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BIOLOGICAL ENGINEERING

EFFECT OF MIXING CEMENT WITH RICE STRAW TO USING AS BUILDING BRICKS

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ABSTRACT

The purpose of this research was to investigate the effects of mixing cement with rice straw on brick making. Two particles size of rice straw were used namely small rice straw chops and large chops. Three formation pressures were used (by handle, 1.3 and 2.5 MPa). Four different ratios of cement were used (35, 45, 60, and 75%). The quality of the bricks was evaluated through the measurements of bulk density, thermal conductivity, water absorption percentage, expansion percentage and compressive strength. The obtained data showed that increasing of cement percentage lead to increase bulk density for both small and large rice straw chops, and increasing formation pressure lead to increase bulk density for both small and large rice straw chops, and the values of bulk density were higher at small chops than large chops. The minimum value of bulk density was 0.29 g/cm^3 at pressing by handle and mixture percentage of 35% for large chops, the maximum value was 1.242 g/cm^3 at 2.5 MPa and mixture percentage of 75% for large chops. The minimum value of thermal conductivity was 0.062 W/m.°c at pressing by handle and mixture percentage of 35% for small chops, the maximum value was 0.204 W/m.°c at 2.5 MPa and mixture percentage of 75% for small chops. Water absorption decreased with increasing of cement percentage for both small and large rice straw chops, and increasing formation pressure lead to decrease water absorption for both small and large rice straw chops, and water absorption percentage increases with the increase of absorption time "T" (h). The values of water absorption percentage were higher at large chops than small chops. The minimum value of water absorption percentage was 32.06 % after 1 h at 2.5 MPa and mixture percentage of 75% for small chops. The maximum value of water absorption percentage was 195.13 % after 3 h at pressing by handle and mixing ratio of 35% for small chops.

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Expansion percentage decreased with increasing of cement percentage for both small and large rice straw chops, and increasing formation pressure lead to increase expansion percentage for both small and large rice straw chops. The values of expansion percentage were higher at large chops than small chops. The minimum value of expansion percentage was 0.70 % at pressing by handle and mixture percentage of 75% for small chops; the maximum value was 44.20 % at 2.5 MPa and mixture percentage of 35% for large chops. Compressive strength increases with increasing of cement percentage for both small and large rice straw chops. The values of compressive strength were higher at small chops than large chops. The minimum value was 1.75 at pressing by handle and mixture percentage of 35% for small chops, the maximum value of compressive strength was 182.15 kg/cm^2 at 2.5 MPa and mixture percentage of 75% for small chops.

INTRODUCTION

The problem of increasing field residues and how to dispose are the biggest problems of agricultural biomass wastes in Egypt. The traditional way for disposing is by burning which not only caused pollution to environment, but also loosing an economic value of these residues, if it were used to produce useful products. This problem became greater nowadays which introduce black clouds covered Cairo's Sky and surrounding region during rice harvesting time. The straw burning process may be considered as the main reason for this black clouds appearance especially after developing a rural kitchen in villages.**(El-Bessoumy, 2005)**

Recently, there is a high level of interest towards agricultural residues utilization in useful ways that will help keeping healthy and friendly environment. There are great efforts towards recycling agricultural residues.

There are different means to solve or diminish this problem; as:
1.   Using these residues for animal feedings or bedding material for farm animals.
2.   Using these residues as organic fertilizer.
3.   Utilizing these residues in recycling industry as in making paper, pressed wood, packaging and building materials.

4.   Utilizing these residues in soil less culture.

5.   Utilizing these residues in biomass fuel.

6.   Utilizing these residues in biogas production. **(Awady 2002)**

F.A.O (2005) mentioned that the total annual Egyptian crop residues are about 30 Tg as shown in Table.1.

Table 2.1: The Egyptian crop residues by – products: (FAO, 2005).

Amount of	Mg / year
Wheat straw	6280000
Barley stalks	896000
Beans stalks	400000
Rice straw	2800000
Other residues	375000
Grain sweet stalks	6000000
Grain sorghum stalks	1050000
Cotton stalks	1400000
Corn core	2200000
Sugarcane residues	2146500
Sugar beet residues	1224000
Vegetable residues	3204000
Fruit residues	1853500
Total	29829000

Toepfer (2002) said that the pollution was caused by the burning of agricultural wastes and fossil fuels, and inefficient cooker emissions from burning.

