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POSSIBILITY OF USING COMPRESSED RICE STRAW AS AN INSULATION MATERIAL

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ABSTRACT

The present work introduces composite manufactured from grounded rice straw via addition urea-formaldehyde "UF" resin as a binding material. The different percentages of commercial urea-formaldehyde resin were used by weight as binder in manufacturing of the composite. The expansion percentage "E" (%), bulk density "Bd" (kg/m^3) and thermal conductivity "k" (W/m.^oC) of the manufactured composite affected by different content of binding material "Bm" UF resin (0, 20, 30, 40 and 50%), different formation pressure "FP" of (5.7, 12.4 and 18.5 MPa) and elapsed time (days) after releasing formation pressure. The results showed that expansion percentage "E" (%) increased with increasing of formation pressure "FP" and elapsed time (days) at different binding material "Bm" (%). The bulk density "Bd" (kg/m^3) was higher at binding material percentages "Bm" of 50 % under formation pressures of 18.5 MPa, after 0, 7 and 14 days. The bulk density “Bd” (kg/m^3) was lower at binding material percentages "Bm" of 0 % (control) under formation pressures of 5.7 MPa, after 0, 7 and 14 days. The thermal conductivity "k"(W/m.^oC) decreased with increasing formation pressure "FP" and binding material percentage.

INTRODUCTION

It is known that the environmental problems include all civilized societies, and in Egypt, it became a huge problem year after year especially in the countryside.

The common problem is associated with agricultural residues accumulated in the field and their disposal by wrong or unsuitable ways, causing many problems to environmental balance. So, the agricultural residues disposal and how to use it in useful applications became the most important subject which takes the first place between different countries and international, regional association's interests. Agricultural wastes were used for animal feed, fertilizer and fuel for energy production, but little work has been carried out to develop utilization of these wastes in production of building materials. One of the most abandoned materials in Egypt is cellulous non-wood fibrous materials, such as rice straw. The total annual Egyptian crop residues are about 30 Tg (teragram), about 3-4 Tg of which is rice straw (MSEA, 2007). In fact, rice straw is so abandoned that the Egyptian government allowed straw burning at agricultural fields. In the fall of 1999, an autumnal black cloud appeared above several Egyptian cities, with a thick bitter-smelling fog, due to the straw burning. Consequently, instead of burning the straw, recycling it with a mixture of cement forms a sustainable low-cost building material, which also reduces atmospheric pollution (Kazragis, 2005). Halvarsson (2010) Said that the annual plant materials (e.g., straw) are natural composite lignocellulosic materials. They consist mainly of cellulose, hemicelluloses and lignin. They include also considerable amount of inorganic components (e.g., silica, potassium, phosphorous and sodium). The ash content is in the range of 4–20% and most of it consists of silica (SiO_2). The rice straw structure and other annual plants are less homogeneous than the perennial softwoods or hardwoods in the morphological structure. The rice straw is composed of the stem and leaves. The stem is divided into nodes and internodes. The internodes are separated by the nodes at which the leaves are attached. The straw internodes are the optimal straw material for the fiberboards and paper producing industries. The amounts of fiber cell elements are less in nodes and leaves and useless as a fiber raw material after the thermo-mechanical defiberation process. El-kassas and Mourad (2013) mentioned that the burning, organic composite or land filling is common practices in Egypt. The rice paddy production in Egypt is about 6.6 million ton per year. It is inedible secondary waste material from annual plant and is not used as efficiently as it could be. In the production of bioenergy the high silica and ash composition of rice straw is a major disadvantage as they build up and require special care and extra costs. They complicate the burning technique and handling of such large amounts of ash. The most important benefits of selecting the rice straw (which