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Development of Vesicular Basalt Fragment Cement Board Reinforced with Steel Wire Mesh

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Abstract

This research aims to develop the cement board from vesicular basalt fragment which reinforced with steel wire mesh. The ratio of Portland cement type1: fine sand: vesicular basalt fragment: sodium silicate: tap water was equal to 1: 2: 4: 0.03: 0.55 by weight. The 5 sizes of steel wire mesh (steel wire no.25) were installed including: 3/8”, 1/2”, 5/8”, 3/4”, and 1”. The cement boards were produced by compression machine. The property tests of cement board followed the TIS. 878-1994 standard (cement bonded particle board: high density). From the results, the 3/4" of steel wire mesh size was the most suitable size for reinforcing the cement board from vesicular basalt fragment. These developed cement boards were the construction materials which had the high bending strength, good thermal insulation, and moisture protection properties.

Keywords: Cement board, vesicular basalt fragment, steel wire mesh, thermal insulation

1. Background/ Objectives and Goals

In Thailand, there are many several potential reserve of basalt such as in Kanchanaburi, Phrae, Lampang, Sisaket, Chanthaburi, Trat, Chiang Rai, Lampang, Phetchabun, Lop Buri, Nakhon Ratchasima, Chonburi, Saraburi, Uthai Thani, Buriram, Ubon Ratchathani and Surin provinces (Department of Mineral Resources, 2010). The vesicular basalt fragment is one of the basalt fragment. This fragment has the cavity or void more than the common basalt fragment which these cavities were occurred by the dissolving gases come out of solution and form bubbles as the magma decompresses as it reaches the surface (Armstrong et al., 2008). The vesicular and common basalt fragment are an igneous rock with generally 45–53% silica (SiO_2) and less than 10% feldspathoidal by volume, and where at least 65% of the rock is feldspar in the form of plagioclase (Le bas and Streckeisen, 1991). Nowadays, the basalt fragment was used as the aggregate in construction industry but the vesicular basalt fragment was removed (Department of Mineral Resources, 2010). According to the texture of vesicular basalt fragment, it is possible to improve the properties of construction materials such as lightweight and thermal insulation (Tonnayopas, 2010). From the previous research, the utilizing vesicular basalt fragment as an aggregate in cement board product can improve the properties and help the manufacturing to reduce the production costs and eliminate the waste materials (Weeranukul et al., 2019). However, the using of cement board product in building, the fracture problem is the important problem. It cannot be used for a long time, especially when apply to the floor and steps of the building. Therefore, the development of vesicular basalt fragment cement board must use the ferrocement technology by reinforcing the cement board with steel mesh (Suweero and Khamput 2018; Lunlar et al., 2010). This research aims to develop the cement board from vesicular basalt fragment which reinforced with steel wire mesh.

Fig. 1: Vesicular basalt fragment

2. Methods

2.1 Materials and equipment

This research uses materials and equipment which consisting of Portland cement type 1, fine sand, vesicular basalt fragment (from Buriram province, Thailand), sodium silicate (Na_2SiO_3) (Weeranukul et al., 2019), 5 sizes of steel wire mesh (wire diameter 0.5 mm, and opening size 3/8”, 1/2”, 5/8”, 3/4”, and 1”), 2 Brands of cement broads in the Thai market (Brand A and B), concrete mixer, compression and sharking machine, mold sized 30 x 30 x 1.5 cm, stone grinder and sieve no. 4), weighing scale, density test kit, moisture and water absorption test kit, universal testing machine (UTM), and thermal conductivity tester.

