Shear and Pull-Out Strength of Steel Anchors installed in Autoclaved Aerated Concrete

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Abstract : In a framework to develop a prefabricated thermal insulation wall system assembled by Autoclaved Aerated Concrete (AAC) wall with thermal insulation and architectural cladding, this paper reported the feasibility of the wall system by investigating shear and pull-out strength of steel anchor installed in AAC. The wall system is designed to withstand wind load 100 kg/m^2 horizontally. In addition to resisting the designed wind load by its pull-out strength, the 400 x 400 mm steel anchor array is also designed to resist hanging weight of thermal insulation and weight of architectural cladding by its shear strength. Three samples of each steel thread diameters 8, 10, 12 and 16 mm installed in AAC by using Polyester adhesive were tested for their short-term shear and pull-out strength. From the shear tests of anchor in AAC, average maximum forces from steel anchor diameters 8, 10, 12 and 16 mm were 247.4, 237.6, 250.2 and 254.5 kg consecutively. From the pull-out tests of anchor in AAC, average maximum forces from steel anchor diameters 8, 10, 12 and 16 mm were 116.5, 189.8, 210.2 and 249.6 kg consecutively. With their statistical Standard Deviations, 5% quantile values were derived as their characteristic strengths. Afterwards the design strength was proposed by dividing the characteristic strength by suggested material factor of safety 3.5. Eventually the design shear strengths were 30, 54, 31 and 44 kg and the design pull-out strengths were N/A, 7, 36 and 33 kg for steel anchor diameter 8, 10, 12 and 16 consecutively per one anchor. The results showed that steel anchor diameter 12 mm was capable to withstand the required loads and was the most economically suitable as an anchor for distance arrangement at 400 x 400 mm.

Key words: Shear Strength, Pull-Out Strength, Autoclaved Aerated Concrete, Prefabricated Wall.

Introduction

World energy consumption has rapidly raised (Wolfram, 2012). In developed countries, energy consumption in residential and industrial buildings has steadily increased reaching figures between 20 and 40 % and has exceeded the other major sectors : industrial and transportation (Perez-Lombard, 2008). In Thailand, energy consumption in commercial and residential sectors reached 22% in 2012 (Department of Energy, 2013). Heating, ventilation and air conditioning used particularly significant energy in buildings (Perez-Lombard, 2008). In Thailand, the national energy reservation plan set one of its targets to reduce the Overall Thermal Transfer Value (OTTV) of buildings envelop from 60 W/m^2 in 2012 to 20 W/m^2 in 2033, which requires a series of researches and development (Chirarattananon, 2012). A traditional wall system comprises a wall with thermal insulation and cladding (Fig. 1) which normally requires Aluminium frames. Within a research framework to replace expensive non-corrosive metal frame by stainless steel anchor (Fig 2), this paper reports the feasibility study of the innovative wall system by investigating short-term shear strength and pull-out strength of steel anchor embedded in Autoclaved Aerated Concrete (AAC). Figure 3 illustrates the idea how the wall system assembled in a factory to improve precision and productivity. Firstly a concrete wall will be casted in place. Afterwards the facade with thermal insulation and array anchor will be placed upon fresh concrete. Figure 4 demonstrates the assembly process in a workshop. This wall system has been designed to resist design wind load 100 kg/m^2. It can generally be installed on the 20 m high buildings in Thailand. With anchor arrangement 400 x 400 mm, each anchor has to resist design wind load 25 kg horizontally and design hanging weight of thermal insulation and facade 12 kg vertically.