is agricultural residue and grown in large areas of the world) material for medium density fiberboard (MDF) production are reduction of open field burning of an annual plant and to capture carbon dioxide (CO_2). In addition, the straw based MDF panels can be recycled or converted to energy after utilization. In addition to these benefits, the straw could act as a thermal insulation material for the unpleasant Egyptian weather. The use of thermal insulation helps reduce energy costs, while creating pleasant indoor temperatures. Jones (2001) reported that the straw provides super-insulation at an affordable cost, the "K" value of straw in a straw bale was 0.09 W/m.°k. Kennedy and Wanek (2002) reported that the straw is available at a cheap price wherever grain is grown and stacked like giant bricks to form a thick wall, bales offer super insulation from the heat or cold or noise outside. It provides a quiet, comfortable living space with modest life-time energy requirements. They also added that unlike manufactured insulation materials, straw is natural and non-toxic and very low in embodied energy. Should a fire get started, lab tests and experience have shown that foam insulations ignite at low temperatures and release poisonous fumes and wood studs and trim will burn readily, but bales, compressed and sealed with plaster, are starved of oxygen and resist combustion. McCabe (1993) determined the insulating value for wheat bales and rice straw bales. He found that the moisture content and bale density affecting insulating values and bales used for construction should have the driest possible conditions for greatest insulating value. Dry bales have higher insulating values than bales with moisture because the moisture migration transfers heat. Straw bale construction has high insulating value. Rice straw is similar to wheat straw in its insulating value, the positioning of straw bale does have an effect on the insulating value of the bale and home energy usage can be reduced by 12.4% by using this building material. El-kassas and Mourad (2013) indicate that the bonding agents are those conventionally employed in forming composite products and include both acidic and alkaline type binders. Typical bonding agents are amino resins, phenolic resins, resorcinol resins, tannin resins, isocyanate adhesives or mixtures thereof. Resins which can be used to bond treated straw fibers include urea–formaldehyde resins (UF, melamine urea–formaldehyde resins (MUF), phenol–formaldehyde (PF), resorcinol– formaldehyde (RF), tannin formaldehyde (TF), polymeric isocyanate (PMDI) and mixture thereof. The resins can be added in different amounts based on several parameters. Hai-Ian *et al.,* (2006) have studied the effect of a modified Urea–formaldehyde resin on the rice-straw medium density fiberboard that is prepared using the conventional method. Yasin *et al.,* (2010) have conduct a study to review the literature on methods to improve the bondability of straw with conventional resins and to help in efficient utilizing wheat and rice straw as an alternate resource for the industrial manufacture of particleboards and fiberboards. Halvarsson *et al.,* (2008) have investigated wheat straw as a raw material for manufacturing of MDF (SMDF). Commercial urea melamine formaldehyde (UMF) and a mixture of UMF-resin and urea melamine phenol formaldehyde (UMPF) adhesives were used as binders. They have produced wheat straw-based MDF panels using a resin content varied between 14% and 17% at average densities ranged from 750 kg/m^3 to 1025 kg/m^3 and final thicknesses of approximately 9 and 16 mm. There results showed that, SMDF panels produced with densities above 780 kg/m^3 and resin contents above 14% met the requirements for wood-based MDF standard (EN 622-5, 1997). They have used the water treatment, heating and chemical additives in the fiber preparation process and also commercial melamine-modified urea formaldehyde (UMF) resin was used as a binder. Everett (1978) defined that the thermal conductivity (k) is a measure of the rate of heat transfer through a material from face to face (not from air to air). The “k” values of materials vary with density, in the examples quoted from 0.029 to 3725 W/m.°k with corresponding variations in density from 64 to 9000 Kg/m^3, conductivity values also vary with temperature, porosity and moisture content.