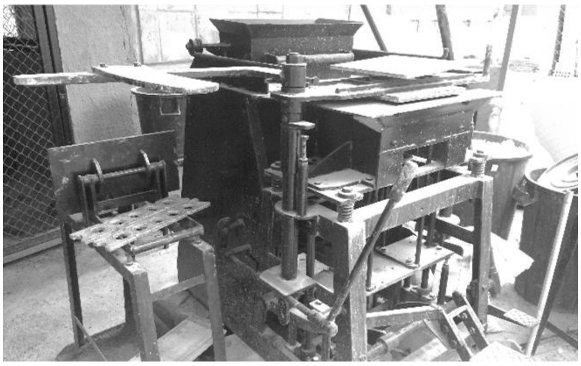

Fig. 2: Compression and sharking machine

2.2 Design of mix ratios

The mix ratios of cement board from vesicular basalt fragment are shown in Table 1.

Table 1: The mix ratios of cement board from vesicular basalt fragment by weight

Ratios	Cement	Fine sand	Vesicular basalt fragment	Sodium silicate	Tap water	Steel mesh	
						Wire diameter	Opening
NON	1	2	4	0.03	0.55	0.5 mm	-
ST-3/8”	1	2	4	0.03	0.55	0.5 mm	3/8”
ST-1/2"	1	2	4	0.03	0.55	0.5 mm	1/2"
ST-5/8”	1	2	4	0.03	0.55	0.5 mm	5/8”
ST-3/4”	1	2	4	0.03	0.55	0.5 mm	3/4”
ST-1”	1	2	4	0.03	0.550	0.5 mm	1”

2.3 Sample preparation

The steps of sample preparation include 1) Grind the vesicular basalt fragment by using the stone grinder and sieve no. 4, 2) Classify the size of vesicular basalt fragment for forming which the size must pass sieve no.4 and retain sieve no.10 (about 80% of amount of all grinded vesicular basalt fragment), 3) Mix the Portland cement type1, fine sand, vesicular basalt fragment, sodium silicate, and tap water by using the ratio in Table1, 4) Clean the mold and put the lubricant on the mold, 5) Pour the mixture into the mold (divide the lower and upper part of mixture by installing the steel wire mesh at the half of thickness) (see Fig. 3), 6) compress the sample by the compression and sharking machine, 7) Cure the sample in the air.

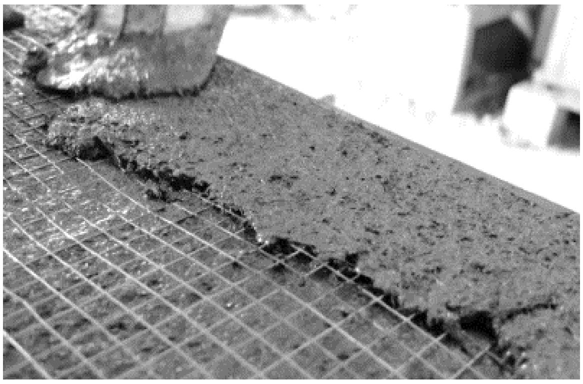

Fig. 3: Pouring the mixture to cover the steel wire mesh

2.4 Properties testing

Testing the physical and mechanical properties of samples in accordance with TIS 878-2537 (cement bonded particleboards: high density) (TISI, 1994) including: general characteristics, moisture, density, thermal conductivity, swelling when immersed in water, bending strength and elastic modulus (see Fig. 4), and tensile strength perpendicular to the surface (see Fig. 5).

Fig. 4: Bending strength test of cement board


Fig. 5: Tensile strength perpendicular to the surface test of cement board

3. Results

3.1 General characteristic

According to the observing and measuring of general characteristics of cement board from vesicular basalt fragment, it found that all cement boards can pass the TIS 878-2537 standard (TISI, 1994). The edge and surface of all cement boards were smooth and angle.

