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SHRINKAGE OF NATURAL PLASTERING FOR STRAW BUILDINGS AFFECTED BY REINFORCEMENT AND DRYING

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ABSTRACT

This study was carried out to determine the shrinkage percentage of natural plaster materials consisted of soil, sand and different fibres. The experiments were carried out at the Institute of Production Engineering and Buildings Research, Federal Agricultural Research Center (FAL), Braunschweig, Germany in summer 2007. Straw was used as a reinforcement fiber for plaster and three types of fibers. The plaster materials were put under drying temperatures of 30, 50 and 70 °C.

The results revealed that the highest shrinkage was for plaster reinforced by wood shaving fibres, while the lowest shrinkage was for plaster reinforced by barley straw fibres for treatments A, B and C. Also, the plaster without reinforcement fibres had a lot of cracks and problems that cause plaster destroyed. The reinforcement fiber has greater effect on the drying shrinkage than sand.

The study recommends using the plaster with 30 °C drying temperature with a quantity of straw for improving the plaster materials to decrease the shrinkage and cracks.

INTRODUCTION

Drying shrinkage is one of the main causes of cracks of plaster materials, and so many studies have been made to prevent cracks. Profitable knowledges have been obtained on drying earth plaster. It is very important to study such a traditional problem as crack prevention in view of the drying shrinkage mechanism. Therefore, examination on behavior of properties due to drying is required, when structural application of such materials is considered.

Campbell and Coutts [1980] investigated the possibility of using the wood fibres as reinforcement for a structural composite material. Although wood fibres have relatively poor mechanical properties compared with synthetic fibres, they have the advantages of low density, low cost and low energy demand during manufacture.

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They indicated that the kraft pulp is suitable for applications where slurry dewatering can be employed during the forming operation and that the thermo mechanical pulp is more suited to applications where low water-cement ratio slurry is used.

Bai et al. [2005] measured the drying shrinkage of concretes with the natural sand replaced with furnace bottom ash (FBA) at 0%, 30%, 50%, 70% and 100% by mass. They mentioned that at fixed water–cement ratios, the compressive strength and the drying shrinkage decreased with the increase of the FBA sand content.

Eve et al. [2006] studied the setting of binary blends such as latex-filled plaster and polyamide fibre-reinforced plaster materials. They showed that the choice of the proper latex to be associated with the plaster was made looking upon its influences on the setting time and the mechanical properties of the blend. Also, the ternary blends were characterized by a drastic increase of the setting time correlated with a reduction of the total swelling.

Omar et al. [2006] compared four types of super plasticizers and used it in conjunction with three types of silica fume to prepare cement concrete slab specimens that were utilized to measure plastic shrinkage strain and time to attain maximum strain. They indicated that the plastic shrinkage strain varied with the type of super plasticizer and the type of silica fume.

Andrea and Harmuth [2008] investigated the mechanisms of crack formation of interior plasters applied on permanent shuttering panels which are used for the erection of concrete in walls. They mentioned that the composition of traditional mud plasters varies from place to place. The clay content is particularly significant, because if it is too low the plaster will lack strength and cohesion, and if it is too high there will be a risk of cracking due to shrinkage, which will weaken the bond to the wall.

Traditionally, clay plasters were often applied in one coat both internally and externally. If applied in two coats, the first coat contains more clay, even if cracks develop, while the second, containing more sand is applied in a thinner layer. The second coat will help to close the microcracks in the first, provided the surface has been lightly dampened before plastering. Finally, lime distemper or whitewash can be applied to give some additional weatherproofing [Hashmi, 2008].

So, the objective of this work was an attempt to examine fundamentally and physically the drying shrinkage of earth plaster reinforced by different fibres under 30, 50 and 70 °C thermal condition drying.

MATERIALS AND METHODS

The experimental site was located at the Institute of Production Engineering and Buildings Research, Federal Agricultural Research Center [FAL], Braunschweig, Germany in summer 2007. Three different plaster materials were selected such as soil, sand and reinforcement fiber. Three fiber types such as barley straw, wheat straw and wood shavings were used. Plaster materials were done by mixing the materials with different percentages [25:0:75%], [25:25:50%], [25:50:25%], [25:75:0%] and [100:0:0%] [soil: sand: reinforcement fiber] for treatments A, B, C, D and E, respectively. Mixing parts were calculated by dry volume. Soil texture consisted of clay [< 2 µm] 31%, silt [20-63 µm] 22% and sand [63-2000 µm] 47%.