Nouno (2003) mentioned that air quality is one of Egypt's more pressing environmental problems, and the smoke from smoldering rice straw pits is one of the major causes of the seasonal, thick, brown smog that hangs over the city scope. The disposal option now accounts for an estimated 90 % of the straw, with the remainder used in fodder or incorporated into the soil.

Zein-Eldin and Sadaka (2000) used adhesive material (cement) with some wastes such as sawdust, rice hall, rice hay and beans stalks to making mixture and their results indicated that the rice hall bricks have the highest general suitable while beans-stalk bricks had the lowest

values. They also revealed that all types of bricks are accepted as carrying bricks except beans-stalk brick with mixing ratios of 8: 1 and 12: 1 cement: waste and the mixing ratio less than 8: 1 corresponding to the other three types of waste materials should not be used as carrying bricks for more safety.

Savastano et al. (2000) studied the effect or reinforced cement – based composites by Brazilian waste fibers. Fiber reinforced cement – based composites were prepared using Kraft pulps from sisal and banana wastes and from Eucalyptus grand's pulp mill residues. Mechanical testing showed that optimum performance of the various waste fiber reinforced composites was obtained at a fiber content of around 12 % by mass, with flexural strength values of about 20 MPa (204 kg/cm^2).

Nouno (2003) mentioned that the process of making the materials is sufficiently simple to put it within reach of local communities. Essentially, residual crops are mixed with a binding (matrix) material in a 70/30 ratio. The binding material is basically limestone, which is readily available in Egypt. A tiny amount of fiber glass is added, which represents 0.05 % of the mix. Some equipment is needed, but it is inexpensive.

John (1999) found that the most apparent and widely used example of inorganic- bonded composites is cement. Portland cement, when combined with water, immediately reacts in a process called hydration to eventually solidify into a solid stone like mass. Successfully marketed Portland cement-bonded composites consist of both low-density products made with excelsior or coir and high-density products made with particles and fibers.

Therefore, the main aim of this research was to investigate and evaluate technically the effects of mixing cement with rice straw on brick characteristics. The characteristics of these bricks were evaluated using criteria of bulk density, thermal conductivity, water absorption percentage, expansion percentage and compressive strength.

<u>MATERIALS AND METHODS</u>

The experiments were carried out at the workshop of Agricultural Engineering Department, Faculty of Agriculture, Al-Azhar University. Cement was used with two cutting sizes of rice straw with adding amount

of water. Four different mixing ratios were chosen to binding material in mixture. These mass ratios were 35, 45, 60 and 75%. Three levels of formation pressure were used namely, by handle, 1.3 and 2.5 MPa. Samples were manually mixed to dry in the air for 21 days. Two particles sizes of rice straw were used in this study, large and small chops. These chops were obtained by using a grinding forage machine. Cylindrical specimens were produced to measure thermal conductivity with inner diameter of 105.4 mm; outer diameter of 110 mm, and length of 210 mm.. Rectangular specimens were produced for other measurements. The pressing mold dimensions were 25x12x10 cm.

- Pressing apparatus:-

The pressing apparatus was used to produce the samples at different formation pressures, PM (PMa). The technical specification of the hydraulic pressing are (according to manufacturing catalogue): Max Capacity 20 Mg; Gauge 0-60 MPa; Resolution of 2 MPa Made by SICMI sa, Trecasali (Parma), Italy (1996).