3.2 Density

From the Fig. 6, it stated that the steel wire mesh effected to increase the density of cement boards. The highest density of cement board was the ST-3/8” (largest opening of wire mesh) which was equal to 1,838.67 kg/m^3. And the lowest density of cement board was the NON (no wire mesh) which was equal to 1,820.55 kg/m^3. These decreasing of density were effect from the volume and density of steel wire mesh (7,750 - 8,050 kg/m^3) (Young, 19921). When comparing the density results of cement board to the TIS 878-2537 standard, it was found that all ratios of cement board had the density higher than the standard (the standard is in ranges of 1,100 to 1,300 kg/m^3) (TISI, 1994). The high density of developed cement boards also were effect from the production method which cannot put more low density materials to reduce the density. However, the developed cement board can be still used in general construction. In case of 2 Brands of the cement broads in the Thai market, the Brand A and B also had the density (1,476.35 and 1,345.13 respectively) higher than the standard but lower than the developed cement broads.

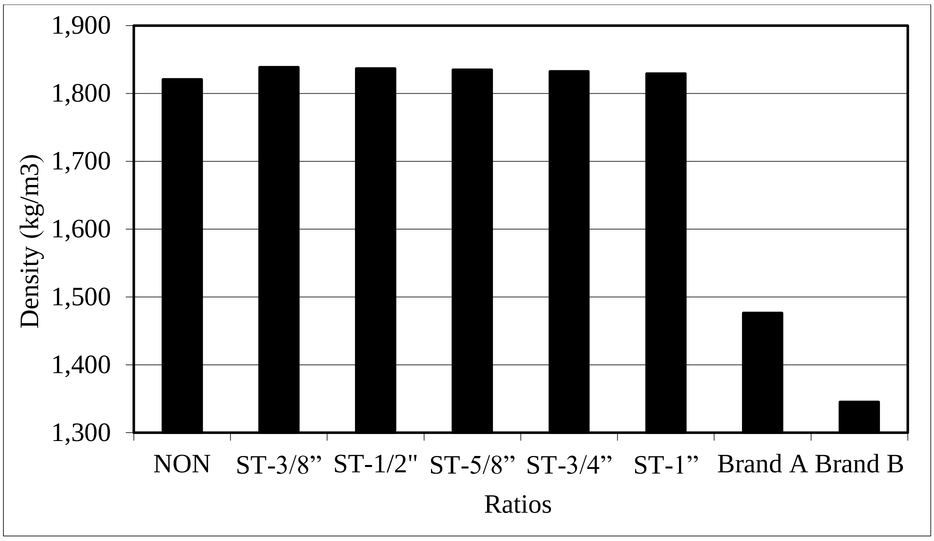

Fig. 6: Density of cement board at 28 days of curing period

3.3 Moisture

Fig. 7 shows the moisture values of all cement boards from vesicular basalt fragment and cement broads from the Thai market. The moisture of cement boards from vesicular basalt fragment were in range of 11.38% to 11.52% which all ratios can pass the TIS 878-2537 standard (must be less than 15 %) (TISI, 1994). For the moisture values of Brand A and B, they were 13.02% and 12.54%, respectively which can pass the standard too. These low moisture of cement boards from vesicular basalt fragment were effected from the low moisture of vesicular basalt fragment, especially when compare to the wood chip in common cement board (Department of Industry Promotion, 1996; Tonnayopas, 2010).

