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Calcium silicate board as wall-facade

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Abstract

Wall as spatial partition and facade of a building gives impact not only for building aesthetic, but especially for the occupant's convenience. In the preference of wall material, especially for high rise apartments, hotels or offices, its mass/m2 and its noise reduction become an important criteria that must be considered by the building owner and architect in order to give a more lightweight construction and a quieter interior for occupant's convenience and privacy. In this paper, lightweight material that has been investigated is calcium silicate board, as an alternative to brick as a common wall material. The findings of this research, by flexural strength test in normal condition, are generally categorized in class 2 and 3. By soak-dry test as durability test for outside uses, there are no cracks found in all samples and the flexural strength decreases but less than 30% so that it meets the SNI 7705:2011 standard. By warm water test, this material cannot withstand against temperature at 60 degree centigrade or higher. By heat and rain test, this material can withstand the heat and rain conditions. By noise reduction as sound isolating enclosure, this material is unable to perform as a noise barrier.

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Keywords: calcium silicate board; durability; flexural strength; noise reduction

1. Overview

Construction development nowadays is supported by the newest invention in building materials. A more lightweight, more sustainable and easier installation material is being considered in material preferences. In the preference of wall material, especially for high rise apartments, hotels or offices, its weight (mass/m^2) and its noise reduction become an important criteria that must be considered by the building owner and architect in order to give a

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more lightweight construction and a quieter interior for occupant's convenience and privacy. Such preference of lightweight wall material, being researched here is calcium silicate board.

2. Calcium silicate board in building construction

Calcium silicate board mainly consists of inorganic material such as silica sand, Portland cement, cellulose and water. It is widely used as an alternative to gypsum and asbestos cement board that have some disadvantages. Asbestos cement board gives a bad influence to building occupants health, while the gypsum board will dissolve in the water so that it cannot be used on the building exterior.
Formerly calcium silicate board was used for indoor partition and ceiling, but later it is widely used for wall facade as it is waterproof, lightweight, has a wide dimension and is easy to install; even it is the solution for a sloping and bending opaque wall surfaces. That is why it has the advantage compared to the brick wall and lightweight concrete. Compared to lightweight concrete, it has the same drywall construction, but at a lower cost.

Fig. 1. Calcium silicate board uses as façade and room partition

Besides its advantages, some of the disadvantages are the high installation cost compared to gypsum and asbestos; and it has limitation in its rain, heat and fire resistance. That is why some modification are needed.
A research in cold-formed steel wall frame with calcium silicate board sheathing conducted by Lin, Pan and Hsu [1] noted that the crack happened mostly at the bottom of the track of wall specimen. That is why modification of the wall with calcium silicate board sheathing is needed. Wang, Chuang and Lin [2] studied the performance of calcium silicate partition fireproof drywall assembly with a junction box and found that the quality of the calcium silicate board plays a big role in the fireproof effectiveness. Different composition may impact the heat and fire resistance of this material. The poorer formula it has, such as substitution of cement with the coal ash to reduce the production cost; the poorer its fire-proofing will be. Since this material needs modification in its application in many kinds of performances, this paper aims to find its capability as facade material by flexural strength test, warm water test, soak-dry test, heat-rain test in tropical climate as well as the sound reduction test.

The warm water test was needed to know its flexural strength due to increase in temperature, compared to normal condition. The soak-dry test was done to get known the flexural strength after soaking in the water and dried while the heat-rain test was conducted to find its durability against the rain and the heat of the sun. The sound reduction test was conducted to find its noise reduction as sound isolating enclosure. The samples were taken from 2 different kinds of thickness and 4 brand products in Indonesia for each thickness ; the 6mm was used for outside ceiling, while the 8 mm thickness was used for outside wall or facade.