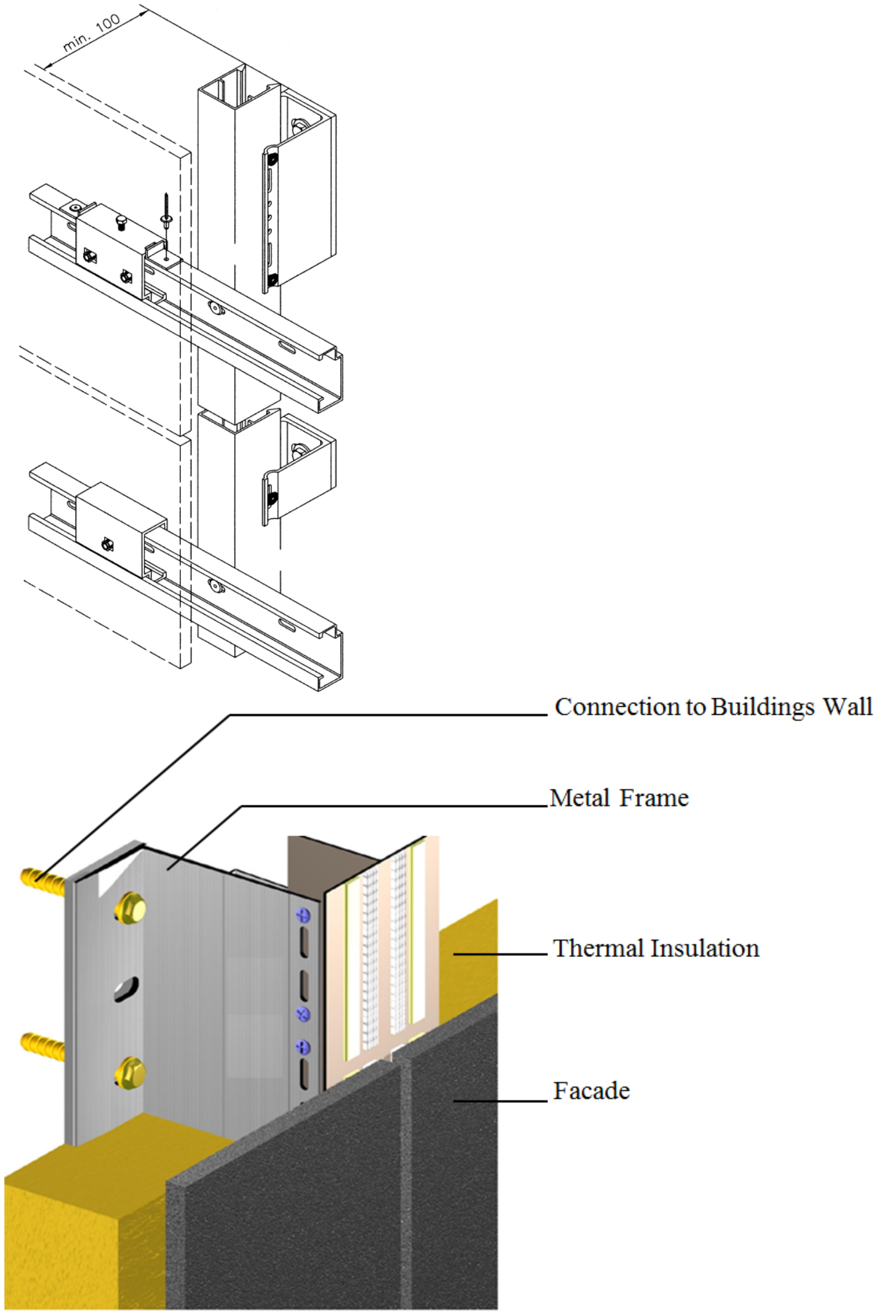

Figure 1: Facade and thermal insulation on wall using metal frames (www.rieder.cc, 2010)

Figure 2 illustrated the concept of the proposed wall system which comprised AAC wall, thermal insulation facade panel and array anchor. Facade would protect the thermal insulation from the environment.

