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STUDY ON FACTORS AFFECTING THE SOUND ABSORPTION PROPERTY OF MAGNESIA- BONDED WOOD-WOOL PANEL

Bin Na, Haiqing Wang, Tao Ding, Xiaoling Lu
Nanjing Forestry University, College of Materials Science and Engineering
Nanjing, China

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ABSTRACT

Magnesia-bonded Wood-Wool Panel is a kind of environmentally friendly inorganic material with wood-wool as matrix materials, and magnesium oxychloride cement (MOC) as binder which is also a kind of porous material with nice sound absorption property. In this study, through single factor experiments, it was found that The thickness of the panel, molar ratio of $MgO/MgCl_2/H_2O$, wood-wool length influenced material sound absorption performance of the panel significantly. The thickness of the panel was the most significant factor affecting the panell's sound absoption property, while the effects of density of the panel and weight ratio of magnesia to wood were not significant. The optimal factors were obtained through orthogonal experiments: Thickness of the panel 25 mm, molar ratio of MgO to $MgCl_2$ to H_2O 5: 1: 10, density of the panel 0.65 $g \cdot cm^{-3}$, weight ratio of magnesia to wood 1.25, wood-wool length 200 mm.

KEYWORDS: Magnesia, wood-wool panel, sound absorption coefficient.

INTRODUCTION

Magnesia-bonded Wood-Wool Panel is a kind of environmentally friendly inorganic material with wood-wool as matrix materials, and magnesium oxychloride cement (MOC) as binder (Bin Na et al. 2014, Bin Na et al. 2012, Bin Na et al. 2013, Zhipeng Wang et al. 2013). It is also a kind of porous material with nice sound absorption property Due to its porous structure, its sound absorption property is not only better than ordinary cement board, but higher than wood-based panels such as fiberboard and plywood.

There are so many factors affecting the panel's sound absorption property, such as thickness and density of panel, porosity, flow resistivity, the internal structure of the material and the like. In the actual production and engineering application, it is difficult to directly control the acoustic and hydrodynamic parameters such as porosity and flow resistivity. While the parameters like thickness, density, wood-wool length, molar ratio of MgO/ $MgCl_2$/ H_2O can be used indirectly to control the sound absorption properties of the panel. So qualitative analysis were studied about influence of thickness and density of the panel, wood-wool length and molar ratio of MgO/ $MgCl_2$/ H_2O on sound absorption property of the panel.

MATERIAL AND METHODS

Experimental design

According to experiments and related literature (YaoFA Liao. 2003. Plekha Nova,T.A et al. 2007. Bin Na et al. 2012, Bin Na et al. 2013, Zhipeng Wang et al. 2013), the following experimental parameters were determined: Steam-pressing temperature was 140°C; Steam-pressing time was 45 min; Steam-pressing maintenance was 5 min; the maximum vapor pressure inside was 0.27 MPa; maintenance time was 28d. And the technological process was also be determined (Bin Na et al. 2014, Bin Na et al. 2012, Bin Na et al. 2013, Zhipeng Wang et al. 2013).

Normal absorption coefficient was tested as an evaluation index of the panel's sound absorption characteristic.

Effects of factors likep thickness and density of the panel, Weight ratio of magnesia-to wood, wood-wool length and the molar ratio of MgO / MgCl2 / H2O to the panel's sound absorption coefficient were studied by the single factor or orthogonal experiments. Factors and levels of experiments are shown in Tab. 1.

Tab. 1: Factors and levels of experiments.

Level	Factor				
	A	B	C	D	E
1	0.45	15	100	1.25	3:1:8
2	0.55	20	100+200	1.5	5:1:8
3	0.65	25	200	1.75	5:1:10

Note: A-Panel density; B-Panel thickness (mm); C-Wood wool length (mm); D- Weight ratio of magnesia-to-wood; E-n(MgO)/n($MgCl_2$)/n(H_2O).