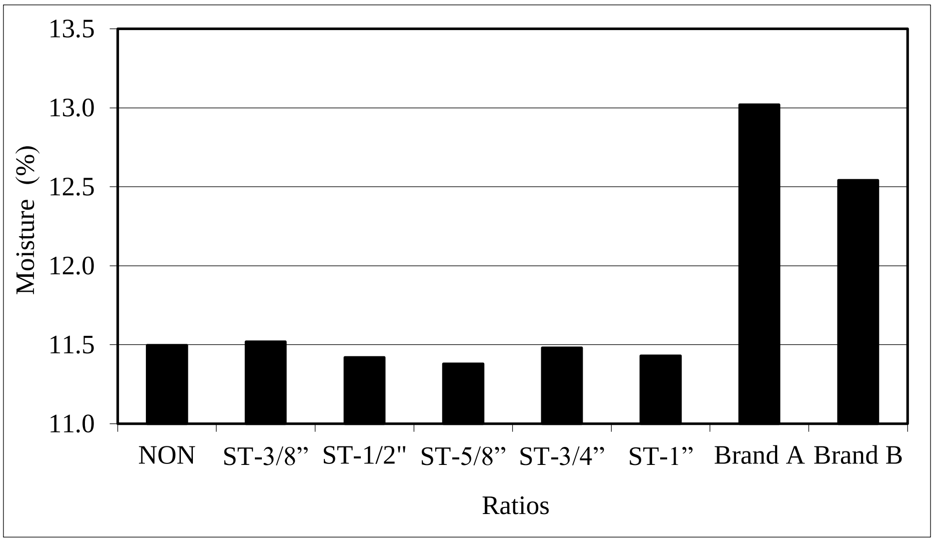

Fig. 7: Moisture of cement board at 28 days of curing period

3.4 Thermal conductivity

According to Fig. 8, it found that the vesicular basalt fragment cement boards reinforced with steel wire mesh had a high thermal conductivity than the vesicular basalt fragment cement boards without steel wire mesh or the cement broads in the Thai market. The TIS 878-2537 standard define the range of thermal conductivity of cement board must not be higher than 0.25 w/m.K (TISI, 1994) that the ST-5/8”, ST-3/4”, ST-1”, NON, Brand A, and Brand A of cement boards can pass this standard. These results depended on the thermal conductivity of steel wire mesh which is very high (29.4 W/m.K or 17 BTU/(hr·ft·°F)) (Holman, 1997). Thermal conductivity is a feature that can indicate the performance of materials to protect the heat transfer. If the cement board has a low thermal conductivity, it will be a good thermal insulation material (Suweero and Khamput, 2018).

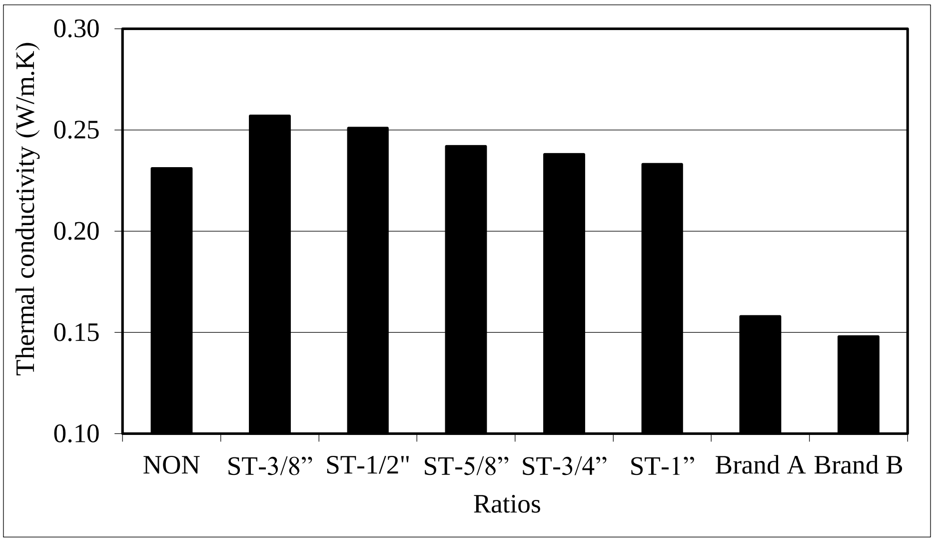

Fig. 8: Thermal conductivity of cement board at 28 days of curing period

3.5 Swelling when immersed in water

The results of swelling test in Fig. 9 indicate that the swelling of all cement boards from vesicular basalt fragment were very low when compared to the cement broads from the Thai market. These swelling values of all cement boards from vesicular basalt fragment were in range of the standard TIS 878-2537 (must be less than 2 %) (TISI, 1994). The low swelling properties of cement boards from vesicular basalt fragment are very importance because the cement board always installed outside the building which the humidity are very high (Suweero and Khamput, 2018).