3. Flexural strength of calcium silicate board

According to SNI (Indonesian National Standard) 7705:2011[3] the flexural strength standard of calcium silicate board is as follows:

Table 1. Calcium Silicate Board Standard Flexural Strength (SNI 7705:2011)

Class	Category	
	A	B
Class 1	4	4
Class 2	7	7
Class 3	13	10
Class 4	18	16
Class 5	24	22
Note: A category for saturated condition of outside uses; B for inside uses Flexural strength in M Pa; 1 M Pa = 10.03735 kg/cm2		

Table 2 shows the quality standard of Calcium silicate board according to SNI 7005:2011 [3]

Table 2. Quality standard of Calcium Silicate Board (SNI 7705:2011)

No	Item	Unit	Quality standard
1	Flexural strength	M Pa	See Table 1
2	Density	g/cm^3	≥0.8
3	Water resistance	-	No leakage
4	Warm-water resistance	-	Li of average ratio r ≥ 0.7 ; no cracks
5	Soak-dry resistance	-	Li of average ratio r ≥ 0.7 ; no cracks
6	Heat-rain resistance	-	SNI 03-1027-2006 [4]
7	Noise reduction	deciBel	See Table 3

3.1. Flexural strength test

Flexural strength test was conducted by proving ring machine that gave loading in 1000 grams per second until the sample put along its transverse fiber was broken.

Fig. 2. Flexural strength test with proving ring machine

3.2. Warm water test

To get the flexural strength of warm water, the sample was soaked in water with the temperature of 60 degrees centigrade for 24 hours. After that, the flexural strength test was conducted with proving ring machine.

Fig. 3. Warm water test

3.3. Soak-dry test

Soak-dry test was conducted to the sample until 10 cycles to sample where one cycle consisted of soaking the sample in 5 degree centigrade room temperature for 2 hours and drying it by heating it to 60 degree centigrade for 2 hours. After settling for 24 hours then the flexural strength was conducted.

Fig.4. Soak-dry test

3.4. Heat-rain test

Heat-rain test was conducted to the sample until 10 cycles where one cycle consisted of spraying it with 2.5 liter/minute water for 2 hours, and after settling for 10 minutes, the sample was heated to 33 degree centigrade for two hours. After 10 minutes being settled, then the sample was checked whether there was any seepage water.

Fig. 5. Heat-rain test

4. Noise Reduction of Calcium Silicate Board

4.1. *Sound and Noise*

Sound emerges from a sound source, and transmits in air as the medium to the ear as the receiver. Noise is defined as a sound, especially one that is loud or unpleasant or that causes disturbance. (www.oxforddictionaries.com/definition/../**noise***)* For any person, noise is subjective; but there is some sound that makes noise for any person such as a sudden high sound level, a loud and continuous sound like the rock music, the engine planting, and the sound of vehicles as well [5]. In terminology, noise can be distinguished into background noise, noise, and ambient noise. Background noise is the sound around us that appears regularly and stable at a certain level, usually lower than 40 decibel. Noise is a sudden sound with the degree of hardness exceeds the background noise in the area. Meanwhile, ambient noise is the combination of background noise and noise. Noise disturbance is determined by the sound level (in decibel) and the sound frequency (in Hz). Both factors are considered in the Noise Criteria that determine the level of sound comfort in a particular room [5].

4.2. Noise reduction (NR) test

The NR between rooms is simply the arithmetical difference in room intensity levels. It means the noise in the source room at an intensity level of IL1 is less than the transmitted noise in the receiving room at a reduced intensity level of IL2[6]. Table 3 shows standard for noise reduction in SNI 7705:2011.

Table 3. Standard of Sound Reduction Index of Calcium silicate board (SNI 7705:2011)

No	Sample thickness(mm)	SRI (dB) density $0.8 \leq D < 1.25$ gram/cm^3	SRI (dB) density $1.25 \leq D < 1.35$ gram/cm^3	SRI (dB) density $D \geq 1.35$ gram/cm^3
1	≤5	19	23	25
2	5 s.d. 10	21	25	27
3	> 10 s.d. 15	24	28	31
4	>15 s.d. 20	27	32	35
5	>20	31	37	41

This research, because of the limitations of the reverberation room, adopted here the ASTM E 596-96 "Laboratory Measurement of the Noise Reduction of Sound-Isolating Enclosures" [7]. By using this method, the noise reduction of the sound isolating of the wall materials tested can be obtained.

