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Physical and Mechanical Properties of Cement-Gypsum Board Made from Core-Kenaf (*Hibiscus cannabinus* L.) Using Autoclave Curing Technology

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ABSTRACT

Cement and gypsum bonded cellulosic fiber reinforced materials are ultimately ideal ecological building products. Their capability to use industrial coproducts and wastes as both their matrix material make its reinforcement also environmentally sustainable products. The objective of this study was to evaluate the effect of proportion cement-gypsum and autoclave curing time on the physical and mechanical properties of cement gypsum board made from core-kenaf. Three levels of proportion cement and gypsum were applied, namely; 40:60, 50:50, and 60:40, where cements mixture with core-kenaf particles contain at face-back layers and gypsum mixtures with core-kenaf particles contain at core layers. Five levels of autoclave curing time were applied, namely ; Control (non autoclave curing / conventional curing - 2 weeks, autoclave curing 2, 4, 8, and 16 hours. CaCl_2 3% and Borax 2 % was used as an accelerator and retarder. The physical and mechanical properties of cement-gypsum board were observed in according to JIS A 5417-1992. The results show that the physical and mechanical properties were gain on the best proportion of cement-gypsum 60:40 with 8 hour autoclave curing.

Keywords : Core-kenaf, Cement-gypsum board, Autoclave curing.

INTRODUCTION

Kenaf (*Hibiscus Cannabinus* L.) as one of the crop producer of fibre which have potency able to be developed as a raw material product substitution of log. Crop which included in set of relatives of *Malvaceae* that a fast grower crop, was usually harvested at 125 - 140 days (Dempsey 1975). With diameter 35 mm, kenaf can produce fibre around 4,4 ton/ha. After taken the fibres, this crop yield result of 'by product' in the form core of kenaf. In one hectare it can be yielded by dry of air core-kenaf (water content 15%) about 6 - 8 ton (Sastrosupadi 1984). This is result of by product which have potency to be exploited as raw material of semen-gypsum board. Cement board beside have excess of high dimension stability, unfortunately, have others problem where curing time of cement was too long namely minimize 28 days (\pm 1 month) and is a type of the heavy enoughness panil. Compared to gypsum board, gypsum board excess was a the lightness panil and easy to in workmanship, but have especial weakness which so easy to absorption of water and also have low strength. One of the way to overcome all problemses of cement board and gypsum board above mentioned was made semen-gypsum board (subtitution cement with gypsum at some selected proportions) with treatment autoclave curing.

This research aims are to find out the influence of proportion of semen-gypsum and also curing time of autoclave to properties of physical and mechanical semen-gypsum board from core-

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kenaf and determine the best of proportion type of semen-gypsum and curing time of autoclave in manufacturing of semen-gypsum board from core-kenaf, also the excellence of curing time autoclave compared to the manufacturing process of semen-gypsum board with 2 weeks conventional curing.

MATERIALS AND METHODS

Core-Kenaf Particles (*Hibiscus Cannabinus* L.) of 4 months old, in form of slivers with particles size among 2 - 3 mm, and also Portland cement and gypsum as a binder. Before manufacturing of cement-gypsum board, measurement of hydration temperature must done to saw the compatibility of core-kenaf as raw material of semen-gypsum board (According to Hydration Temperature Standard by LPHH Dephut in Kamil 1970).

Manufacture of cement-gypsum board with size 30 x 30 x 1,2 cm with target of density 1,2 g/cm³. Cement-gypsum board made by cement, gypsum and core-kenaf particles with formulation for the face and back of cement-gypsum board mixture by cement, core-kenaf particles and water with comparison 2,5:1:1,25. While for middle of cement-gypsum board made by mixture of gypsum, core-kenaf particles and water with comparison 3:1:1,5. Additional materials which used by for example CaCl₂ as an accelerator (3%) and borax as a retarder (2%).