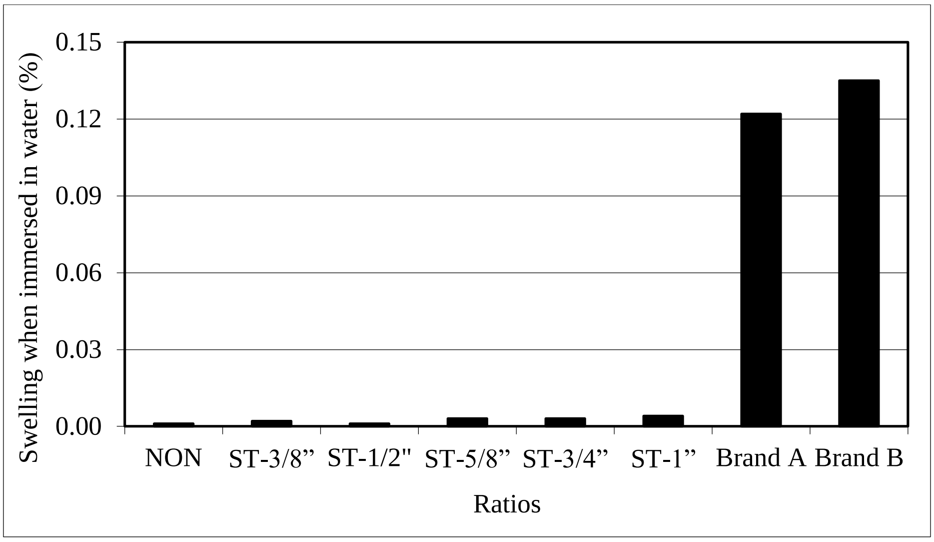

Fig. 9: Swelling when immersed in water of cement board at 28 days of curing period

3.6 Bending strength

According to the bending strength results in Fig. 10, the proper opening size of steel wire mesh was the ST-3/8 because this ratio had the bending strength higher than the other cement broads reinforced with steel wire mesh, especially higher than the cement broads without steel wire mesh. Due to the high strength of steel wire mesh, the cement broad reinforced with the higher area to section ratio of steel wire mesh that will has the bending strength more than the cement broad reinforced with lower area to section ratio of steel wire mesh (Suweero and Khamput, 2018). From the TIS 878-2537 standard, the requirement value of bending strength must not be less than 9 MPa (TISI, 1994). The ST-3/8”, ST-1/2", ST-5/8”, and ST-3/4” ratios can pass the standard. Moreover, the reinforced steel wire mesh can reduce the cracking damage of cement broads, especially when it fractures suddenly (see Fig.11) (Suweero and Khamput, 2018). In case of the cement broads in the Thai market. It found that Brand A can pass the standard only.