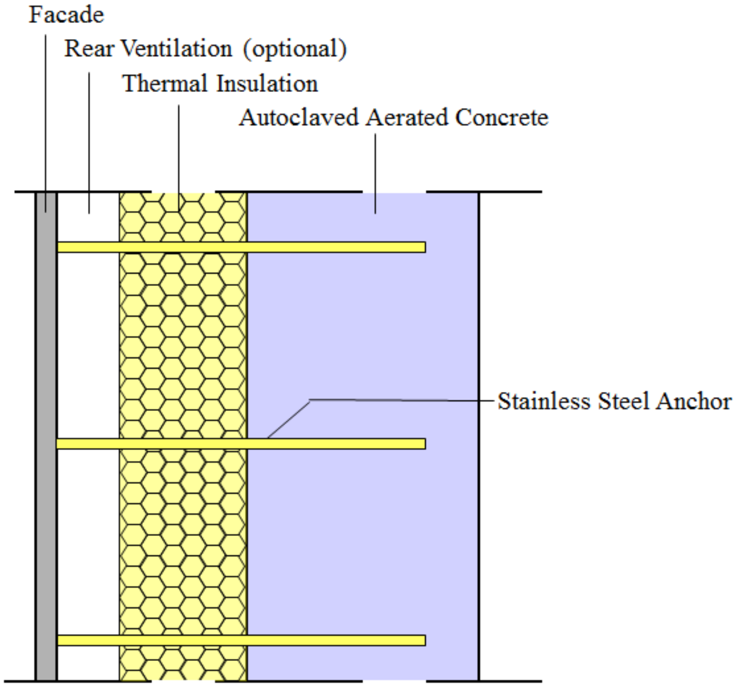

Figure 2: Innovative wall system with stainless steel anchor array

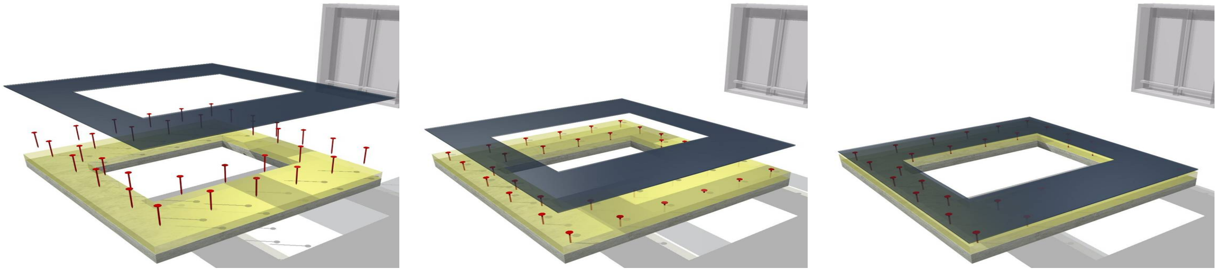

Figure 3: Assembly idea of the wall system

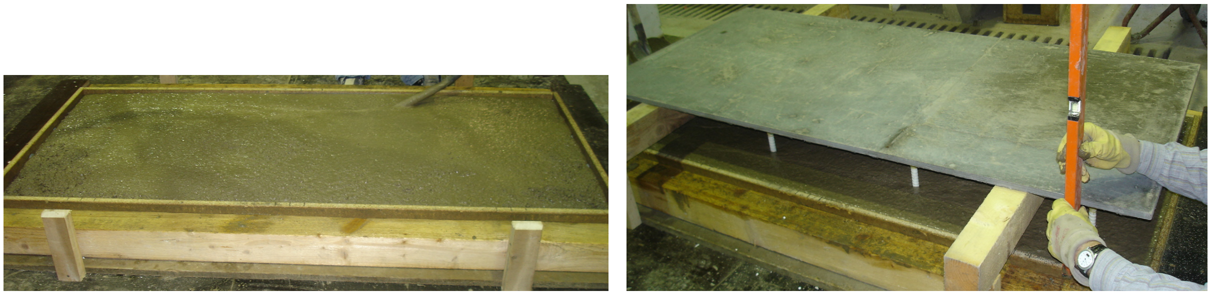

Figure 4: Facade with anchor array placed into fresh normal concrete without thermal insulation