Density:

Samples density was calculated by using the following equation:

$$\rho = \frac{W}{V} \qquad [1]$$

Where:

ρ : density in kg/m^3,

W : mass of sample in kg and

V : sample volume in m^3.

Shrinkage test:

Shrinkage test was measured according to ASTM D4943-95, but with different length and specialized equipment. The earth plaster was packed in a steel frame box with interior dimensions of 20 x 5 x 5 cm [length x width x height]. The box had sides, but no top or bottom and the inside surfaces of the box were smooth to avoid bonding between the steel and the plaster [Fig. 1]. The samples were put in the back oven and dried under different temperatures 30, 50 and 70 °C, until the constant weight according to DIN EN ISO 12570: 2000. The shrinkage was measured by pushing the complete sample (including separated lumps) tightly up to one end of the box and measuring the gap created by the shrinkage. The shrinkage values were measured by using vernier scale [Fig. 2].

Fig. 1: Frame for sample preparation.

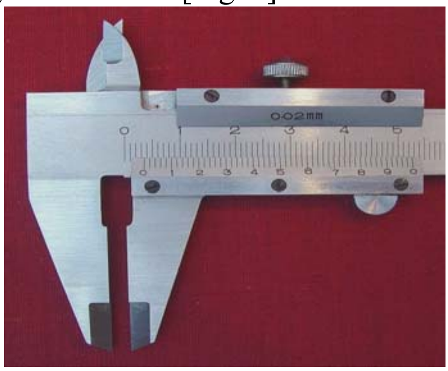

Fig. 2: Vernier scale for measuring the shrinkage.

Moisture content:

Moisture content for the materials was measured according to [Ashrae, 1997] as follows:

$$MC.(\%)=\frac{(W_m - W_d)}{W_d}.100 \qquad [2]$$

Where:

- MC : moisture content (d.b) in %,
- W_m : moist mass in kg and
- W_d : dry mass in kg.

Shrinkage percentage:

The shrinkage percentage is the deformation in sample length with the original length. The shrinkage percentage was calculated according to [Lerner and Donahue 2003] as follows:

$$\text{Shrinkage}\ (\%) = (\Delta L/L).100 \qquad [3]$$

Where:

- ΔL : change in height in cm and
- L : original height in cm.

RESULTS AND DISCUSSIONS

- The effect of drying temperature on shrinkage for wood shavings plaster

The densities of plaster material reinforced by wood shaving fibres were 681, 1110 and 1435 kg/m³ for treatments A, B and C, respectively. The relationship between different treatments. The average drying shrinkage values of treatment A were 1.75, 2.64 and 3.20 mm for drying temperatures of 30, 50 and 70 °C, respectively. Shrinkage values were 1.88, 3.0 and 3.60 mm for drying temperatures of 30, 50 and 70°C, respectively. On the other hand, shrinkage values of treatment C were 2.06, 3.7 and 5.40 mm for drying temperatures of 30, 50 and 70°C, respectively.

The average shrinkage percentages of treatment A were 0.88, 1.32 and 1.60% for drying temperatures of 30, 50 and 70 °C, respectively. At treatment B, shrinkage percentages were 0.94, 1.50 and 1.80% for different drying temperatures of 30, 50 and 70°C, respectively. Meanwhile, shrinkage percentages of treatment C were 1.03, 1.85 and 2.70% for drying temperatures of 30, 50 and 70°C, respectively as shown in Fig. 3.

The results indicated that increasing of drying temperature from 30 to 70 °C lead to increased shrinkage percentage of 0.72%. Furthermore, increasing wood shavings fibres from 25 to 75% caused decreasing of shrinkage percentages 0.15, 0.53 and 1.1 % for drying temperatures 30, 50 and 70 °C, respectively. The results showed that drying temperatures has a great effect on shrinkage of plaster reinforced by wood shaving fibres.

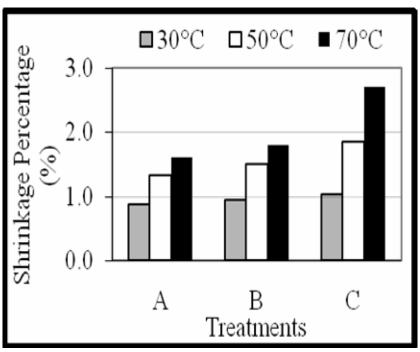

Fig. 3: Shrinkage percentages of plaster reinforced by wood shaving fibres.