RESULTS AND DISCUSSION

Analysis of orthogonal experiment results

Tab. 2: Results and analysis of orthogonal experiment.

Mumber	A	B	C	D	E
1	0.45	15	100	1.25	3:1:8
2	0.45	20	100+200	1.5	5:1:8
3	0.45	25	200	1.75	3:1:10
4	0.55	15	100	1.5	3:1:8
5	0.55	2	100+200	1.75	5:1:10
6	0.55	25	200	1.25	5:1:8

7	0.65	15	100+200	1.25	5:1:10
8	0.65	20	200	1.5	5:1:8
9	0.65	25	100	1.75	3:1:8
10	0.45	15	200	1.75	3:1:8
11	0.45	20	100	1.25	5:1:10
12	0.45	25	100+200	1.5	5:1:8
13	0.55	15	100+200	1.75	5:1:8
14	0.55	20	200	1.25	5:1:8
15	0.55	25	100	1.5	5:1:10
16	0.65	15	200	1.5	5:1:10
17	0.65	20	100	1.75	5:1:8
18	0.65	25	100+200	1.25	3:1:8
K_1	1.297	1.123	1.285	1.505	1.318
K_2	1.482	1.504	1.506	1.494	1.301
K_3	1.586	1.738	1.574	1.074	1.746
k_1	0.432	0.374	0.428	0.502	0.439
k_2	0.494	0.501	0.502	0.498	0.434
k_3	0.529	0.579	0.525	0.358	0.582
Range(R)	0.096	0.205	0.096	0.144	0.148
Primary Order	B>E>D>A=C				
O optimal Level	A_3	B_3	C_3	D_1	E_3
Optimal Combination	$A_3B_3C_3D_1E_3$				

Note: A- Density of the panel; B-thickness of the panel(mm); C- Wood-wool length(mm); D-Weight ratio of magnesia-to-wood; E-n(MgO)/n($MgCl_2$)/n(H_2O).

Tab. 3: Variance analysis of orthogonal experiment.

Variation Source	Sum of Square	DOF	MS	F	Sig.
A	0.007	2	0.004	2.017	0.203
B	0.032	2	0.016	9.069	0.011
C	0.008	2	0.004	2.149	0.187
D	0.002	2	0.001	0.562	0.594
E	0.021	2	0.011	5.984	0.031
Error	0.012	7	0.002		
Sum	1.141	18			

Note: A- Density of the panel; B- Thickness of the panel(mm); C- Wood -wool length(mm); D-Weight ratio of magnesia-to-wood ; E-n(MgO)/n($MgCl_2$)/n(H_2O)

Tab. 3 showed that thickness of the panel, molar ratio of MgO/$MgCl_2$/ H_2O and the length of wood-wool effected sound absorption performance of the panel significantly, among which thickness of the panel was the most significant factor, while the effects of density of the panel and weight ratio of magnesia to wood were not significant. From the viewpoint of sound absorption performance, it could be found from Tab. 2, On the basis of meeting the basic physical properties, that the optimal values of the factors should be thickness of the panel 25 mm, molar ratio of MgO/$MgCl_2$/H_2O 5: 1: 10, density of the panel 0.65 g·cm^{-3}, weight ratio of magnesia to wood 1.25, wood-wool length 200 mm.

Effects of magnesia to wood ratio on sound absorption coefficients

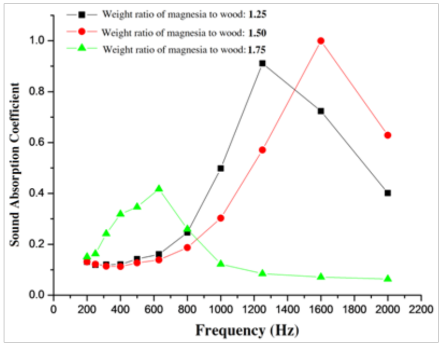

Fig. 1: Effects of weight ratio of magnesia –to wood ratio on sound absorption coefficients.