Materials and Method

Three samples of each steel thread diameters 8, 10, 12 and 16 mm as anchors embedded 60 mm by using Polyester adhesive at the center of 200 x 200 x 70 mm Autoclaved Aerated Concrete were tested for their shear resisting capacity and pull-out resisting capacity (Fig. 5). Short-term tests were undertaken with pulling velocity 1 mm/min. AAC has compressive strength of 5 N/mm^2, thermal conductivity of 0.089 W/m.K, water absorption of 25% and density of 655 kg/m^3. Steel has yield stress of 240 N/mm^2 and Young's modulus of 200,000 N/mm^2. Polyester adhesive has compressive strength of 50 N/mm^2 and tensile strength of 15 N/mm^2. In shear test, tensile force is 4 mm eccentric from the surface of AAC.

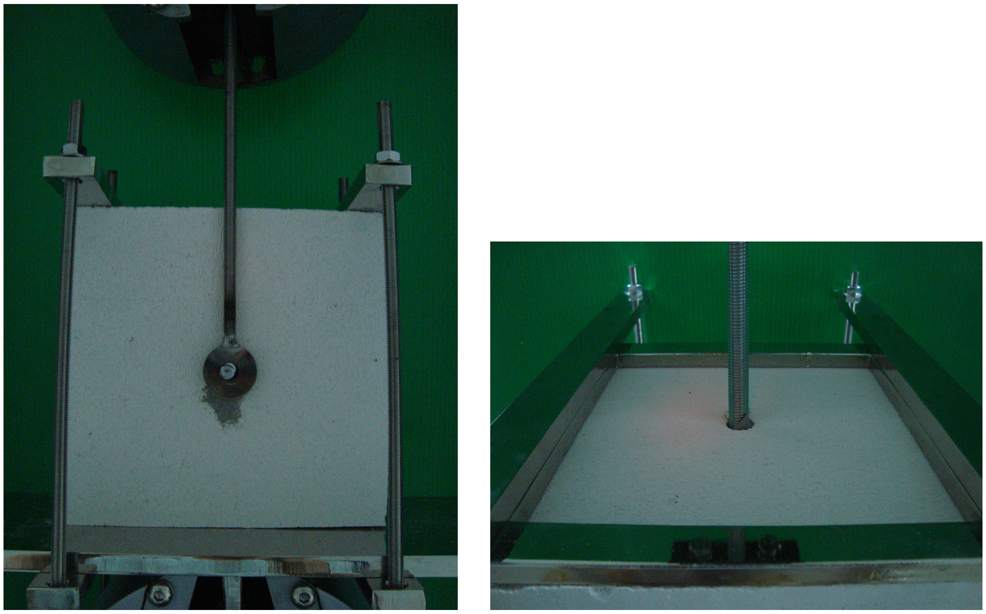

Figure 5: Shear and pull-out test configuration

Results

The result of short-term shear test and pull-out test were showed in table 1 and table 2. From average values and standard deviations, 5% quantile values were derived with confidence interval 0.90. For anchor shear test, the thread diameter 8, 10, 12 and 16 mm yielded average shear force 247, 237.6, 250.2 and 254.4 kg consecutively.

Table 1: Shear resisting force of 8, 10, 12 and 16 mm thread 60 mm embedded in 70 mm thick AAC

Thread Diameter	max Shear Force				Standard Deviation	5% Quantile	Factor of Safety	Design Value
	Sample 1	Sample 2	Sample 3	Average				
(mm)	(kg)	(kg)	(kg)	(kg)		(kg)		(kg)
8	247.1	274.6	220.6	247.4	27.00	104.0	3.5	30
10	226.7	242.3	243.7	237.6	9.44	187.4	3.5	54
12	234.5	235.2	281.0	250.2	26.65	108.7	3.5	31
16	253.2	236.5	273.9	254.5	18.74	155.0	3.5	44

For anchor pull-out test, the thread diameter 8, 10, 12 and 16 mm yielded average pull-out force 116.5, 189.8, 210.2 and 249.6 kg consecutively. Examples of specimens after experiments were shown in Fig. 6.