-Thermal conductivity apparatus:

A thermal conductivity apparatus was used "K"(W/ m.^{o}c) of building material samples. An apparatus was developed according to Lees' method (Noakes.,1953). The apparatus was constructed at the workshop of Ag. Eng. Dept., Faculty of Ag. AL-Azhar Un. (EL-Bessoumy,2005).
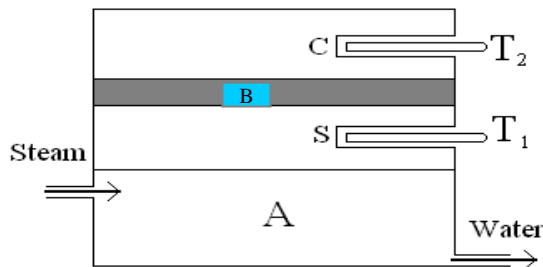

Fig. (1): A schematic diagram for steam unit and sample of thermal conductivity apparatus (C, S) Brass disks, (B) Sample, (T_1, T_2) Thermometers.

- Moisture content "MC" (%):

Water was added by different quantities based on type of mixing ratio, and measuring moisture content (%) for mixtures before and after forming pressure.

Measurements:
1- Bulk density "B.D":
 calculated by equation:
(B.D.) = M / V   -- 1
where; M: mass of sample, V: volume of specimens.
2-Thermal conductivity "k":

   The thermal conductivity "k" for sample was calculated from the following equation:

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

$$= \frac{32492\,(T_3-T_4)x}{t\,(T_1-T_2)} \qquad \text{.....................} \qquad 3$$

Where:

k :   Thermal conductivity for sample, W/m.°C.,

m: Mass of brass disk (C) of 0.74 kg.,

r :   The radius of sample, m.,

t :   Time, s.,

S :   Specific heat for brass, 380 J/kg.°C.,

x :   Thickness of sample, m.,

T_3:   Temperature of brass disk (C) above T_2, °C. and

T_4:   Temperature of brass disk (C) below T_2 as T_3 was above it, °C.

3- Expansion percentage:
All specimens in the present study expanded, this is because adding the rice straw. Thickness of specimens was measured when they were wetted and after dried it, and expansion percentage was calculated as follows:

Expansion "E",% $\dfrac{\text{Dry thickness - Wet thickness}}{\text{Wet thickness}}$ x100 = ... 4

4- Compressive strength:
The compression test was carried out by placing the specimen (after measure its dimensions) between two parallel plates, a continuous load was at a constant cross head rate until failure. The compressive strength σ was calculated as follows:

$$\sigma = \frac{F}{A} \quad , \quad kN/m^2 \quad ....5$$

Where:

F : Force, kN. and

A : Specimen surface area, m^2.

5- Water absorption:

The water absorption test was carried out by using cylindrical specimens, the initial mass for specimen was recorded, each specimen was placed on a narrow wiry mesh and immersed in fresh, clean water at 293- 295°K (20 - 22°C) for duration of 1, 2, 3 and 4 (h) at the end of each period a sample and a narrow wiry mesh were withdrawn from water and the excess water was strained, then was weighed again, every specimen was soaked again to another period of 1 hour the same measurements were executed and recorded and so on until 4 hours were last. In the end of these fore hours the water absorption percentage (Wa) was calculated as follows:

$$"Wa" = \frac{M_w - M_d}{M_d} \times 100,\% \quad .... 6$$

Where:

M_w : Mass of wet sample (g). and

M_d : Initial mass of specimen (g).

Preparation of test specimens:

Two shapes from specimens were prepared, rectangular and cylindrical. Cylindrical specimens were produced to measure thermal conductivity and water absorption. Rectangular specimens were produced to the other measurements (bulk density, expansion percentage and compressive strength). Specimens were manually mixed using the proposed mixing ratios. The mortar was made by adding water to straw and then mixed with cement. The molds were placed on a wooden surface that covered with a thin layer of sand to prevent sticking. The molds were filled in segments, and the mix was compacted by hand as much as possible to prevent air voids. Manufacturing batches were segmented to two levels pressure and one pressing by handle of 1.3 and 2.5 MPa. The first level (pressing by handle) was placed immediately on a wooden surface. Other

levels (1.3 and 2.5 MPa) were placed under hydraulic piston. The specimens were dried in air for about 21 day.

RESULTS AND DESCUSSION

1- Bulk density:

Fig. 2 show the relationship between bulk density and four cement percentage for bricks at the three different pressures for small and large rice straw chops.