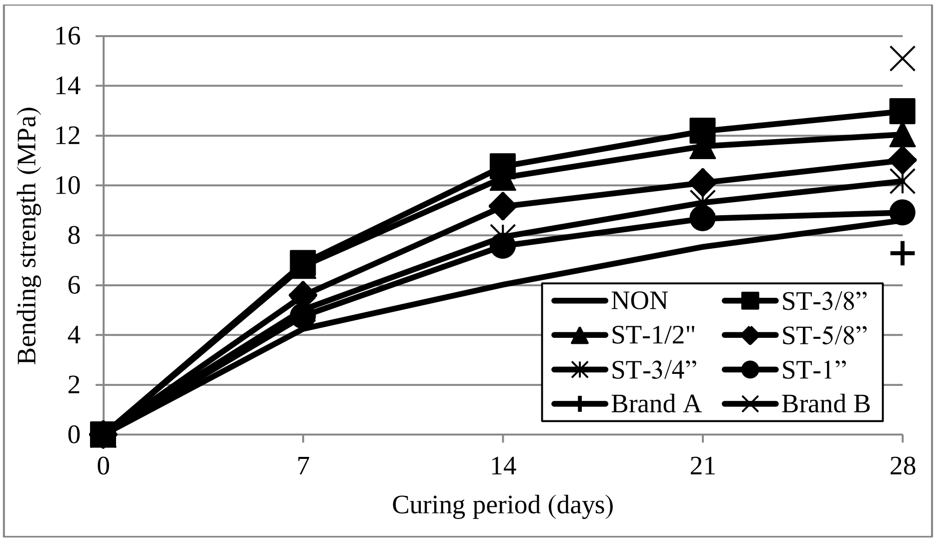

Fig. 10: Bending strength of cement board

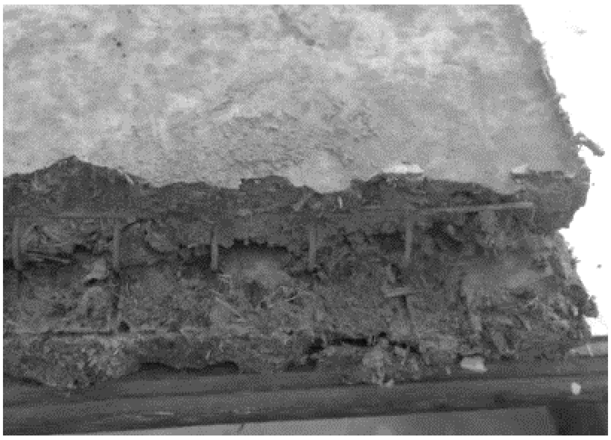
Fig. 11: Bending crack of cement board

3.7 Elastic modulus

When comparing the elastic modulus results of cement broads in Fig.12 and the TIS 878-2537 standard (must be over than 3,000 MPa) (TISI, 1994), it found that the all developed vesicular basalt fragment cement broads and the cement broads in the Thai market passed the TIS 878-2537 standard.

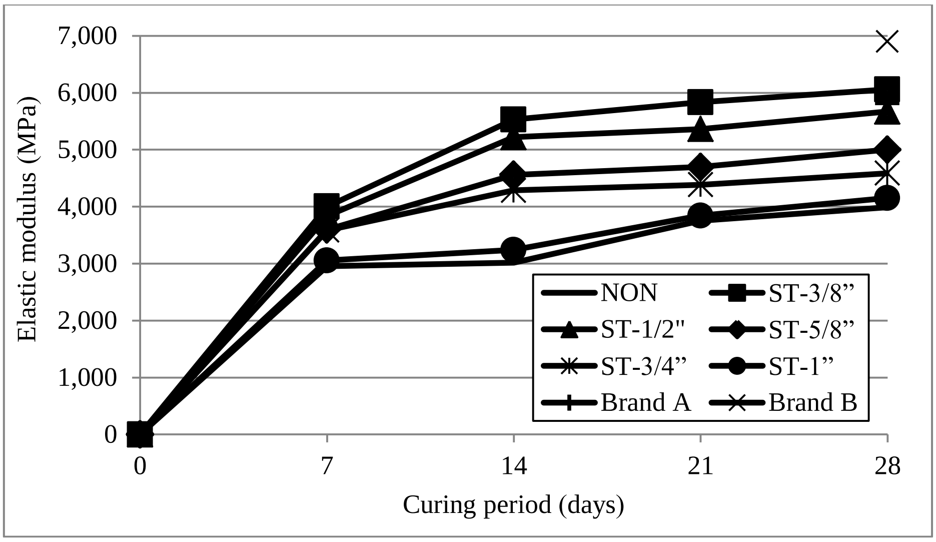

Fig. 12: Elastic modulus of cement board

3.8 Tensile strength perpendicular to the surface

According to the TIS 878-2537 standard, the cement board must have a tensile strength perpendicular to the surface more than 0.5 MPa (TISI, 1994). Fig. 13 showed the results of tensile strength perpendicular to the surface of cement board from vesicular basalt fragment and the Thai market were lower than the standard. The low tensile strength of developed cement broads was effected from the area of steel wire mesh which instead of area of cement binder. However, when installing the developed cement broads by using screw diameter 7 mm in real building, it found that the all developed cement broads have no cracking and can use as the cement board wall (see Fig.14 - 15).

