engineering and Applied Sciences, vol. 5, no. 4, 2010.

[16] E. P. Aigbomian, M. Fan, "Development of Wood-Crete building materials from sawdust and waste paper," Construction and Building Materials, vol. 40, pp. 361-366, 2013. https://doi.org/10.1016/j.conbuildmat.2012.11.018

[17] X. Zhou, Z. Li, "Light-weight wood–magnesium oxychloride cement composite building products made by extrusion," Construction and Building Materials, vol. 27, No. 1, pp. 382-389, 2012. https://doi.org/10.1016/j.conbuildmat.2011.07.033

[18] H. Y. Kordkheili, M. Farsi, Z. Rezazadeh, "Physical, mechanical and morphological properties of polymer composites manufactured from carbon nanotubes and wood flour," Composites Part B: Engineering, vol. 44, No. 1, pp. 750-755, 2013. https://doi.org/10.1016/j.compositesb.2012.04.023

[19] M. D. Campbell, R. S. P. Coutts, "Wood fiber-reinforced cement composites," CSIRO Division of Chemical Technology, Victoria Australia , Journal of Materials Science, vol. 15, pp. 1962-1970, 2016.

[20] NAHB Research Center INC., "Insulating concrete forms: installed cost and acoustic performance “prepared for us department of housing and urban development," Portland Cement Association, and National Association of Home Builders Prepared by Upper Marlboro, December 2009.

[21] A. Zziwa, S. Kizito, A. Y. Banana, J. R. S. Kaboggoza, R. K. Kambugu and O. E. Sseremba, "Production of composite bricks from sawdust using portland cement as a binder," Uganda Journal of Agricultural Sciences, vol. 12, No. 1, pp. 38-44, 2015.

[22] A. O. Olorunnisola, "Strength and water absorption characteristics of cement-bonded particleboard produced from Poconut Husk," Journal of Civil Engineering Research and Practice, vol. 31, pp. 41–49, 2006.

[23] P. Turgut, "Cement composites with limestone dust and different grades of wood sawdust," Building and Environment, vol. 42, pp. 3801–3807, 2014.

[24] A. A. Erakhrumen, S. E. Areghan, M. B. Ogunleye, S. L. Larinde and O. O. Odeyale, "Selected physico-mechanical properties of cement bonded particle board made from pine (Pinus caribaea M.) sawdust-coir (Cocos nucifera L.) mixture," Scientific Research and Essay, vol. 3, No. 5, pp. 197-203, May, 2014.

[25] W. D. Callister, "Fundamentals of Materials Science and Engineering," 5th edition, 2015.

[26] H. T. Mark, I. M. Sernek, Wood-based panels an introduction for specialists," Cost Office, Cover photos: Courtesy of Dieffenbacher GmbH, Eppingen, Germany Layout: Henrik Schmidt, Wentorf, Germany, 2015.

[27] R. Vaickelioniene, Cement hydration in the presence of wood extractives and pozzolan mineral additives giedrius vaickelionis," Faculty of Chemical Technology, Kaunas University of Technology Radvilenu Str. 19, 50254 Kaunas, accepted march 30, 2016.

[28] H. Mustafa, "Influence of oil products on mechanical properties of polymer concrete," MSc. Thesis in Applied Sciences, Materials Sciences 2014.

[29] E. Amenah, A comparative stud y of developing insulating and improved mechanical properties of raw materials re-enforced lightweight concrete," MSc. Thesis in Applied Sciences, Materials Sciences, 2015.