Results indicated that bulk density increases with increasing cement percentage and increases with increasing formation pressure for both small and large chops. These results were expected because the pressures affected on the volume of specimens. The values of bulk density were higher at small chops than large chops, this is may be due to the small shops can compact easy more than large chops with cement and have lowered porous. The minimum value of bulk density was 0.29 g/cm^3 at pressing by handle and mixture percentage of 35% for large chops, the maximum value was 1.242 g/cm^3 at 2.5 MPa and mixture percentage of 75% for large chops. These values of bulk density lead to classify these bricks according to interbuild specification encyclopedia (2003) as a medium in class weight. The standard bulk density of cement- bricks were of 1.2 to 1.5 g/cm^3 and sand- bricks were of 0.60 to 0.65 g/cm^3. These results indicate that the brick made using the rice straw, considered in this study and its mixing ratios, are in the acceptable range of weights and these could be considered as an advantage.

2- Thermal conductivity:

Fig. 3 illustrate the relationship between thermal conductivity "k" and four cement percentage for bricks at the three different pressures for small and large rice straw chops. The data indicate that the thermal conductivity increases with the increase of cement percentage and increases with increasing formation pressure for both small and large chops. The values of thermal conductivity were lower (high insulation) at large chops than small chops in the overall adhesive materials. This is may be due to that the large chops have wide porous than small chops.
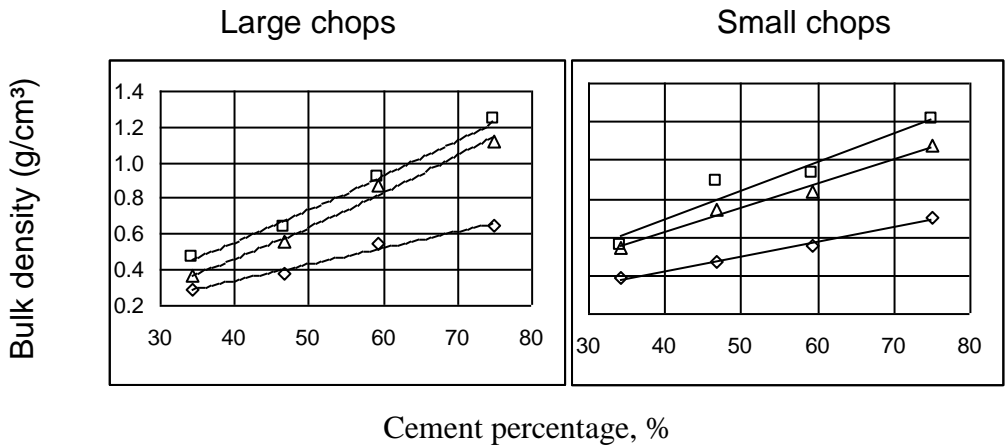
Large chops   Small chops

Fig.2: Relation between bulk density (g/cm³) and cement ratios (%) in brick at different formation pressure (MPa) for small and large rice straw chops.
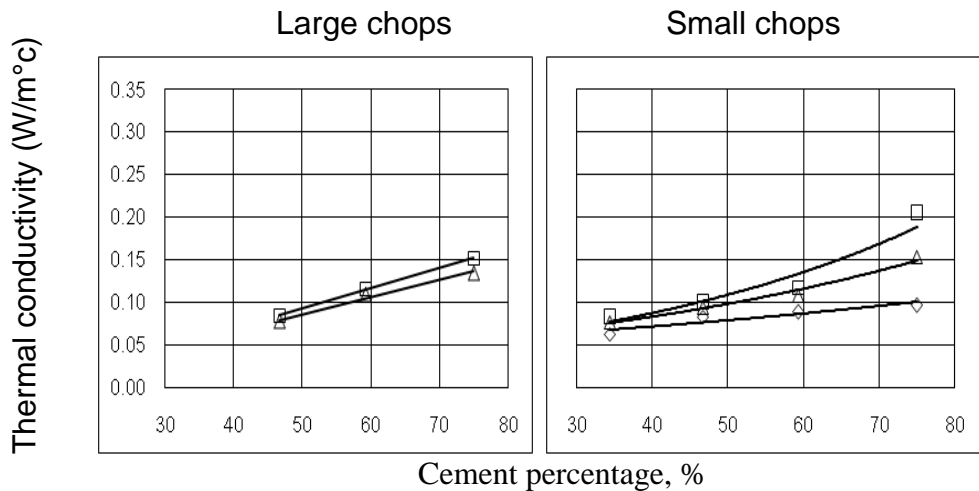
Large chops   Small chops

Fig.3: Relation between thermal conductivity "k" (W/m°c) and cement ratios(%) in brick at different formation pressure (MPa) for small and large rice straw chops.