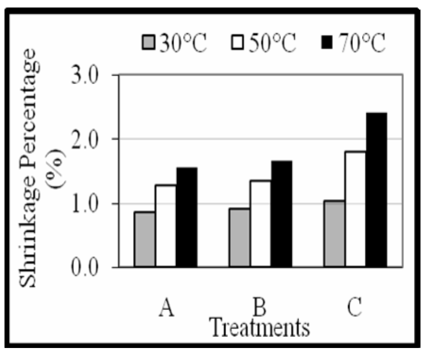

Fig. 4: Shrinkage percentages of plaster reinforced by wheat straw fibres.

- The effect of drying temperature on shrinkage for wheat straw plaster

The densities of plaster materials were 594, 1099 and 1400 kg/m³ for treatments A, B and C, respectively. For plaster reinforced by wheat straw fibres, the overall shrinkage values of treatment A were 1.70, 2.53 and 3.10 mm for drying temperatures of 30, 50 and 70 °C, respectively. While for treatment B, they were 1.80, 2.70 and 3.30 mm for different drying temperatures of 30, 50 and 70 °C, respectively. Furthermore, shrinkage values of treatment C were 2.05, 3.6 and 4.80 mm for drying temperatures of 30, 50 and 70°C, respectively.

For treatment A, shrinkage percentages were 0.85, 1.27 and 1.55% for drying temperatures of 30, 50 and 70 °C, respectively. For treatment B shrinkage percentages were 0.90, 1.35 and 1.65% for different drying temperatures of 30, 50 and 70 °C, respectively. Moreover, shrinkage percentages of treatment C were 1.03, 1.80 and 2.40% for drying temperatures of 30, 50 and 70 °C, respectively as shown in Fig. 4.

The results indicated that increasing of drying temperature from 30 to 70 °C lead to increased shrinkage percentages of 0.70, 0.75 and 1.37% for treatments A, B and C, respectively. Furthermore, increasing of wheat straw fibres from 25 to 75% caused decreasing of shrinkage percentages 0.18, 0.53 and 0.85% for drying temperatures 30, 50 and 70 °C, respectively.

- The effect of drying temperature on shrinkage for barley straw plaster

Densities for plaster materials reinforced by barley straw were 584, 1078 and 1391 kg/m³ for treatments A, B and C, respectively. The overall shrinkages for plaster reinforced by barley straw fibres of treatment A were 1.64, 2.30 and 2.60 mm for drying temperatures of 30, 50 and 70 °C, respectively. Meanwhile for treatment B, they were 1.75, 2.60 and 3.10 mm for different drying temperatures of 30, 50 and 70°C, respectively. On the other hand, shrinkage values of treatment C were 1.90, 3.33 and 4.60 mm for drying temperatures of 30, 50 and 70°C, respectively.

The average shrinkage percentages of treatment A were 0.82, 1.15 and 1.30% for drying temperatures of 30, 50 and 70 °C, respectively. For treatment B shrinkage percentages were 0.86, 1.30 and 1.55% for different drying temperatures of 30, 50 and 70°C, respectively. On the other hand, shrinkage percentages of treatment C were 0.95, 1.67 and 2.30% for drying temperatures of 30, 50 and 70 °C, respectively as shown in Fig. 5.

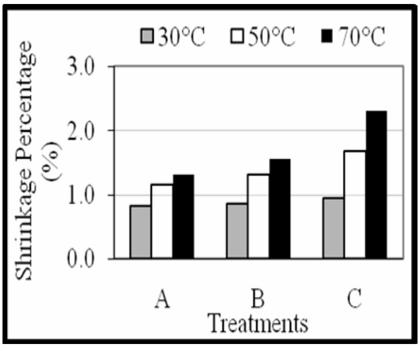

Fig. 5: Shrinkage percentages of plaster reinforced by barley straw fibres.

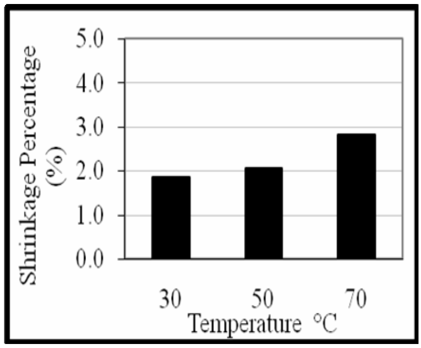

Fig. 6: Shrinkage percentages of sand plaster without reinforcment fibres.