According to ASTM, the effective reverberation room volume should not be less than 200 m^3. The reverberation chamber in this research was only 53.4 m^3 volume. However, if the point requirement 9.1.2 and 9.5 of the standard are satisfied, room volume is not critical. The 9.1.2 requires that the enclosure is at least one-half wavelength away from the reverberation walls and ceiling and any diffusing surfaces at the center frequency of the lowest one-third octave band in which the noise reduction is to be measured. The wavelength of the 125 Hz as the lowest frequency here is 2.72 m, so the one-half wavelength must be 1.36 m.

The 9.5 requires that microphone positions shall be at least one-half wavelength away from any solid surface of the test frequency; thus it is in the same distance, 1.36 m. From the layout and section in the Fig 6, it will be found that both requirement are fulfilled. To maintain its validity, we refer to Section 11 of the standard that the room has to fulfill sound diffusion condition and the measurement result reaches 95% confidence to within 1 dB at all test frequencies, except the lowest, should be in 95% confidence to within 2 dB. To make sure that the reverberation chamber is diffuse, the preliminary measurement has been done. After doing some adjustment so that the diffusion in all points reach the 95%, the reverberation chamber is ready to be used.

The noise reduction was measured with 2 microphones that has been calibrated. The first was put at the sound source area and the second one was put inside the enclosure. Then, the result was read on each sound level meter. To get the NR, the calculation was taken by using this formula:

$$NR = L_1 - L_2 \tag{1}$$

Fig.6. Noise reduction test

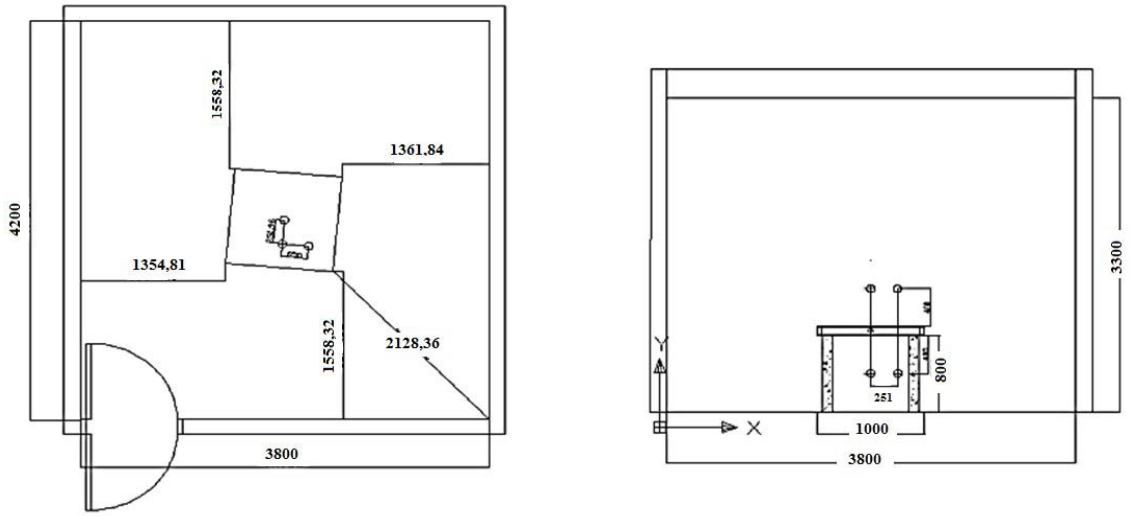

Fig.7. Reverberation room layout and section (length 4.26m x width 3.80m; height 3.30m)