The minimum value of thermal conductivity was 0.062 W/m.°c at pressing by handle and mixture percentage of 35% for small chops, the maximum value was 0.204 W/m.°c at 2.5 MPa and mixture percentage of 75% for small chops.

These results lead to these bricks are good heat insulation compared to types other bricks, for example sand-bricks are insulation and its thermal conductivity of 0.27 to 0.34 W/m°c interbuild specification encyclopedia (2003).

3- Expansion percentage:

Fig. 4 show the relationship between expansion percentage and four cement percentage for bricks at the three different pressures for small and large rice straw chops. The obtained data showed that the expansion percentage decreases with increasing binding material percentage for both small and large chops and increases with the increasing formation pressure for both small and large chops. This is may be due to rice straw have high elasticity with pressure. The values of expansion percentage were higher at large chops than small chops. The minimum value of expansion percentage was 0.70 % at pressing by handle and mixture percentage of 75% for small chops; the maximum value was 44.20 % at 2.5 MPa and mixture percentage of 35% for large chops.
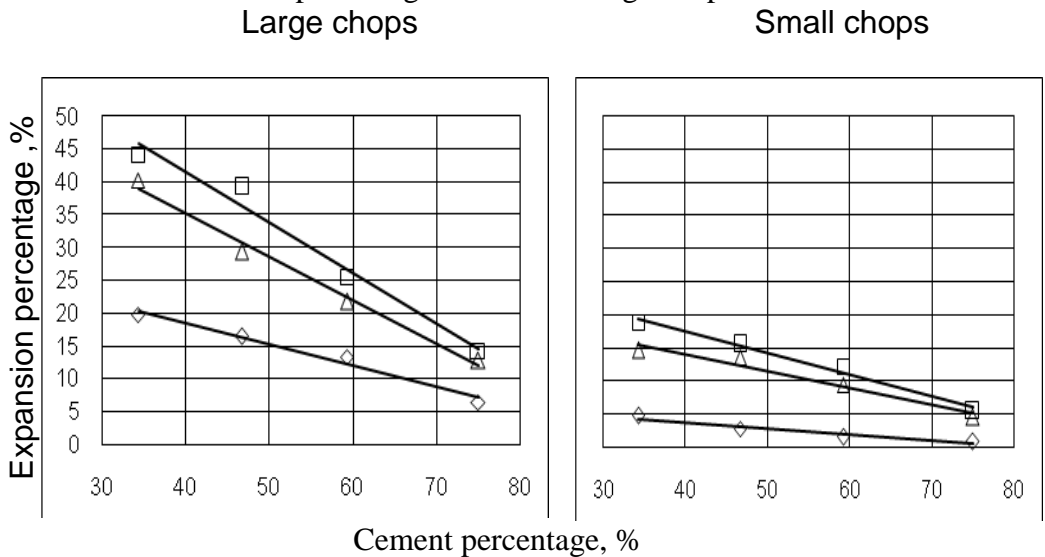

Fig.4: Relation between expansion percentage (%) and cement ratios(%) in brick at different formation pressure (MPa) for small and large rice straw chops.

4- Compressive strength:

Fig. 5 show the relationship between compressive strength "σ" and four cement percentage for bricks at the three different pressures for small

and large rice straw chops. The results indicated that increasing binding material percentage increases compressive strength significantly and increasing formation pressure increases compressive strength significantly for both small and large chops. This is due to the heat generated from the pressure increased the effect of binding materials. The values of compressive strength were higher at small chops than large chops. This is may be due to the large chops have wide porous than small chops. The minimum value was 1.75 at pressing by handle and mixture percentage of 35% for small chops, the maximum value of compressive strength was 182.15 kg/cm^2 at 2.5 MPa and mixture percentage of 75% for small chops.