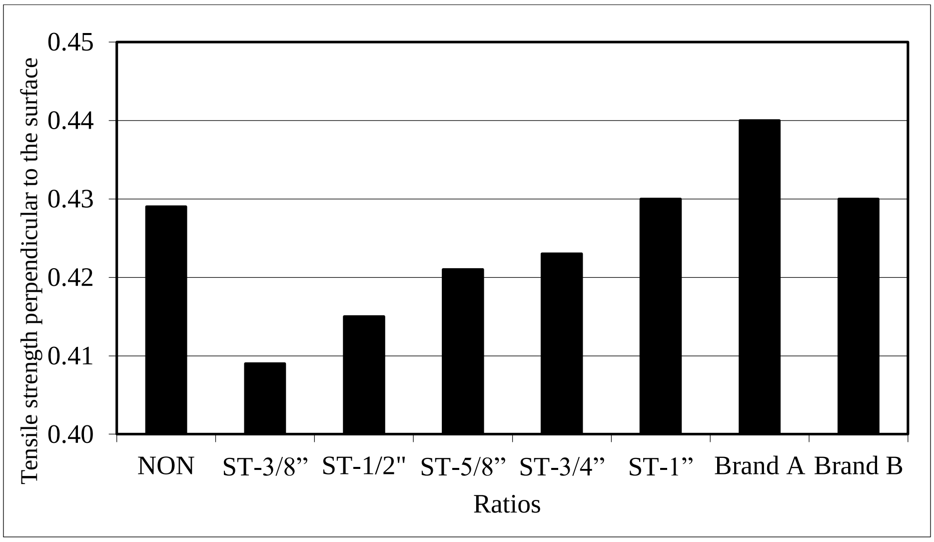

Fig. 13: Tensile strength perpendicular to the surface of cement board at 28 days of curing period

Fig. 13: Installing the developed cement broads by using screw diameter 7 mm

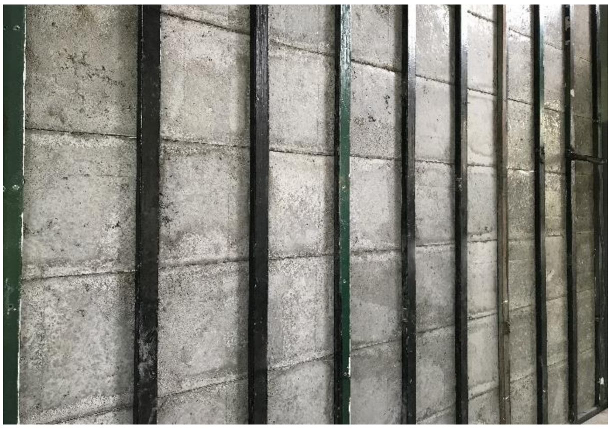

Fig. 13: The wall from the developed cement broads

4. Conclusion

From the results, it can be summarized as following: the vesicular basalt fragment can use as the aggregate in cement board product. The ST-3/4” ratio was the most suitable ratio of developed vesicular basalt fragment cement board reinforced with steel wire mesh. This product can apply the vesicular basalt fragment to use as the cement broads with light-weight, high strength, good thermal insulation, and moisture protection properties. In the next research, it should reduce the weight of cement board from vesicular basalt fragment by using a lightweight aggregate or increasing the gap inside the cement board.

5. Acknowledgement

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