MATERIALS AND METHODS

Raw materials:

Ground rice straw:

The rice straw variety used was SAKHA 101 from season 2011/2012. The average length for this variety was about 900 mm. The rice straw was chosen in the present study because of the huge amounts of it that found in Egypt. These amounts are about 3-4 Tg/year (MSEA, 2007). The desired size of rice straw used in the present study was obtained by using two machines; the first one was a cutting forage machine and the second was a grinding residues machine. The desired size of rice straw was obtained by putting a lot of rice straw in the cutting forage machine. The output chops were put in the second machine which has a screen of 2 mm.

The urea–formaldehyde resin:

The urea–formaldehyde resin was supplied by Mansoura for Resins and Chemical Industries, Egypt, Nutrition.

A pressing apparatus:

The hydraulic press was used in manufacturing the composite. The press upon the samples was achieved manually by a manual pump and simple acting cylinder with manually return. Model (pm); Press max. (20 Mg); Production Year (1996); Gauge (0- 60 MPa); Resolution (2 MPa), The hydraulic press made by SICMI sa.s., Trecasali (Parma), Italy.

Pressing cylinder:

The samples were compressed in a cylindrical shape to satisfy the requirements of the other measurements. A cylinder was used to compress samples inside it, which was constructed, by El-Bessoumy, 2005 from mild steel. The inner diameter of 105.4 mm, outer diameter of 110 mm, thickness of 5 mm and length of 210 mm. The cylinder was divided into two longitudinal halves to ease release the sample without any deformation. The two longitudinal halves of the cylinder were connected by two steel rings. In order to compress the sample inside the compression cylinder, two disks from steel were used. The diameters of disks were made to be 104.5 mm (0.5 mm less than compression cylinder diameter) to decrease the friction between disks and the cylinder inner surface. A hollow circle was done in one side of the upper disk with diameter equal the diameter of the pressing apparatus cross-head. This hollow circle has a depth of 2 mm and in the center of disk surface to insure that the pressure always directed to the cylinder axis. The upper and lower disks thicknesses were done to be 32.5 mm and 30.5 mm, respectively. The samples obtained from the cylinder after compression was formed to a disk shape with diameter of 104.5 mm and the thickness differs according to the treatments.

Thermal conductivity apparatus:

In order to study the thermal conductivity of the samples of composite, an apparatus was developed according to Lee's method (Noakes *et al.,* 1953). The apparatus was constructed, by El-Bessoumy, 2005. The apparatus as in the following Fig. (1) consists of: (1) an electrical heater of 1 kW. (2) Steam unit made from stainless-steel. (3) A hose to transport the steam to the steam chamber. (4) Steam chamber of 100 mm height and 105 mm diameter (5) Brass disk attached with the steam chamber, its diameter is 105 mm and its thickness is 10 mm. (6) Lower brass disk its mass is 740 g. (7) Thermometer. (8) Supported chains.

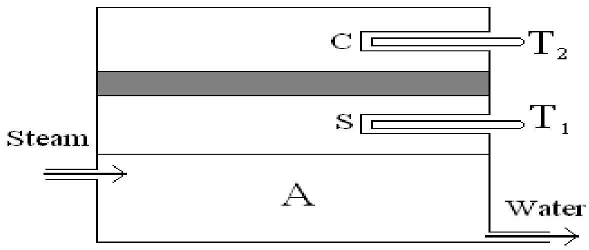

Fig. (1) : A schematic diagram for steam unit and sample of thermal conductivity Apparatus (C, S) Brass disks, (B) Sample, (T_1, T_2) Thermometers, El-Bessoumy,2005).

Test procedures:

Rice straw is one of agricultural residues that used in this study, in order to study thickness expansion percentage (%), bulk density (kg/m^3) and thermal conductivity (W/m.°C) as affected by the following variables: Binding materials percentage "UF" (%) and Formation pressure "FP" at constant holding time of 15 min. The experiments were carried out at the research center of Agricultural Engineering Faculty, Al-Azhar University, Nasr city, Cairo, Egypt.

Binding material percentage (%):

Four percentages of Urea - formaldehyde (UF), as a binding material, were added to ground rice straw residue. The ratio were 20, 30, 40 and 50 (%) by weight, in addition that there was one without adding "UF" as a control sample.

Formation pressure levels (MPa):

Three formation pressures of 5.7, 12.4 and 18.5 "MPa" were used.

Sample adjustment for pressing:

Every sample had a constant weight of 25 g. The mass of samples were measured by a digital electronic balance with accuracy of 0.01 g for a mass of 5 kg, the sample was put inside the compression cylinder and compressed between tow disks by hydraulic pressing at a selected loading level for a constant hold time of 15 min. The thickness of sample was recorded (by a steel tap) several times while the sample under pressing. The sample was released from the cylinder at the end of pressing and thickness of sample was recorded too. Finally, every sample was put into a plastic page to conserve the moisture content and stored inside a wooden container for a period of 14 days.

An experimental design:

The combination of one shape of grounded rice straw and three levels of Formation pressures "FP" (MPa) results in three treatments. These treatments experimented at fives ratios of binding materials percentages "UF" (%) resulting 15 treatments. Each treatment was repeated three times to give three replicates resulting 45 samples.

Measurements:

The following measurements were made at each sample after 14 days:

Expansion percentage "E":

All specimens in the present study expanded, this may be attributed to adding the rice straw and binding material percentages. Thickness of dry samples was measured after releasing formation pressure, 7 and 14 days. The expansion percentage was calculated as follows:

Expansion "E" (%) = (Thic. after press respect to time - Thic. under press)/ (Thic. under press) …….(1)

Bulk density "Bd":

The lengths of samples which were recorded under pressing and after releasing formation pressure were used to calculate the bulk density "Bd" at previous different conditions:

$$\text{Bulk density (Bd)} = \frac{M}{\frac{\pi\, d^2 L}{4}} \qquad \text{…….(2)}$$

Where :

M : A constant mass of sample and equal 25 g.

L : Length of sample at different cases.

d : The inner diameter of compression cylinder.