5- Water absorption:

Fig. 6 illustrate the relationship between water absorption percentage and four cement percentage for bricks at the three different pressures for small and large rice straw chops. Results revealed that increasing amount of cement decreases water absorption significantly and decrease with increasing formation pressure for both small and large chops. The data indicated that the water absorption percentage increases with the increase of absorption time "T". The values of water absorption percentage were higher at large chops than small chops. This is may be due to the large chops have wide porous than small chops in mixture. The minimum value of water absorption percentage was 32.06 % after 1 h at 2.5 MPa and mixture percentage of 75% for small chops. The maximum value of water absorption percentage was 195.13 % after 3 h at pressing by handle and mixing ratio of 35% for small chops.
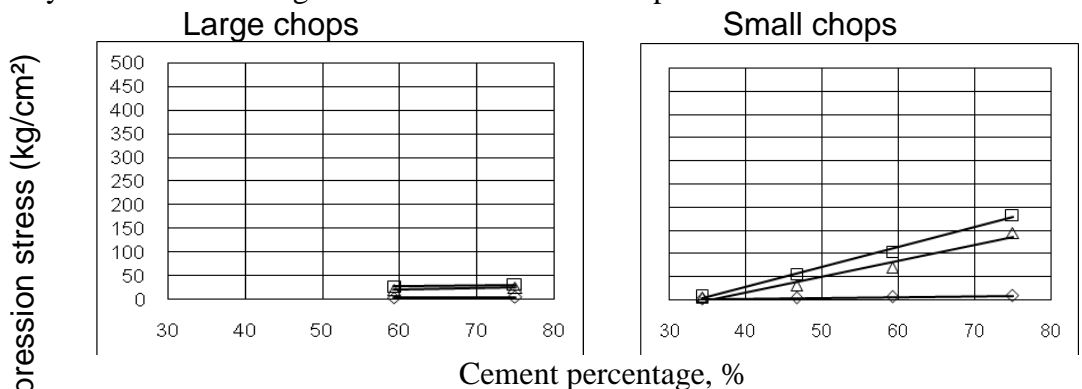

Fig.5: Relation between compression stress (kg/cm²) and cement ratios(%) in brick at different formation pressure (MPa) for small and large rice straw chops.
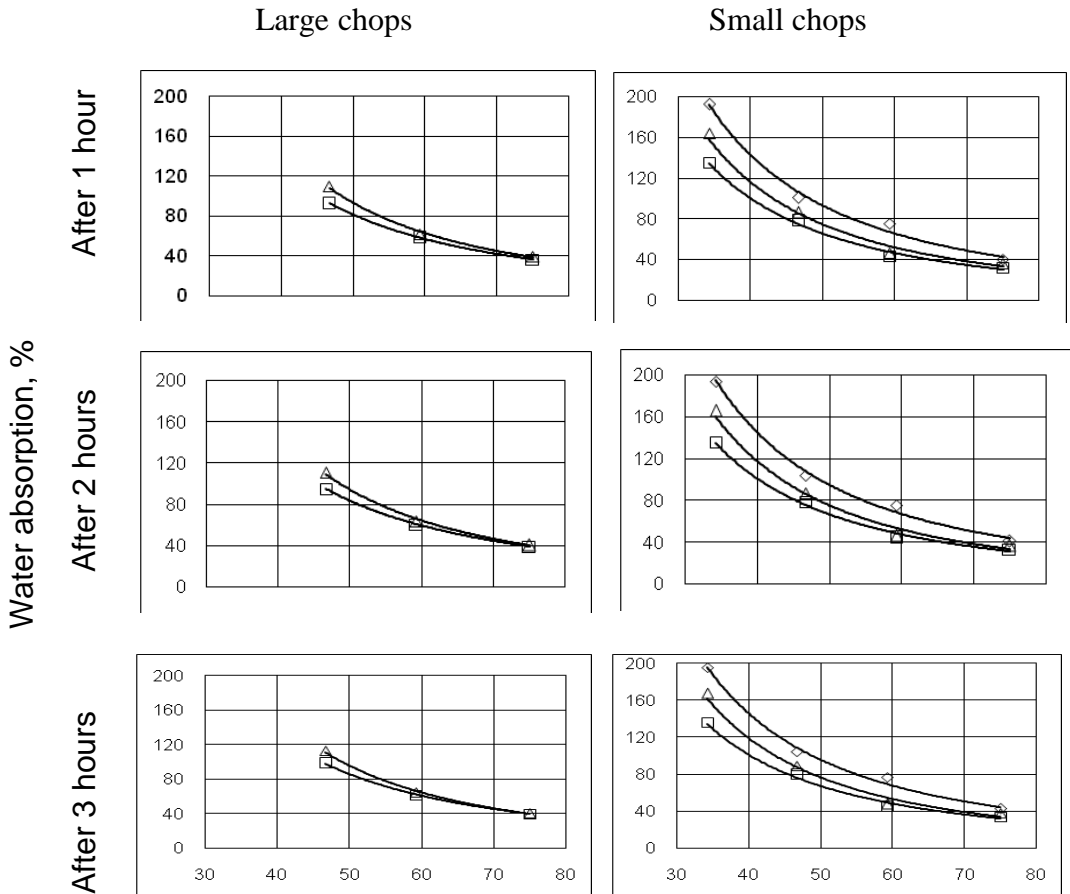
Fig.6   : Relation between water absorption (%) and cement ratios(%) in brick at different formation pressure (MPa) for small and large rice straw chops.