5. Results and Discussions

5.1. Flexural strength test

Table 4. Flexural strength result and class summary

No	Code	Load (kg)	Moment (kg.cm)	Flexural strength (M Pa)	Class Category	Average Flexural strength (M Pa)	Class summary
1	S 6 I	27.58	148.23	11.00	Class 2	13.95	Class 3
2	S 6 II	41.37	222.35	16.89	Class 3		
3	K 6 I	34.47	185.29	9.61	Class 2	10.47	Class 2
4	K 6 II	38.61	207.53	11.33	Class 2		
5	N 6 I	48.26	259.41	14.99	Class 3	15.07	Class 3
6	N 6 II	42.75	229.76	15.15	Class 3		
7	G 6 I	44.13	237.17	17.04	Class 3	18.01	Class 4
8	G 6 II	49.64	266.82	18.98	Class 4		
9	K 8 I	41.37	222.35	8.68	Class 2	8.76	Class 2
10	K 8 II	44.13	237.17	8.85	Class 2		
11	N 8 I	121.35	652.23	21.57	Class 4	20.76	Class 4
12	N 8 II	113.07	607.76	19.95	Class 4		
13	S8 I	68.95	370.58	11.18	Class 2	12.76	Class 2
14	S8 II	89.63	481.76	14.34	Class 3		
15	G8 I	82.74	444.70	15.98	Class 3	15.34	Class 3
16	G8 II	75.84	407.64	14.70	Class 3		

The results show that the average flexural strength of the sample was 14.39 M Pa. In average, the flexural strength of the sample were categorized in class 2 and class 3; except the G6 and N8 were categorized in class 4.

Table 5. Warm-water test result

No	Code	Load kg)	Moment (kg.cm)	Flexural strength (M Pa)	Class category	Ratio	Warm water test	SNI requirement
1	G6	48.26	259.41	16.76	Class 3	0.93	No crack	Passed
2	G8	55.16	296.47	10.22	Class 2	0.67	No crack	Failed
3	K6	26.20	140.82	7.79	Class 2	0.74	No crack	Passed
4	K8	34.47	185.29	6.63	Class 1	0.76	No crack	Passed
5	N6	39.99	214.94	12.73	Class 2	0.84	No crack	Passed

6	N8	57.91	311.29	10.62	Class 2	0.51	No crack	Failed
7	S6	28.96	155.65	12.21	Class 2	0.88	No crack	Passed
8	S8	71.70	385.41	11.88	Class 2	0.93	No crack	Passed

From table 5, it was found that the flexural strength of all samples decreased compared to its normal condition. After 24 hours warm water treatment, no crack was found in all samples; but after the flexural strength test was conducted, it was found that there were sample that could not pass the requirement of SNI ratio has to be ≥0.7. The samples with a ratio of flexural strength lower than 0.7 were the G8 and N8. This meant that calcium silicate board could not stand well against hot temperature at 60 degree centigrade or higher.

Table 6. Soak-dry test result

No	Code	Load (kg)	Moment (kg.cm)	Flexural strength (MPa)	Class Category	Ratio	Soak-dry test	SNI requirement
1	G6	34.473	185.29	12.74	Class 2	0.71	No crack	Passed
2	G8	71.704	385.41	14.18	Class 3	0.92	No crack	Passed
3	K6	41.368	222.35	12.62	Class 2	1.21	No crack	Passed
4	K8	55.157	296.47	10.91	Class 2	1.25	No crack	Passed
5	N6	44.125	237.17	14.37	Class 3	0.95	No crack	Passed
6	N8	96.524	518.82	18.20	Class 4	0.88	No crack	Passed
7	S6	39.989	214.94	17.09	Class 3	1.23	No crack	Passed
8	S8	62.051	333.53	9.68	Class 2	0.76	No crack	Passed

From the soak-dry test, it was found that all samples passed the SNI 7705:2011 requirement that the ratio of the flexural strength compared to the normal condition should be ≥0.7. There were no cracks found in all samples as well. This meant that calcium silicate board withstood against the soak-dry condition.