Test of physical and mechanical properties of semen-gypsum board according to **Japanesse Industrial Standard of JIS A 5417-1992** which covering test of Density, Water Content, Water Absorption, Thickness Swelling and Linear Exspansion, Internal Bond (IB), Modulus of Elasticity (MOE), Modulus of Rupture (MOR) and Screw Holding Strength. The result of test has analyse used Multiplay Linier Regresion which have two variable independent, namely : 1) the proportions of cement-gypsum consist of three levels; 40:60, 50:50 and 60:40; and 2) autoclave curing times consist of five levels; conventional curing (2 weeks curing), autoclave curing 2, 4, 8 and 16 hours. Research used three repetitions, with the result 45 test of samples.

RESULT AND DISCUSSION

Hydration Temperature.

Figure 1 was indicated that mixture of gypsum and water have highest hydration temperature was 52⁰C with attainment of maximum temperature happened during 20 minutes, followed by mixture of gypsum, water and kenaf with hydration temperature was 50⁰C; later then mixture of gypsum, water, kenaf and borax (2% and 5%) equal to 48⁰C with time attainment of maximum temperature which almost the same (36 and 38 minutes). Hydration time of gypsum more shorten compared to cement hydration time.

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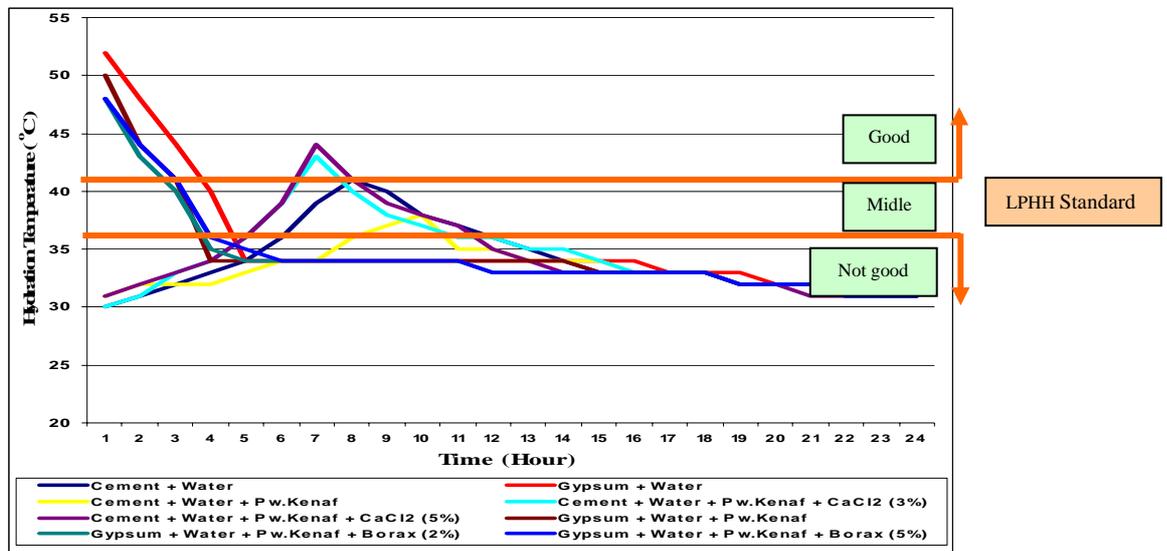


Figure 1. Grafic of Hydration Temperature

Different from gypsum which having quickly curing time when mingled by water, mixture of cement and water have maximum temperature 41⁰C and reached during 8 hours, while mixture of cement with water and kenaf powder have maximum temperature 38⁰C reached during 10 hours. If added CaCl₂ equal to 3% and 5% into mixture of cement with water and kenaf powder have maximum temperature 43⁰C and 44⁰C during 7 hours. If adapted for standard of hydration temperature cement by LPHH Dephut in Kamil (1970) hence all treatment which applied in this research shown pertained result 'good' because maximum temperature was bigger than 41⁰C. This matter gave indication that core-kenaf (*Hibiscus cannabinus* L.) can be used as a raw material to manufacture cement-gypsum board.