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الملخص العربى

تأثير خلطة الأسمنت مع قش الأرز لإستخدامها كطوب للبناء

ا.د / محمد فايد عبدالفتاح خيرى٢	ا.د / سمير أحمد محمد طايل١
م / عاطف موسى إبراهيم موسى٤	د / إبراهيم سيف السؤالى٣

الهدف من هذا البحث هو دراسة تأثير خلطة الأسمنت مع قش الأرز على إنتاج الطوب . تم استخدام حجمين مختلفين من قش الأرز وهما قطع قش أرز صغيرة وكبيرة وتم تشكيل الخلطة تحت ثلاث مستويات من الضغط وهي: يدوي ، ١،٣ و ٢،٥ ميجا باسكال. تم اختيار أربع نسب خلط مختلفة للأسمنت وهي : ٣٥ و ٤٥ و ٦٠ و٧٥ % بالوزن . تم تقييم الطوب الناتج فنيا عن طريق القياسات التالية : الكثافة الظاهرية – الموصلية الحرارية – نسبة امتصاصية المياه – نسبة التمدد – مقاومة الضغط . وكانت النتائج كالتالي:

١- تؤدي زيادة كمية الأسمنت إلى زيادة الكثافة الظاهرية لكل من قطع قش الأرزالصغيرة والكبيرة .وأدي زيادة مستوى ضغط التشكيل إلي زيادة الكثافة الظاهرية لكل من قطع قش الأرز الصغيرة والكبيرة .وكانت قيم الكثافة الظاهرية للقطع الصغيرة أعلي منها في القطع الكبيرة.

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١- أستاذ متفرع – قسم الهندسة الزراعية – كلية الزراعة – ج الازهر بالقاهرة .
٢- أستاذ متفرع – قسم الهندسة الزراعية – كلية الزراعة – ج الازهر بالقاهرة.
٣- أستاذ مساعد ورئيس قسم الهندسة الزراعية – ك الزراعة –ج الازهر بالقاهرة .
٤- مدرس مساعد – قسم الهندسة الزراعية – ك الزراعة –ج الازهر بالقاهرة.

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وتم تحقيق أقل قيمة للكثافة الظاهرية ٠,٢٩ ج/ سم٣ عند مستوي الضغط اليدوي ونسبة خلط ٣٥ % للخلطة مع القطع الكبيرة, بينما كانت أعلي قيمة للكثافة الظاهرية ١,٢٤٢ ج/سم٣ عند مستوي ضغط ٢,٥ ميجا باسكال ونسبة خلط ٧٥ % للخلطة مع القطع الصغيرة . وهذه القيم التي سبق ذكرها تصف الطوب علي أساس مقياس الكتلة بأنه وسط بين أنواع الطوب الأخري المعروفة .