Thermal conductivity "k":

The Lee's method (Noakes *et al.,* 1953) for the thermal conductivity determination of a bad conductor was used on all samples. A sample (B) of thickness (x) and radius (r) was placed between the two brass disks (S,C). The steam generated from water and transport through a hose to the steam chamber (A). There was a period of waiting until the readings (T_1) and (T_2) of thermometers (1) and (2) are steady. As brass is an extremely good conductor the thermometers can be taken as an indicator to the temperatures of sample faces. Thus the temperature gradient in the steady state is (T_1 - T_2) / x. The rate of heat flow through the sample was found by the following way. The temperature of (B) was steady it was therefore the sample receiving heat by conduction from (A) with the same rate which the sample loosing heat to surroundings from (C). For calculating the rate of heat loss from (C), the mass (m) of the disk (C) was found and the specific heat (S) of brass obtained from a set of tables. The disk (C) was only heated gently and raised few degrees of temperature (T_3) above (T_2). The specimen alone was placed on a top of (C) and the time (t) sec. was taken for the temperature to fall to (T_4) which was far below (T_2) as (T_3) was above it. The thermal conductivity for sample was calculated from the following equation:

$$K = \frac{m.s\,(T_3 - T_4)\,x}{t\,(T_1 - T_2)\pi\, r^2} \qquad \text{......... (3)}$$

where :

k : Thermal conductivity for sample (W/m.°C).
m : Mass of brass disk (C) 0.74 (kg).
r : The radius of sample (m).
t : Time (sec.).
S : Specific heat for brass, (380 J/kg.°C).
x : Thickness of sample (m).

RESULTS AND DISCUSSION

Effect of binding material percentage "Bm" (%) and formation pressure "FP" (MPa) on expansion percentage "E" (%):

Experiments were carried out for formation pressure (5.7, 12.4 and 18.5 MPa) and binding material (0, 20, 30, 40 and 50 %). Figures (2, 3 and 4), show the relation between expansion percentages (%) and binding material percentage (%) at different times and formation pressures. It is clear that the all curves have the same trends for all experiments. The expansion percentage (%) increases with formation pressure and elapsed time increasing at different binding material percentage (%). The expansion percentage (%) decreases with increasing binding material percentage (%) until 30% and after that the expansion percentage (%) increases with increasing binding material percentage (%)
at different times and formation pressures, may be due to the effect of UF percentage and pressure. At formation pressure 5.7 MPa, the expansion percentages (%) ranged between (48.15 to 97.14 %), (90.63 to 194.44 %) and (103.70 to 219.44 %) after 0, 7 and 14 day respectively as in figure (2). While the expansion percentages (%) at formation pressure 12.4 MPa ranged between (68.18 to 146.15 %), (116.00 to 223.08 %) and (128.00 to 257.69 %) after 0, 7 and 14 day respectively as in figure (3). Also the expansion percentages (%) with formation pressure 18.5 MPa ranged between (95.00 to 262.50 %), (125.00 to 325.00 %) and (142.50 to 343.75 %) after 0, 7 and 14 day respectively as in figure (4).

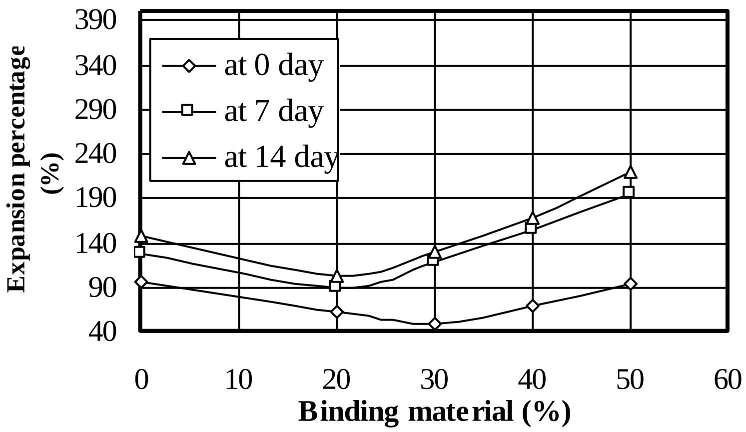

Fig. (2): Effect of binding material percentage"Bm" (%) on expansion percentage "E" (%) at diffrent times (day) and formation pressure"FP" of 5.7 (MPa).