The results indicated that increasing drying temperature from 30 to 70 °C lead to increased shrinkage percentages of 0.48, 0.69 and 1.35% for treatments A, B and C, respectively. Furthermore, increasing wheat straw fibres from 25 to 75% caused decreasing of shrinkage percentages 0.13, 0.52 and 1.00% for drying temperatures of 30, 50 and 70 °C, respectively.

- The effect of drying temperature on shrinkage for plaster without reinforcement fibres

The density of plaster without reinforcement fibres was 1642 kg/m³. The relationship between different treatments and the shrinkage rate for sand plaster without reinforcement fibres. The average drying shrinkage values were 3.72, 4.12 and 5.61 mm for drying temperatures of 30, 50 and 70 °C, respectively. The results revealed that shrinkage increased with increasing drying temperature while increasing temperature from 30 to 70 °C caused increasing of shrinkage value to 1.89 mm.

The average values of shrinkage percentages for plaster material without reinforcement fibres were 1.86, 2.06 and 2.81% for drying temperatures of 30, 50 and 70 °C, respectively. Also, the shrinkage percentage increased as drying temperature increased while increasing temperature from 30 to 70 °C caused increasing drying shrinkage to 0.95% [Fig. 6].

- The effect of drying temperature on shrinkage for clay plaster

The density of plaster without reinforcement fibres and without sand was 1481 kg/m³. The average drying shrinkage values were 6.90, 7.01 and 9.13 mm for drying temperatures of 30, 50 and 70 °C, respectively. The results revealed that shrinkage increased as drying temperature increased while increasing temperature from 30 to 70 °C caused increasing drying shrinkage to 2.23 mm.

The average values of shrinkage percentage for plaster material without reinforcement fibres were 3.45, 3.51 and 4.57% for drying temperatures of 30, 50 and 70 °C, respectively. Also, the shrinkage percentage increased as drying temperature increased while increasing temperature from 30 to 70 °C caused increasing drying shrinkage to 1.12% as shown in Fig. 7.

Also, high cracks were shown under drying temperatures of 50 and 70 °C and the sample was fully destroyed [Fig. 8].

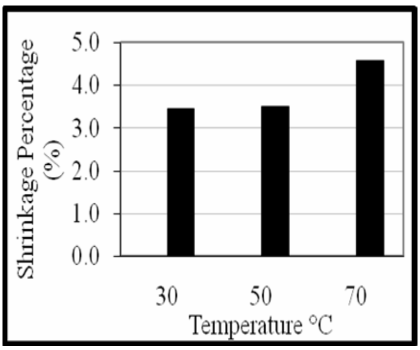

Fig. 7: Shrinkage percentages of clay plaster without sand and reinforcement fibres.

Fig. 8: Shrinkage and cracks for clay samples.

- Comparisons of the different plaster materials under the study

For treatment A, overall shrinkage values were 1.75, 1.70, 1.64, 3.72 and 6.90 mm at 30 °C for plaster reinforced by wood shavings, wheat, barley, without fibers (sand plaster) and clay, respectively. Meanwhile at 50 °C overall shrinkage values were 2.64, 2.53, 2.30, 4.12 and 7.01 mm for wood shavings, wheat, barley, sand and clay plaster, respectively. On the other hand, overall shrinkage values at 70 °C were 3.20, 3.10, 2.60, 5.61 and 9.13 mm of plaster reinforced with wood shavings, wheat, barley, sand and clay, respectively.

Furthermore, shrinkage percentages were 0.88, 0.85, 0.82, 1.86 and 3.45% at 30 °C for plaster reinforced by wood shavings, wheat, barley, without fibers (sand plaster) and clay, respectively. While at 50 °C, shrinkage values were 1.32, 1.27, 1.15, 2.06 and 3.51% for wood shavings, wheat, barley, sand and clay plaster, respectively. On the other hand, overall shrinkage percentages at 70 °C were 1.60, 1.55, 1.30, 2.81 and 4.57% of plaster reinforced with wood shavings, wheat, barley, sand and clay, respectively as shown in Fig. 9.

The results revealed that clay plaster without reinforcement fibres and straw had high shrinkage values with high cracks in the plaster samples. Also, sand plasters without fibres had high shrinkage but lower than only clay. For the reinforcement fibres plasters, the highest shrinkage was for plaster reinforced by wood shavings fibres, while the lowest shrinkage was plaster reinforced by barley straw fibres.