٢- تؤدي زيادة كمية الأسمنت فى الخلطة إلي زيادة الموصلية الحرارية (إنخفاض العزل الحرارى) لكل من القطع الصغيرة والكبيرة .

وزيادة مستوى ضغط التشكيل إلى زيادة المصلية الحرارية (إنخفاض العزل الحرارى) لكل من قطع قش الأرز الصغيرة والكبيرة.

و قيم الموصلية الحرارية للقطع الصغيرة أعلى منها فى القطع الكبيرة لكل الخلطات المختلفة.

وتم تحقيق أقل قيمة للموصلية الحرارية ٠,٠٦٢ وات / م.م° عند مستوي الضغط اليدوي ونسبة خلط ٣٥% للخلطة مع القطع الصغيرة بينما كانت أعلي قيمة للموصلية الحرارية ٠,٢٠٤ وات / م.م° عند مستوي ضغط ٢,٥ ميجا باسكال ونسبة خلط ٧٥ % للخلطة مع القطع الصغيرة.

وهذه النتائج السابقة تصنف هذا الطوب بأنه عازل جيد للتوصيل الحراري .

٣- تؤدى زيادة كمية الأسمنت إلى انخفاض النسبة المئوية لامتصاص الماء لكل من قطع الأرز الصغيرة والكبيرة. وتؤدى زيادة مستوى ضغط التشكيل إلى انخفاض النسبة المئوية لامتصاص الماء بزيادة زمن الامتصاص لكل من قطع قش الارز الصغيرة والكبيرة . وكانت قيم إمتصاص الماء للقطع الكبير أعلى منها فى القطع الصغير .

وتم تحقيق أقل قيمة لنسبة إمتصاص الماء ٣٢,٠٦ % بعد زمن ساعه واحدة عندمستوى ضغط ٢,٥ ميجا باسكال ونسبة خلط ٧٥% للخلطة مع القطع الصغيرة , بينما كانت أعلى قيمة لنسبة أمتصاص الماء ١٩٥,١٣% بعد زمن ٣ ساعات عند مستوى الضغط اليدوى ونسبة خلط ٣٥% للخلطه مع القطع الصغيره.

٤- تؤدى زيادة كمية الاسمنت إلى انخفاض النسبة المئوية للتمدد لكل قطع قش الارز الصغيرة والكبيرة وزيادة ضغط مستوى التشكيل إلى زيادة النسبة المئوية للتمدد لكل قطع قش الأرز الصغيرة والكبيرة . وكانت قيم التمدد للقطع الكبير أعلى منها فى القطع الصغيرة. وقد تم التوصل إلى أقل قيمة لنسبة التمدد ٠,٧٠ % عند مستوى الضغط اليدوى ونسبة الخلط ٧٥% للخلطة مع القطع الصغيرة , بينما كانت اعلى قيمة للنسبة الئوية للتمد ٤٤,٢% عند مستوى ضغط ٢,٥ميجا باسكال ونسبة خلط ٣٥% للخطة الكبيرة.

٥- تؤدى زيادة كمية الأسمنت إلى زيادة إجهاد الضغط لكل من قطع قش الارز الصغيرة والكبيرة . وتؤدى زيادة مستوى ضغط التشكيل إلى زيادة إجهاد الضغط لكل من قطع قش الارز الصغيرة والكبيرة وقد تم تحقيق قيم إجهاد الضغط للقطع الصغيرة وأعلى منها فى القطع الكبيرة وكانت أقل قيمة لإجهاد الضغط ١,٧٥ كج /سم٢ عند مستوى الضغط اليدوى ونسبة خلط ٣٥% للخلط مع القطع الصغيرة , بينما كانت أعلى قيمة لإجهاد الضغط ١٨٢,١٥% كج /سم٢ عند مستوى ضغط ٢,٥ باسكال ونسبة خلط ٧٥% للخلطة مع القطع الصغيرة .