Physical Properties

Density

Figure 2 showing that density value of cement-gypsum board was ranging from 1,05 - 1,14 g/cm³. Highest density was 1,14 g/cm³ obtained at board with proportion of cement 60 and gypsum 40 with autoclave curing 8 hours, while lowest density value was 1,05 gr/cm³ obtained at board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks. Result of analyse indicate that density of cement-gypsum boards influenced by proportion of semen-gypsum without influenced by autoclave curing time and usage of larger ones cement proportion to proportion of gypsum (cement 60 and gypsum 40) will influence to board density where density of cement-gypsum board become excelsior and come near target of density.

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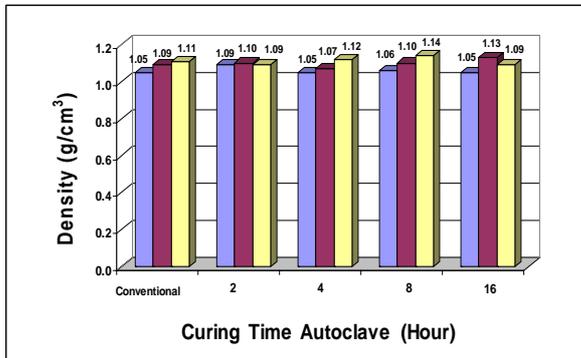


Figure 2. Histogram of Board Density

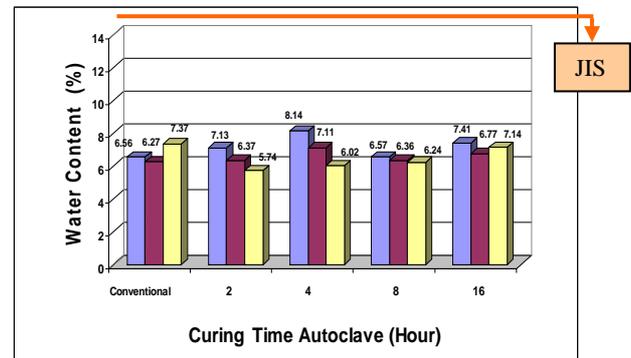


Figure 3. Histogram of Board Water Content

■ Cement 40: Gypsum 60
 ■ Cement 50:Gypsum 50
 ■ Cement 60:Gypsum 40

Water Content

Result measurement of board water content was ranging from 5,74 - 8,14%. Figure 3 indicating that board with proportion of cement 40 and gypsum 60 with autoclave curing 4 hours have highest value (8,14%), while lowest water content get at board with proportion of cement 60 and gypsum 40 with autoclave curing during 2 hours (5,74%). Result analyse indicate that water content of semen-gypsum boards do not influence by proportion of semen-gypsum and curing time autoclave which used in manufactured process of cement-gypsum board. According to JIS A 5417 standard which require water content board maximally 16% hence result of water content of semen-gypsum board in this research entirely fulfill that standard.

Water Absorption

Water absorption for 2 and 24 hours of water immersion of the boards can see in Figure 4. The water absorption of cement-gypsum board for 2 hours water immersion was ranging from 15,57 - 25,27%, whereas for 24 hours water immersion was 21,70 - 34,39%. Highest value for 2 hours water immersion get at board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks (25,27%), lowest value get at board with proportion of cement 60 and gypsum 40 with curing autoclave during 8 hours (14,14%). After 24 hours water immersion, highest value get at board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks (34,39%) and lowest value get at board with proportion of cement 60 and gypsum 40 with autoclave curing during 8 hours (21,70%).

Result analyse indicate that water absorption value of cement-gypsum boards influence by proportion of semen-gypsum used for 2 hours water immersion and 24 hours water immersion; where proportion of gypsum the ever greaterness to cement will cause water absorption of board after 2 hours water immersion and 24 hours water immersion become excelsior. So need semen-gypsum board with low water absorption which will show the highness dimension stability of semen-gypsum board that is board with proportion cement bigger than proportion of gypsum namely cement 60 and gypsum 40 with autoclave curing during 8 hours.