Table 2: Pull-out resisting force of 8, 10, 12 and 16 mm thread 60 mm embedded in 70 mm thick AAC

Thread Diameter	max Pull-Out Force				Standard Deviation	5% Quantile	Factor of Safety	Design Value
	Sample 1	Sample 2	Sample 3	Average				
(mm)	(kg)	(kg)	(kg)	(kg)		(kg)		(kg)
8	91.4	117.6	117.6	116.5	24.52	N/A	3.5	N/A
10	177.1	166.9	166.9	189.8	31.20	24.1	3.5	7
12	223.6	192.7	192.7	210.2	15.87	126.0	3.5	36
16	277.0	226.7	226.7	249.6	24.46	114.4	3.5	33

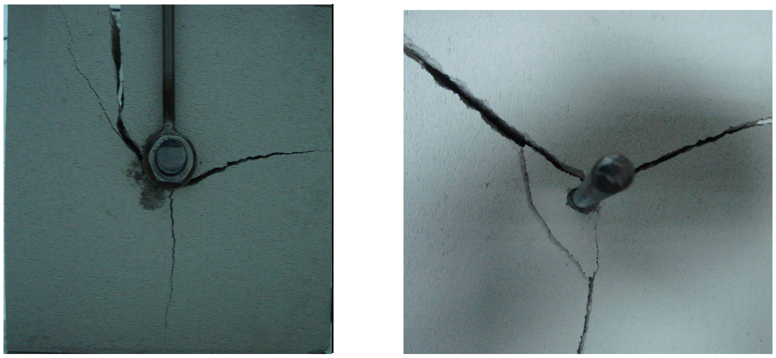

Figure 6: Examples of specimens after shear (left) and pull-out (right) experiments

Discussion

For shear test, the larger diameter did not result in higher shear bearing capacity. Steel anchors were much stronger than AAC resulting in 100% failure in AAC. By using reduction factor of material safety 3.5 (Jutakanon & Sathitisangworn, 2007), design values of material shear bearing capacity were 30, 54, 31 and 44 kg for steel thread 8, 10, 12 and 16 mm consecutively. In comparison with design shear load 12 kg per anchor, shear design resistance of anchor 12 mm was higher than design shear load.

For pull-out test, the larger diameter yielded higher pull-out force. By using reduction factor of material safety 3.5 (Jutakanon & Sathitisangworn, 2007), design values of material pull-out capacity were N/A, 7, 36 and 33 kg for steel thread 8, 10, 12 and 16 mm consecutively. In comparison with the design wind load 25 kg per anchor, pull-out design resistance of anchor 12 mm was higher than design pull-out load.

Because of exposure to environment, stainless steel could possibly be used as an anchor. To realize the complete wall system, a series of tests has to be additionally performed for example an interaction of shear and pull-out force at the same time, simulation of dynamic of wind pressure acting on the system, strengthening of AAC wall, full scale test, etc.

Conclusions

This paper reported two aspects of the feasibility study to substitute Aluminium frame in a wall system with steel anchor by investigating short-term shear and pull-out strength of steel anchor embedded in Autoclaved Aerated Concrete. The innovative wall system with steel anchor and thermal insulation has been designed to resist wind pressure 100 kg/m^2 with anchor arrangement 400 x 400 mm. The wall made from Autoclaved Aerated Concrete. Anchors were installed 60 mm depth in AAC by using Polyester adhesive. One anchor has to resist design wind pressure 25 kg horizontally and design shear load from facade 12 kg vertically. The result showed that the anchor 8, 10, 12 and 16 mm yielded shear and pull-out design value 30, 54, 31, 44 and N/A, 7, 36, 33 kg consecutively. A larger diameter of anchor exhibited higher anchor pull-out strength. From the design value, it would be economically possible to use anchor 12 mm with Polyester adhesive in the wall system.

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