As shown in Fig. 1, For weight ratio of magnesia to wood, When It was 1.25 or 1.5, the panel's sound absorption coefficient from 1000 Hz to 2000 Hz was greatly higher than that when weight ratio of magnesia to wood was 1.75, while sound absorption coefficient of the panel at lower frequencies was significantly less than that when weight ratio of magnesia to wood was 1.75. This could be contributed to the internal structure of high porosity and small pores when weight ratio of magnesia to wood was 1.75, and the greater curvature of the panel internal structure, so that multiple reflections and refractions were obtained when sound waves spread into the panel, meanwhile energy was lost due to the viscous effects generated on the inner wall of the pore. But when weight ratio of magnesia to wood was 1.75, a large area of the complex salt crystals covered the panel, leading to a higher value of surface characteristic impedance, as the wavelength of high-frequency sound was shorter, and the absorption effect of high-frequency wave mainly occured on the surface of the material, thus the panel's high frequency sound absorption performance is poor. Given the panel's average sound absorption coefficient, and the panel's good sound-absorbing effect at 1000 Hz, it is recommended to select that weight ratio of magnesia to wood was 1.25.

Effects of panel thickness on sound absorption coefficients

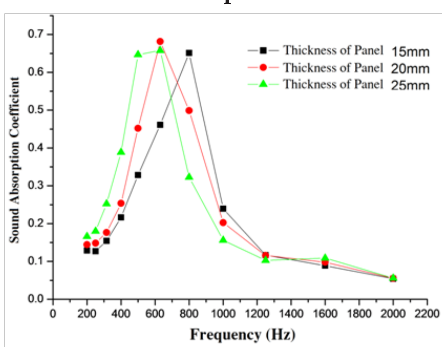

Fig. 2: Effects of thickness of the panel on sound absorption coefficients.

Fig. 2 shows that with the increase of the thickness of the panel, the low frequency absorption coefficients significantly increased, the peak value moved to lower frequencies. This is due to the more acoustic energy loss that occured in the pores with the pore length increase under a certain pore size and porosity. The longer the sound waves went into the pores through the pore channels, which also verified the quantitative analysis of low frequency sound absorption: the only way to improve panel's low-frequency sound absorption effect was to raise the value of capacitance k/jwd, namely increasing material thickness (Ruyu Lv. 1983) . Sound absorption coefficient of high-frequency sound wave obviously decreased with increase of panel thickness because the absorption of high-frequency sound wave mainly occurred on the surface of the panel and the absorption of low-frequency sound wave mainly occurred inside the panel.

Effects of Density on Sound Absorption Coefficients

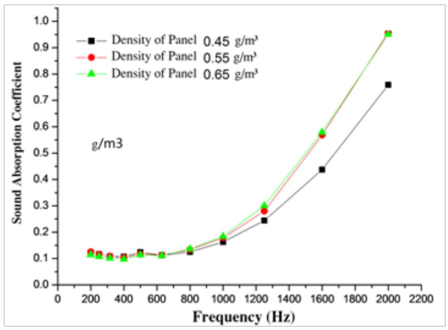

Fig. 3: Effects of density of the panel on sound absorption coefficients.

According to Fig. 3, the sound absorption coefficient of the panel was significantly higher when the density was 0.55 $g·cm^{-3}$ or 0.65 $g·cm^{-3}$. This was partly due to the large pore diameters in comparative low density panel which led to low flow resistance. At the same time, under this condition, the degree of curvature was reduced, so the reflecting and refraction times of the sound waves entering into the internal of the panel was reduced. It should be noted that the water molar quantity of all the samples of this group were reduced in order to explore the effects of water molar ratio on the panel properties, the consistency of magnesite solution was increased, but this adjustment would not effect the inter-group comparison of density, which formed the surface with high density, high porosity and small pore size, whereas intermediate structure with low density, large pore size, the significantly reduced porosity, this structure feature reduced the panel's middle and low frequency sound absorption performance.