Table 7. Heat-rain test result

No	Code	Heat-rain test	Crack length (mm)
1	G6	No crack	---
2	G8	No crack	---
3	K6	No crack	---
4	K8	No crack	---
5	N6	No crack	---
6	N8	No crack	---
7	S6	No crack	---
8	S8	No crack	---

SNI 7705:2011 requirement for heat and rain conditions that any cracks should be less than 50 mm were fulfilled by all samples. From the heat-rain test, no cracks were found in all samples. This meant that calcium silicate board withstood against the heat-rain condition.

Noise reduction of calcium silicate board as sound isolating enclosure measured in decibel (dB) was taken in low to high frequency: 125 Hz, 250 Hz, 500 Hz, 1kHz, 2kHz and 4 kHz. Table 8 shows the result.

From the noise reduction test result, it was found that all samples could not fulfill the SNI 7705:2011 standard. However, from the result we can find that calcium silicate board as sound isolating enclosure can reduce better the low frequency especially at 125 Hz and 250 Hz than sound with high frequency.

Because the result was not satisfying, a modification has been done to get a better noise reduction by inserting some types of local sand into the frame of the enclosure in order to increase its mass/kg. By this insertion, the mass increased from 25.4 kg/m2 to 62-65.9 kg/m2. The result shows in Fig 8 that as long as the mass increases, the noise reduction increases as well. But the best frequency of noise reduction was the 125 Hz and 250 Hz that increased 120-410% its noise reduction; while the 4 kHz increased only 10-27%. From the result, it was found that all samples could not reduce noise required by SNI standard.