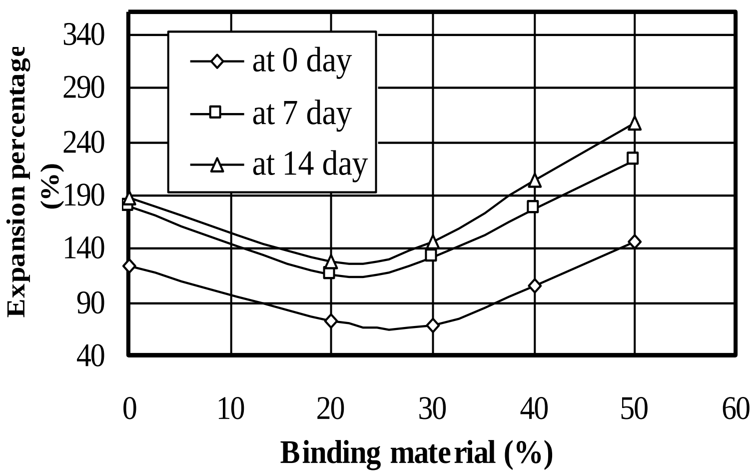

Fig. (3):Effect of binding material percentage "Bm" (%) on expansion percentage"E" (%) at different times (day) and formation pressure "FP"of 12.4 (MPa).

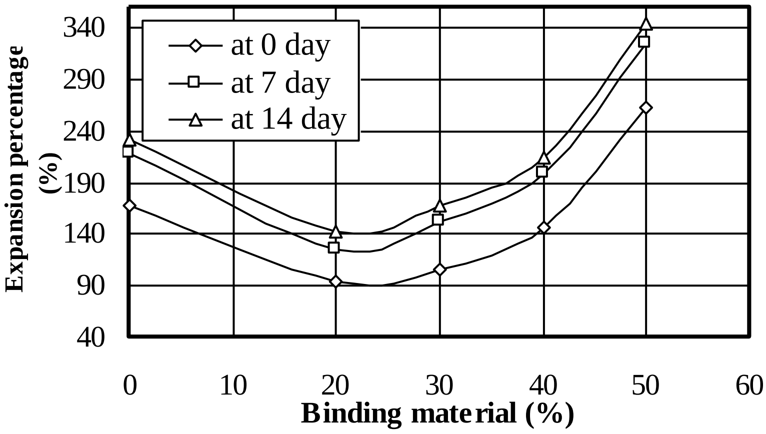

Fig.(4):Effect of binding material percentage "Bm" (%) on expansion percentage "E" (%) at different times (day) and formation pressure "FP" of 18.5 (MPa).

Effect of binding material percentage "Bm" (%) and formation pressure "FP" (MPa) on bulk density "Bd" (kg/m^3):

Figures (5, 6, 7 and 8) show the relation between bulk density (kg/m^3) and formation pressures "FP" at different binding material percentages (%) under formation pressure and 0, 7 and 14 days respectively. In all curves the bulk density increases with increasing formation pressure and binding material percentage (%) while the bulk density decreases with increasing time. Figure (5) shows the bulk density values under pressure and indicates that the lower value of bulk density is 820 (kg/m^3) at formation pressure of 5.7 (MPa) and binding material of 0 (%) while the higher value is 3588 (kg/m^3) at formation pressure of 18.5 (MPa) and binding material of 50 (%). Figure (6) shows the bulk density values after releasing the pressure directly (0 days) and indicates that lower value of bulk density is 416 (kg/m^3) at formation pressure of 5.7 (MPa) and binding material of 0 (%) while the higher value is 990 (kg/m^3) at formation pressure of 18.5 (MPa) and binding material of 50 (%). Figure (7) shows the bulk density values after 7 days and illustrates that the lower value of bulk density is 329 (kg/m^3) at formation pressure of 5.7 (MPa) and binding material of 0 (%) while the higher value is 736 (kg/m^3) at formation pressure of 18.5 (MPa) and binding material of 50 (%). Figure (8) shows the bulk density values after 14 days and indicates that the lower value of bulk density is 315 (kg/m^3) at formation pressure of 5.7 (MPa) and binding material of 0 (%) while the higher value is 704 (kg/m^3) at formation pressure of 18.5 (MPa) and binding material of 50 (%).