Effects of molar ratio of MgO to $MgCl_2$ on sound absorption coefficients

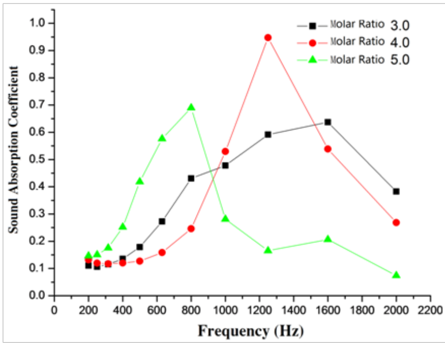

Fig. 4: Effects of molar ratio of MgO to $MgCl_2$ on sound absorption coefficients

As shown in Fig. 4, when the molar ratio of MgO to $MgCl_2$ changed, the sound absorption coefficient varied widely. This was because that the proportion of $5Mg(OH)_2 \cdot MgCl_2 \cdot 8H_2O$ to $3Mg(OH)_2 \cdot MgCl_2 \cdot 8H_2O$ after reaction was completely different with different molar ratio of MgO to $MgCl_2$, leading to the change of the material's porosity, pore size and air flow resistance which were considered to be the key factors affecting sound absorption performance of the inorganic porous sound-absorbing material with rigid walls (Bin Na et al. 2014). When the molar ratio of MgO to $MgCl_2$ was 5.0, the sound absorption performance of f≤800 Hz was good, and the sound absorption frequency band was wide, the sound absorption coefficient at 800 Hz is up to 0.7. When the molar ratio was 3.0, the peak value was at f=1650 Hz, and when the molar ratio was 4.0, the peak value appears at f=1200 Hz. Considering that the panel was primarily designed to be residential wall sound-absorbing material, which mainly required for the high sound absorption property of 200-1000 Hz, and since the mechanical strength of 5-phase was higher than 3-phase, so ,in order to ensure the cement strength, it should be considered to maximize the molar ratio of MgO to $MgCl_2$ to make the magnesium oxychloride cement contains more 5 phases (Hui Guan et al. 2009. Therefore, to obtain the better performance in practice, the molar ratio should be 5.0.The reason that the panel with high molar ratio had good sound absorption property at 800 Hz was because that excessive MgO could generate more layered $Mg(OH)_2$ phase which had loose structure and high porosity thus had significant effect to enhance low-frequency sound absorption property of the panel accord with sound-absorbing characteristics of porous material (Chuanyou Xu et al. 2008).

Effects of wood-wool length on sound absorption coefficients

As shown in Fig. 5, the panel made of wood-wool with different lengths did not differ significantly in low-frequency sound absorption coefficient. But with the increase of frequency, the panel made by (100 + 200) mm and entirely by 200 mm length wood-wool appeared better sound absorption coefficient compared to the panel entirely made by wood-wool length of 100 cm. When f was 2000 Hz, panel made by 200 mm length wood wool's sound absorption coefficient was significantly higher than that made by (100 + 200) mm length wood-wool probably because of the pore size of panel made of 100 mm length wood-wool was relatively small, but with higher density which influenced the sound wave's entrance and propagation.

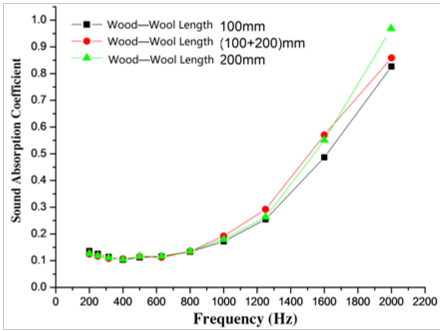

Fig. 5: Effects of wood-wool length on sound absorption coefficients.