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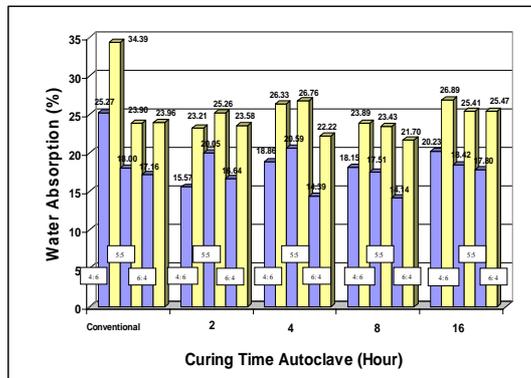


Figure 4. Histogram of Board Water Absorption

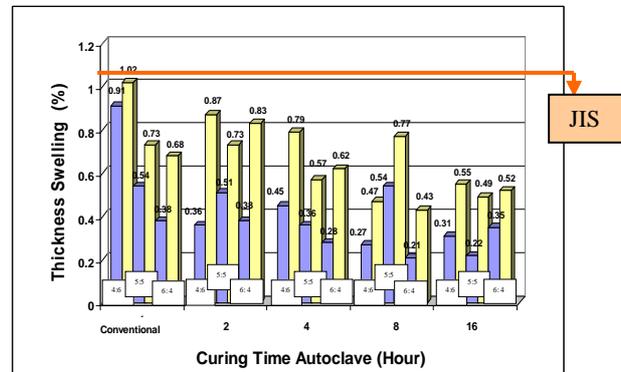


Figure 5. Histogram of Board Thickness Swelling

■ 2 Hours water immersion ■ 24 Hours water immersion

Thickness Swelling and Linear Expansion

Thickness swelling of the boards after 2 hours of water immersion ranging from 0,21 - 0,91%, whereas after 24 hours of water immersion ranging from 0,43 - 1,02%. Highest value after 2 hours of water immersion was 0,91% got at board with proportion cement 40 and gypsum 60 with conventional curing 2 weeks, while lowest value was 0,21% got at board with proportion cement 60 and gypsum 40 with autoclave curing 8 hours. After 24 hours of water immersion, highest value was 1,02% got at board owning proportion cement 40 and gypsum 60 with conventional curing 2 weeks, while lowest value was 0,43% got at board with proportion cement 50 and gypsum 50 with autoclave curing 8 hours.

Linear expansion of the boards after 2 hours of water immersion ranging from 0,07 - 0,23%, and after 24 hours of water immersion ranging from 0,09 - 0,31%. Highest value after 2 hours of water immersion was 0,23% got at board with proportion cement 40 and gypsum 60 with autoclave conventional curing 2 weeks, while lowest value was 0,07% got at board owning proportion cement 60 and gypsum 40 with autoclave curing 8 hours. After 24 hours of water immersion, highest value was 0,31% got at board with proportion cement 40 and gypsum 60 with conventional curing 2 weeks, while lowest value was 0,09% got at board with proportion cement 60 and gypsum 40 with autoclave curing 8 hours.

The value of thickness swelling and linear expansion after 2 and 24 hours of water immersion can be seen on Figures 5 and 6.

Result analyse indicated that thickness swelling and linear expansion of semen-gypsum boards do not influence by proportion of semen-gypsum and curing time of autoclave. This matter mean that although properties of gypsum which is absorbent of water and have an effect on to thickness swelling and linear expansion of boards, however, in generally influence of proportion of semen-gypsum and curing time autoclave do not have an effect to change board dimension, specially thickness swelling and linear expansion of cement-gypsum boards. All boards fulfill JIS Standard for thickness swelling and linear expansion properties.