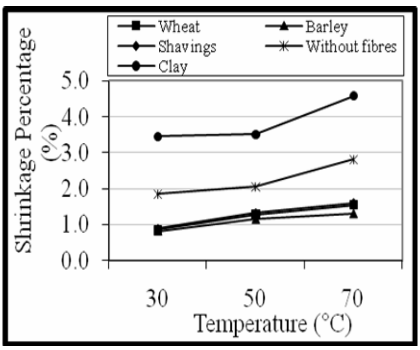

Fig. 9: Shrinkage percentage of different plaster materials for treatment A.

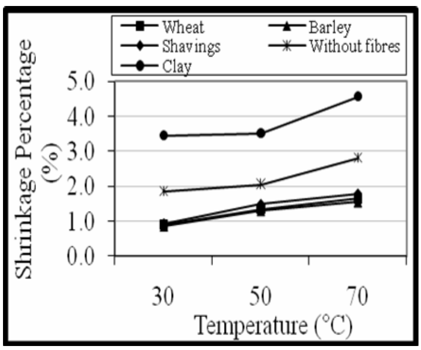

Fig.10: Shrinkage percentage of different plaster materials for treatment B.

For treatment B, overall shrinkage values were 1.88, 1.80, 1.75, 3.72 and 6.90 mm at 30 °C for plaster reinforced by wood shavings, wheat, barley, without fibers (sand plaster) and clay, respectively. While at 50 °C, overall shrinkage values were 3.00, 2.70, 2.60, 4.12 and 7.01 mm for wood shavings, wheat, barley, sand and clay plaster, respectively. On the other hand, overall shrinkage values at 70 °C were 3.60, 3.30, 3.10, 5.61 and 9.13 mm for plaster reinforced with wood shavings, wheat, barley, sand and clay, respectively.

Furthermore, shrinkage percentages were 0.94, 0.90, 0.86, 1.86 and 3.45% at 30 °C for plaster reinforced by wood shavings, wheat, barley, without fibers (sand plaster) and clay, respectively. While at 50 °C, shrinkage percentages were 1.50, 1.35, 1.30, 2.06 and 3.51% for wood shavings, wheat, barley, sand and clay plaster, respectively. On the other hand, overall shrinkage percentages at 70 °C were 1.80, 1.65, 1.55, 2.81 and 4.57% of plaster reinforced with wood shavings, wheat, barley, sand and clay, respectively as shown in Fig. 10.

In treatment C, overall shrinkage values were 2.06, 2.05, 1.90, 3.72 and 6.90 mm at 30 °C for plaster reinforced by wood shavings, wheat, barley, without fibers (sand plaster) and clay, respectively. While at 50 °C, overall shrinkages were 3.70, 3.60, 3.33, 4.12 and 7.01 mm for wood shavings, wheat, barley, sand and clay plaster, respectively. On the other hand, overall shrinkages at 70 °C were 5.40, 4.80, 4.60, 5.61 and 9.13 mm for plaster reinforced with wood shavings, wheat, barley, sand and clay, respectively.

Furthermore, shrinkage percentages were 1.03, 1.03, 0.95, 1.86 and 3.45% at 30 °C for plaster reinforced by wood shavings, wheat, barley, without fibers (sand plaster) and clay, respectively. While at 50 °C, shrinkage percentages were 1.85, 1.80, 1.67, 2.06 and 3.51% for wood shavings, wheat, barley, sand and clay plaster, respectively. On the other hand, overall shrinkages at 70 °C were 2.70, 2.40, 2.30, 2.81 and 4.57% plaster reinforced with wood shavings, wheat, barley, sand and clay, respectively [Fig. 11].

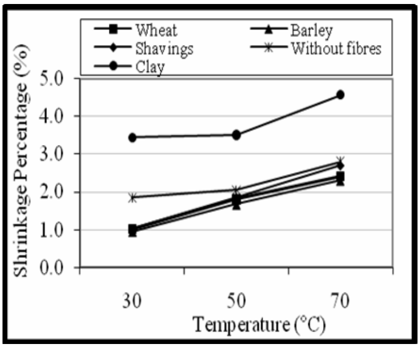

Fig.11: Shrinkage percentage of different plaster materials for treatment C.

The average of shrinkage percentages for treatments A, B and C ranged between 0.82 – 1.03%, 1.15 – 1.85% and 2.60 – 5.40% for temperatures 30, 50 and 70 °C, respectively.