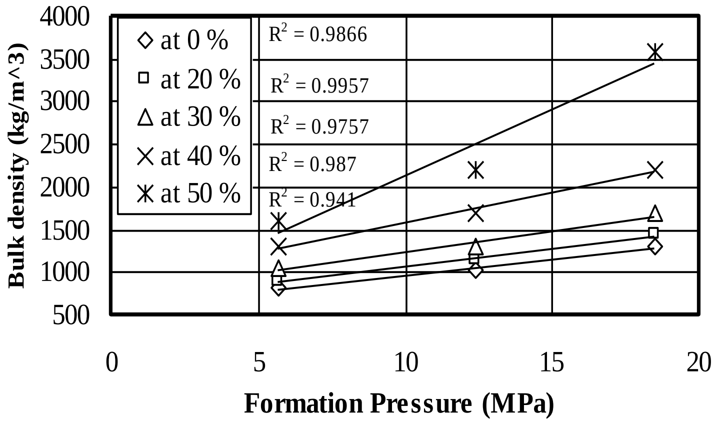

Fig. (5): Effect of formation pressure "FP" (MPa) on bulk density "Bd"(kg/m^3) at different binding material percentage (%) under formation pressure "FP".

Also it is clear that the bulk density "**Bd**" for all experiments were the linearly according to the following equation:

Bd = a FP + b

Where: **a** and **b** constants depending on formation pressure "FP' (MPa), binding material percentage (%) and elapsed time (days) after removing formation pressure as in table (1).

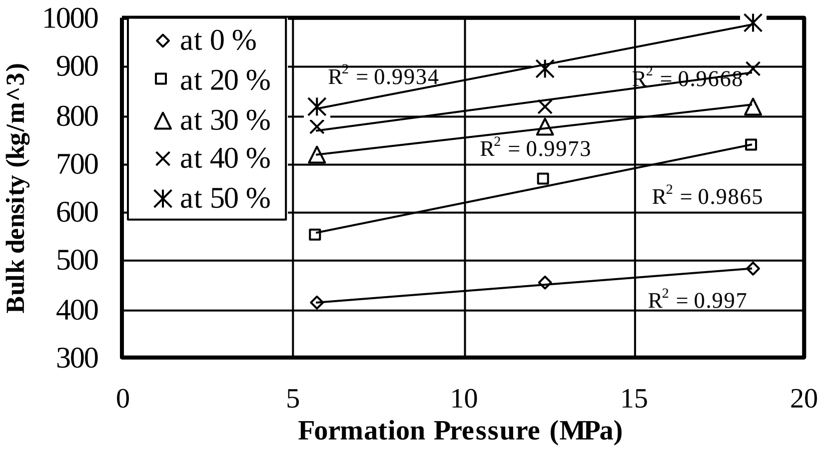

Fig. (6):Effect of formation pressure "FP" (MPa) on bulk density "Bd" (kg/m^3) at different binding material percentage (%) after releasing formation pressure directly (0 day).

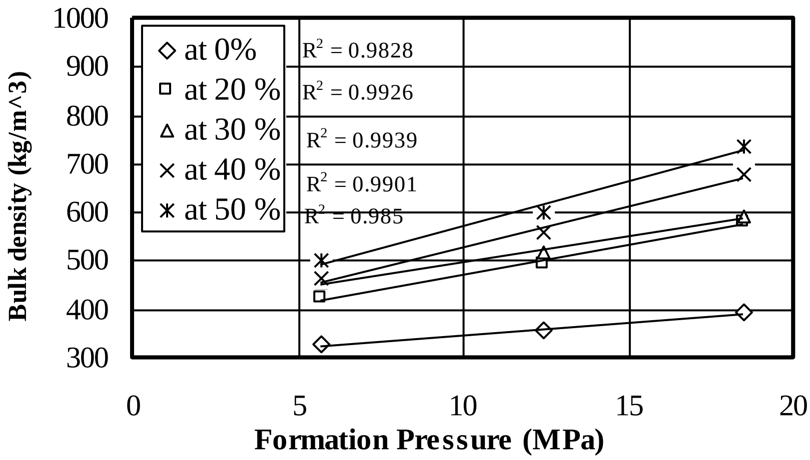

Fig. (7):Effect Of formation pressure "FP" on bulk density "Bd" (kg/m^3) at different binding material percentage "Bm" (%) after 7 day.