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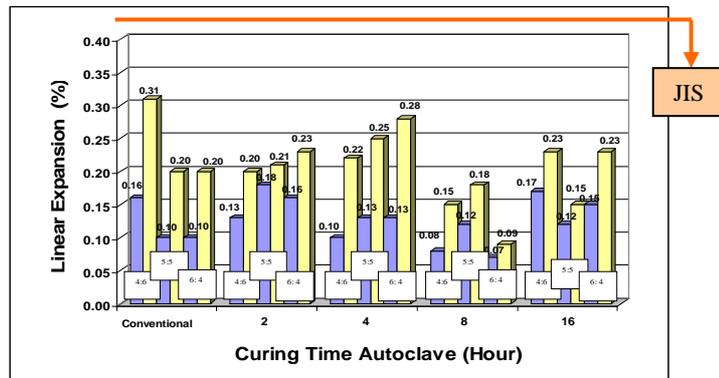


Figure 6. Histogram of Board Linear Expansion

■ 2 Hours water emmision ■ 24 Hours water emmision

Mechanical Properties

Internal Bond (IB).

According to result at Figure 7, Internal bond (IB) ranging from 3,15 - 20,91 kg/cm². Highest value was 20,91 kg/cm² show by board with proportion of cement 60 and gypsum 40 with autoclave curing during 8 hours, while lowest value of board was 3,05 kg/cm² show by board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks.

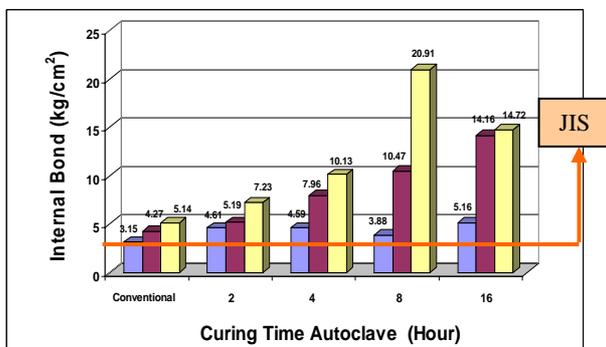


Figure 7. Histogram of Board Internal Bond

Legend : See Figure 2.

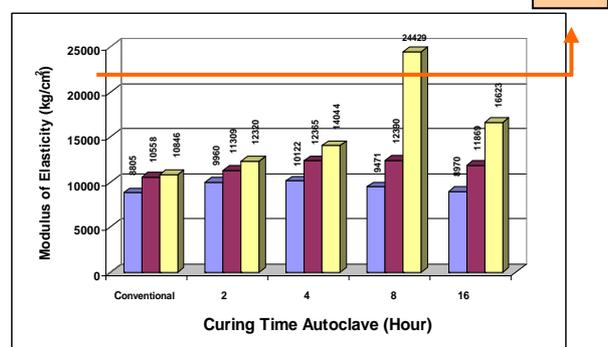


Figure 8. Histogram of Board MOE

Result analyse indicate that internal bond (IB) of semen-gypsum boards influence by proportion of semen-gypsum and curing time of autoclave. This matter mean that proportion of semen-gypsum where proportion of cement more bigger than gypsum, and the increasing of curing time autoclave can improve value of internal bond. According to JIS A 5417 which requiring internal bond value minimize 3,10 kg/cm² hence internal bond of semen-gypsum boards result of research entirely fulfill that standard.

Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

According to result at Figure 8, Modulus of Elasticity (MOE) was ranging from 8805 - 24429 kg/cm². Highest value was 24429 kg/cm² show by board with proportion of cement 60 and gypsum 40 with autoclave curing during 8 hours, while lowest value was 8805 kg/cm² show by board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks.

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Figure 9 indicate that Modulus of Rupture (MOR) was ranging from 33,19 - 84,26 kg cm². Highest value was 84,26 kg/cm² show by board with proportion of cement 60 and gypsum 40 with autoclave curing during 8 hours, while lowest value was 33,19 kg/cm² show by board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks.

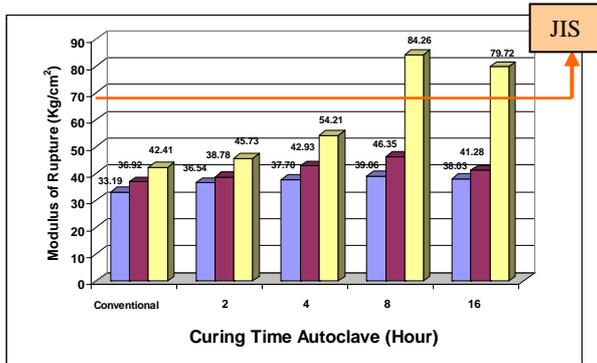


Figure 9. Histogram of Board MOR

Legend : See Figure 1.