The results confirmed that the highest shrinkage was for plaster reinforced by wood shaving fibres, while the lowest shrinkage was for plaster reinforced by barley straw fibres for treatments A, B and C. The results also revealed that the plaster without reinforcement fibres had a lot of cracks and problems that cause plaster destruction.

CONCLUSIONS

The results confirmed that:

- The average shrinkage percentages for treatments A, B and C ranged between 0.82 – 1.03%, 1.15 – 1.85% and 2.60 – 5.40% for temperatures of 30, 50 and 70 °C, respectively.
- The highest shrinkage was for plaster reinforced by wood shaving fibres, while the lowest shrinkage was for plaster reinforced by barley straw fibres for treatments A, B and C.
- The plaster without reinforcement had a lot of cracks and problems that cause plaster destruction. Also, the reinforcement fiber had greater effect on the drying shrinkage than sand. The drying temperature had a high effect on shrinkage values as a result of forced desorption from the plaster surfaces.
- The cracks decreased as reinforcement fibres increased and increased as clay and sand content increased. Also, the cracks increased as drying temperatures increased and vice versa.

It will be better when the plaster cusses at low temperature condition (30 °C) and use a quantity of straw for improving the plaster to decrease shrinkage and cracks.

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الملخص العربى

إنكماش المحارة الطبيعية لمباني القش وتأثرها بالتقوية والتجفيف

طه عاشور*، أسعد درباله**

تعتبر المحارة بالمواد الطبيعية مثل الطين من أهم لوازم المبانى الطبيعية، وخاصة التي تستخدم القش في البناء. من أهم ما يميز المحارة بالطين هو انكماشها وما يترتب على هذا الإنكماش من تشققات وتلف وانهيار لها، وكذلك ظروف جفاف المحارة من العوامل المؤثرة على الإنكماش.

أجري البحث بمعهد هندسة الإنتاج وبحوث المباني بالمركز الفيدرالي للبحوث الزراعية – براون شفايج – ألمانيا الإتحادية في صيف 2007 م بهدف دراسة خلط وتقوية المحارة بمصادر مختلفة من الألياف وهي:

قش الشعير - قش القمح - نشارة الخشب وذلك تحت ثلاثة مستويات من درجات التجفيف وهي: 30، 50، 70 درجة مئوية (303.15، 323.15، 343.15 درجة كلفن، علي الترتيب). تم خلط مكونات المحارة بنسب مختلفة طبقاً للحجم الجاف، وكانت نسب الخلط كالتالي:

(75:0:25%)، (50:25:25%)، (25:50:25%)، (0:75:25%)، (0:0:100%) وهي تمثل (الطين : الرمل: القش%) للمعاملات A، B، C، D، E على التوالى.

وخلصت الدراسة إلي:

- إرتفاع نسبة الإنكماش للمحارة التى تم تقويتها بنشارة الخشب عن مثيلاتها من القش، كما أن أقل نسبة إنكماش كانت للمحارة المخلوطة بألياف قش الشعير.و على الرغم من حدوث انكماش بسيط للمعاملات التى تم خلطها بالألياف، إلا أنه لم تحدث تشققات للمحارة حيث أن الخلط يربط المحارة جيداً.
- أظهرت المعامله E أكثر إنكماش وأكثر تشقق لكونها طين فقط بدون رمل وبدون خلط بالألياف.
- كان مدى متوسط نسبة الإنكماش للثلاثة أنواع من الألياف التى تم تقوية المحارة بها للمعاملات A، B، C هى 0.82 – 1.03%، 1.15 – 1.85%، 2.6 – 5.4% عند التجفيف على درجات حرارة 30، 50، 70°م على التوالى.
- زيادة نسبة الإنكماش بإرتفاع درجات الحرارة، حيث كانت المعامله 30°م هى أقل إنكماش.

لذلك توصي الدراسة بالأتي:

- عمل المحارة فى درجات حرارة أقل من 30 درجة مئوية (303.15 درجة كلفن).
- ضرورة خلط وتقوية المحارة بالألياف مثل قش الشعير، قش القمح، ونشارة الخشب أو أى نوع من أنواع القش مثل قش الأرز وذلك لتقليل الإنكماش وحماية المحارة.
- كلما زادت نسبة الألياف فى المحارة كما فى المعامله A كلما قلل ذلك من نسبة الإنكماش وتشققات المحارة.
- إمكانية استخدام المعاملاتA، B، C لمحارة مبانى القش.

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