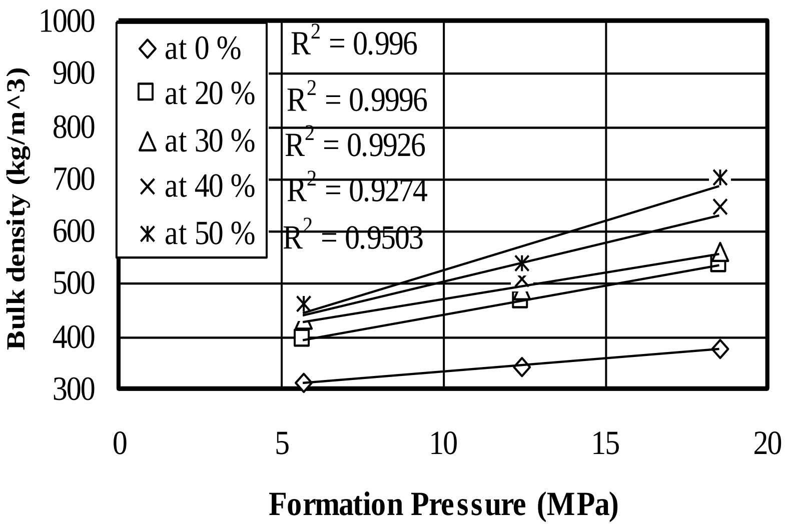

Fig. (8): Effect of formation pressure "FP"(MPa) on bulk density "Bd"(kg/m^3) at different binding material percentag "Bm" (%) after 14 day.

Table (1): Values of constants a and b at different binding material percentage (%) and different elapsed time (days).

Elapsed time	Binding material (%)									
	0 %		20 %		30 %		40 %		50 %	
	a	b	a	b	a	b	a	b	a	b
Under FP	0.038	0.589	0.042	0.648	0.049	0.759	0.070	0.876	0.155	0.576
After FP (0day)	0.006	0.386	0.014	0.476	0.008	0.674	0.009	0.716	0.013	0.741
7 day	0.005	0.297	0.012	0.351	0.011	0.394	0.017	0.363	0.018	0.389
14 day	0.005	0.285	0.011	0.332	0.010	0.374	0.015	0.356	0.019	0.340

Effect of binding material percentage "Bm" (%) and formation pressure "FP" (MPa) on thermal conductivity "k" (W/m.°C):

Figure (9) shows the relation between thermal conductivity "k" (W/m.°C) and formation pressure "FP' (MPa) at different binding material percentage (%). It is clear that the thermal conductivity decreases with formation pressure "FP' (MPa) and binding material percentage (%) increasing. The thermal conductivity were (0.0260, 0.0250, 0.0237, 0.0228 and 0.0171 W/m.°C) at "FP" 5.7 MPa; (0.0216, 0.0150, 0.0142, 0.0136 and

0.0132 W/m.°C) at "FP" 12.4 MPa and (0.0194, 0.0132, 0.0117, 0.0106 and 0.0102 W/m.°C) at "FP" 18.5 MPa for binding material percentage (%) of (0. 20, 30, 40 and 50 %) respectively.

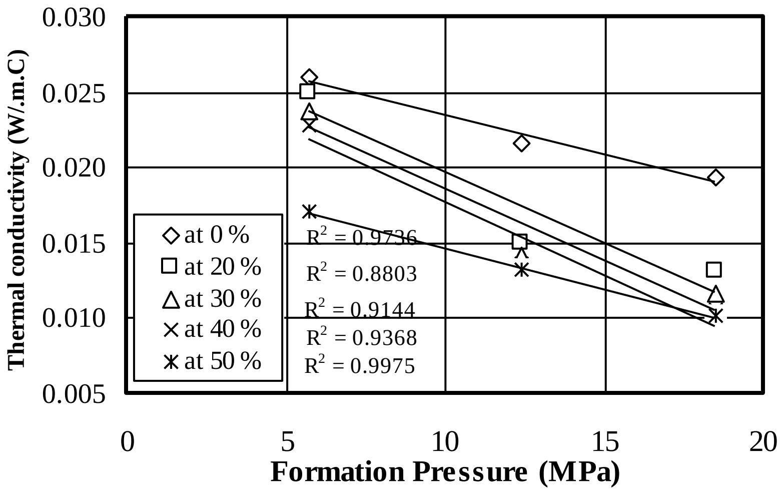

Fig. (9): Effect of formation pressure "FP" on thermal conductivity "k" at different binding material percentage (%).

Also, the data indicates that the relation between the thermal conductivity "k" (W/m.°C) and formation pressure "FP" (MPa) at different binding material percentage (%) were linearly equation of the form:

K = - c FP + d

Where: **c** and **d** constants depending on formation pressure "FP" (MPa) and binding material percentage "Bm" (%) as in table (2).