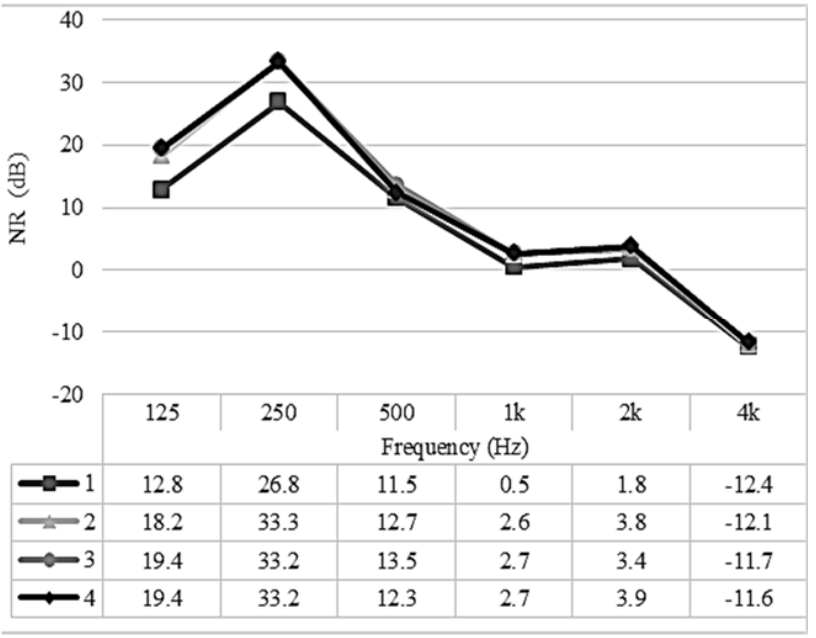

Fig.8. Increases of noise reduction with sand insertion

Table 8. Noise Reduction test result

No	Code	Frequency (Hz)	NR			Average NR	Density (g/m^3)	Mass (kg/m^2)
			1	2	3			
1	G6	125	14.3	12.9	11.1	12,8	1,645	9,56
		250	34.6	33.2	32.7	33,5		
		500	11.5	10.5	10	10,7		
		1K	1.2	0.2	0.2	0,5		
		2K	3.3	2.8	2.8	3,0		
		4K	-9.8	-8.4	-9.1	-9,1		
2	K6	125	13.3	12.8	12.5	12,9	1,267	8,54
		250	31.4	34.2	34.6	33,4		
		500	11.8	13.7	13.4	13,0		
		1K	3.5	3.5	4.1	3,7		
		2K	5.4	6.5	6.5	6,1		
		4K	-8.8	-7.1	-7.9	-7,9		
3	N6	125	16,3	14,4	5,4	12,0	1,242	7,78
		250	34,0	31,2	31,7	32,3		
		500	13,4	14,4	14,9	14,2		
		1K	3,1	3,6	3,2	3,3		
		2K	5,8	5,6	5,2	5,5		
		4K	-8,2	-7,9	-8,5	-8,2		
4	S6	125	13,5	12,6	12,4	12,8	1,276	7,28
		250	33,8	33,5	31,8	33,0		
		500	8,8	8,6	9,2	8,9		
		1K	-0,4	-0,7	-1,6	-0,9		
		2K	2,4	1,3	2,0	1,9		
		4K	-10,1	-9,8	-10,0	-10,0		

5	G8	125	16,7	16,7	15,5	16,3	1,554	12,78
		250	33,9	34,5	33,0	33,8		
		500	15,4	15,2	14,3	15,0		
		1K	3,2	2,6	2,0	2,6		
		2K	4,7	4,2	4,5	4,5		
		4K	-8,2	-8,7	-8,9	-8,6		
6	K8	125	15,5	15,3	13,7	14,8	1,334	10,64
		250	33,8	32,2	32,0	32,7		
		500	16,0	16,7	13,6	15,4		
		1K	3,9	4,0	2,4	3,4		
		2K	7,1	6,8	7,1	7,0		
		4K	-7,8	-8,1	-7,6	-7,8		
7	N8	125	18,0	13,7	16,3	16,0	1,390	11,89
		250	35,2	33,8	33,8	34,3		
		500	14,4	13,7	14,5	14,2		
		1K	4,0	4,5	4,4	4,3		
		2K	5,5	5,4	5,2	5,4		
		4K	-8,2	-8,8	-8,5	-8,5		
8	S8	125	16,4	16,8	14,5	15,9	1,418	12,77
		250	35,1	32,2	33,0	33,4		
		500	13,2	11,6	12,8	12,5		
		1K	3,3	1,9	1,9	2,4		
		2K	4,3	4,6	3,8	4,2		
		4K	-9,4	-8,4	-8,6	-8,8		

6. Conclusion

By the test of its strength, durability and noise reduction according to Indonesian National Standard (SNI) 7705:2011, it can be concluded that:

- By flexural strength test in normal condition, the 6 mm and 8 mm thickness were generally categorized in class 2 and 3; only one sample in each thickness was categorized class 4 (G6 and N8 samples).
- By soak-dry test as durability test for outside uses, there were no cracks found in all samples. The flexural strength decreased but less than 30%. Thus, it met the standard.
- By warm water test, no cracks were found in all samples. For 6 mm thickness, all samples met the standard; however, for 8 mm thickness there were two samples that decreased strength > 30%, so they could not pass the standard (G8 and N8). It means this material cannot withstand against temperature at 60 degree centigrade or higher.
- By heat and rain test, no crack was found in all samples. Thus, this means that this material can withstand the heat and rain conditions.
- By noise reduction as sound isolating enclosure, all samples could not fulfil the SNI standard. By sand insertion to increase its masses, this standard could not be fulfilled as well. It means this material is unable to perform as a noise barrier.

From the result above, the calcium silicate board can be recommended as building facade or outside ceiling as long as the building surface is not exposed to heat and hot water exceeding 60 degree centigrade and the sound performance is not crucial since this material cannot perform well as a noise barrier.

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