CONCLUSIONS

This paper studied the effects of density and thickness of the panel, weight ratio of magnesia to wood , $MgO/MgCl_2/H_2O$ molar ratio, wood-wool length and other processing conditions on the sound absorption properties of porous materials by orthogonal experiments. The effects of each factor on the property and the mechanism analysis were further investigated by single factor experiment. The optimum processing conditions were obtained.

(1) Thickness of the panel, molar ratio of $MgO/MgCl_2/H_2O$ and the length of wood-wool influenced the sound absorption performance of the panel significantly, among which, thickness was the most significant factor, while the effects of density of the panel and weight ratio of magnesia to wood were not significant.

(2) With the increase of thickness of the panel, low frequency absorption coefficients significantly increased, the peak value moved to lower frequencies. The increase of thickness of the panel could effectively improve the material's low frequency sound absorption property, but in the actual building engineering, increasing the thickness too much would not only increase the panel cost but also increase the The measure of area, thus, improving the sound absorption property by adjusting other conditions was important.

(3) There was not obvious difference in low frequency sound absorption property between panels made with different lengths wood-wool, except that at 2000 Hz, 200mm panel's sound absorption coefficient of the panel made of (100 + 200) mm length wood-wool was significantly higher than that made of (100 + 200) mm length wood-wool.

In conclusion, considering optimize the panel's sound absorption property under the premise of enough physical properties, the optimal level of the factors are: thickness of the panel 25mm, molar ratio of MgO to $MgCl_2$ to H_2O 5: 1: 10, density of the pane l0.65 $g{\cdot}cm^{-3}$, weight ratio of magnesia to wood 1.25, wood-wool length 200 mm.

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REFERENCES

1. Yaofa Liao, 2003: Architectural Physics. Wu Han University Press, China,
2. PlekhaNova,T.A.,Keriene,J.,Gailius,A.,Yakovlev,G.I.,2007:Structural, physical and mechanical properties of modified wood-magnesia composite. Construction and Building Materials 21(9):1833-1838.
3. Bin Na, Zhipeng Wang, Zhiqiang Wang et al (2014). Study on hydration mechanism of low density agnesia-bonded wood wool panel [J].Wood Research, 59(1):137-148.
4. Bin Na, Zhipeng Wang, Zhiqiang Wang et al (2012). Study on improvement of hygroscopicity property of low density magnesia-bonded wood-wool panel [J].Journal of Building Materials,15(5):660-664. (In Chinese)
5. Bin Na,Yuxiang Zhao, Zhipeng Wang et al(2013) .Effects of additives on mechanical property and hygroscopicity property of low density magnesia-bonded wood wool-panel (2013).Journal of Northwest Forestry University, 28(2):168-172.(In Chinese)
6. Chuanyou Xu, Fengxiang Gou. Xin Du et al (2008).Developments of sound-absorbing materials.Brick and Tile. (9):11-14
7. Hui Guan,Hengjing Ba(2009).Study on phase stability of Magnesium oxychloride cement. Journal of Harbin Engineering University , 30(11):1213-1218.(In Chinese)
8. Ruyu Lv (1983).Sound absorption mechanism and design principles of acoustic material[J]. Noise and Vibration Control, (3):52-58.(In Chinese)
9. Zhipeng Wang, Dandan Sun, Xiaoyan Chen et al (2013).Study on the sound absorption and thermal conductivity properties of low density magnesia-bonded wood wool panel. Journal of Southwest Forestry University,33(3):97-99. (In Chinese).
10. Zhipeng Wang, Dandan Sun, Xiaoyan Chen et al (2013). Steam-pressing M echanism of Low Density Magnesia-bonded Wood Wool Panel. Journal of Northwest Forestry University 28(6): 165-168. (In Chinese)

Bin Na*, Haiqing Wang, Tao Ding, Xiaoling Lu
Nanjing Forestry University,
College of Materials Science And Engieering
Nanjing, 210037
China
Corresponding author: nabin8691@126.com