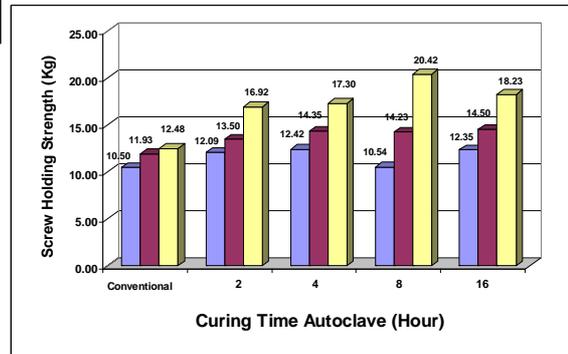


Figure 10. Histogram of Board Screw Holding Strength

Result analyse show that Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) cement-gypsum boards influenced by proportion of semen-gypsum and curing time of autoclave. This matter mean that proportion of semen-gypsum where cement proportion more bigger than gypsum and the increasing of curing time autoclave can improve Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) value of boards. According to JIS A 5417 which requiring Modulus of Elasticity (MOE) value minimize 24000 kg/cm² and Modulus of Rupture (MOR) value minimize 63 kg/cm², hence Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) of semen-gypsum board in this research fulfill the standard of Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) firmness value of semen-gypsum board with proportion cement 60 and gypsum 40 with autoclave curing during 8 hours.

Screw Holding Strength

Figure 10 show that screw holding strength value was ranging from 10,50 - 20,42 kg. Highest value was 20,42 kg show by board with proportion of cement 60 and gypsum 40 with autoclave curing 8 hours, while lowest value was 10,50 kg show by board with proportion of cement 40 and gypsum 60 with conventional curing during 2 weeks.

Result analyse indicate that value of screw holding strength influence by proportion of semen-gypsum and curing time of autoclave. This matter mean that proportion of semen-gypsum where proportion of cement more bigger than gypsum and the increase of curing time of autoclave can improve screw value of holding strength. Although JIS A 5417-1992 do not require value of screw holding strength board but board of semen-gypsum in this research owning highest screw holding strength was semen-gypsum board with proportion of cement 60 and gypsum 40 with autoclave curing during 8 hours.

The examination of mechanical properties of cement-gypsum board show that any mechanical properties of semen-gypsum board made with curing process by autoclave have Internal Bond (IB), Modulus of Elasticity (MOE), Modulus of Rupture (MOR) and Screw Holding Strength better than cement-gypsum board made with conventional curing during 2 weeks. The mentioned anticipated to be caused by done curing process with autoclave (temperature 126°C and pressure 1,5 kg/cm²) earn stimulation forming of Calcium Silicate Hydrate (Ca₃Si₂O₇·3H₂O) so that the forming process process becoming quicker and also mount at the time of curing reaction early (setting) and have influence in interlocking reaction with Calcium Carbonate

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(CaCO₃) at the time of curing process. This phenomenon partake to support strength of board which will make mechanical properties of cement-gypsum board become excelsior.

If according to requirement of structure of building which related to mechanical properties that is ability or strength of board to accounting load, this board have low strength. Usage of this product was better for the parts of building which not many accounting of loads like for the sheating of wall and others.

CONCLUSION

Core-kenaf can use as a raw material in manufacture of semen-gypsum board. Proportion of semen-gypsum and curing time of autoclave have an effect to physical and mechanical properties of board. Proportion of cement 60 and gypsum 40 with curing time by autoclave during 8 hours makes the properties of cement-gypsum boards fulfill all the examination parameters of JIS A 5417 standard, also made curing process by autoclave more better than curing process by conventional curing during 2 weeks. Manufacture cement-gypsum board using curing by autoclave can be conducted with briefer time and products of semen-gypsum board have better of physical and mechanical properties.

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