Table (2): Values of constant c and d at different binding material percentage %

Binding material (%)	Constant c and d	
	c	d
0	0.0005	0.0287
20	0.0009	0.0291
30	0.0009	0.0281
40	0.0010	0.0274
50	0.0005	0.0201

CONCLUSION

The compressed composite manufactured from grounding rice straw and urea-formaldehyde “UF” resin as a binding material, the experiments of this composite were carried out at the workshop of agricultural engineering faculty, Al-Azhar University during end of 2014. The expansion percentage “E” (%), bulk density "Bd" (kg/m^3) and thermal conductivity “ k” (W/m.^{o}C) of the manufactured composite affected by different binding material percentages "Bm" (0, 20, 30, 40 and 50 %), different levels of formation pressure (5.7, 12.4 and 18.5 MPa) and elapsed time (days) after removing formation pressure.

The expansion percentage "E" (%) was lower at binding material percentages "Bm" of 20, 30 and 40 % respectively under all formation pressures after 0, 7 and 14 days. The lower expansion percentage “E” (%) is a good advantage for the manufactured composite. The bulk density "Bd" (kg/m^3) was higher at binding material percentages "Bm" of 50 % under formation pressures of 18.5 MPa, after 0, 7 and 14 days. The bulk density “Bd” (kg/m^3) was lower at binding material percentages "Bm" of 0 % (control) under formation pressures of 5.7 MPa, after 0, 7 and 14 days. The thermal conductivity "k" (W/m.^{o}C) was lower at binding material percentages "Bm" of 50 % under formation pressures of 18.5 MPa, while, the thermal conductivity "k" (W/m.^{o}C) was higher at binding material percentages "Bm" of 0 % (control) under formation pressures of 5.7 MPa. The lower thermal conductivity "k" (W/m.^{o}C) is a good advantage for the manufactured composite. From the previous conclusions the binding material (UF resin) had a good effect on the expansion percentage “E” (%), bulk density "Bd" (kg/m^3) and thermal conductivity "k" (W/m.^{o}C) of the manufactured composite. Otherwise the compressed composite manufactured without binding materials 0 (%), control, appeared badly results in expansion percentage "E" (%), bulk density “Bd” (kg/m^3) and thermal conductivity "k" (W/m.^{o}C).

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إمكانية استخدام قش الأرز المضغوط كمادة عازلة

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***قسم هندسة المنشآت الزراعية والتحكم البيئى - كلية الهندسة الزراعية – جامعة الازهر– مدينة نصر- القاهرة .**

****قسم هندسة المنشآت الزراعية والتحكم البيئى - كلية الهندسة الزراعية – جامعة الأزهر- مدينة نصر- القاهره.**

*****قسم هندسة تصنيع المنتجات الزراعية – كلية الهندسة الزراعية – جامعة الأزهر- مدينة نصر-القاهره.**

تم تصنيع مكون من مفروم قش الارز واليوريا فورمالدهيد كمادة لاحمة لمعرفة مدى إمكانية استخدامها كمادة عازلة, وتم إجراء الإختبارات فى كلية الهندسة الزراعية – جامعة الأزهر – بالقاهرة فى نهاية عام 2014 .

- تم دراسة تأثير نسب مختلفة من المادة اللاحمة 20 , 30 , 40 ,50 % بالإ ضافة إلى عينة بدون مادة لاحمة (صفر%) , وأيضاً تم دراسة تأثير استخدام ضغوط مختلفة 5,7 و 12,4 و18,5 (ميجابسكال) مع زمن كبس ثابت 15 دقيقة.

- وتم قياس الخواص الأتية: النسبة المئوية للتمدد (%) والكثافة الظاهرية(كجم/م^3) و معامل التوصيل الحرارى(وات/م.م°) عند المتغيرات السابق ذكرها على العينات التى تم تصنيعها.

وأظهرت النتائج مايلى:

1- أقل نسبة تمدد كانت عند نسب 20 و 30 40 % مادة لاحمة عند مختلف ضغوط التشكيل وذلك بعد إزالة الضغط مباشرة (صفر يوم) وبعد (7 يوم) وبعد (14 يوم).
2- أعلى كثافة كانت عند استخدام مادة لاحمة 50% مع ضغط تشكيل 18,5 ميجا بسكال و أن أقل كثافة كانت للعينات التى لم يستخدم فيها مادة لاحمة (صفر %) عند ضغط تشكيل 5,7 ميجا بسكال لكل العينات أثناء الضغط وبعد إزالة الضغط مباشرة (صفر يوم) وبعد 7 أيام بعد 14 يوم.
3- أقل موصلية حرارية كانت عند مادة لاحمة 50 % عند ضغط تشكيل 18,5 ميجا بسكال وأن أعلى موصلية كانت للعينات التى لم يستخدم فيها مادة لاحمة (صفر%) عند ضغط تشكيل5,7 ميجا بسكال.