Advanced Materials Research Vols. 671-674 (2013) pp 1941-1944
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doi:10.4028/www.scientific.net/AMR.671-674.1941

Using GFRP to develop the mechanical performance of structural insulated panels

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Keywords: structural insulated panels (SIP), glass fiber reinforced polymer (GFRP), compressive test, flexural test, mechanical performance

Abstract. As an energy efficient means of construction, structural insulated panels (SIP) are now widely used in the world. In this paper, Glass Fiber Reinforced Polymer (GFRP) sheets were used as strengthening materials in the SIPs to develop the mechanical performance of it. Eighteen specimens were constructed. Six of them were normal SIPs used as control specimens while twelve specimens were SIPs with different GFRP sheets pasted between face boards and foam cores. Compressive and flexural test programs were conducted to provide a basic understanding of the mechanical performance of this new kind of SIP panel system. The results showed that, the new kind of SIP materials behaved better load bearing capacity and better ductility.

Introduction

The idea of using structural insulated panels (SIPs) for construction began in U.S. in the 1930s. Now it is widely used as an energy efficient means of constructing residential and light commercial buildings in the world SIPs are a composite building material consisting of a sandwich of two layers of structural board with an insulating layer of foam in between. The face layers of the panel are usually fiber-cement board, plywood or Oriented Strand Board (OSB). The materials used as core substrate are synthetic, rigid foam, such as extruded and expanded polystyrene (XPS and EPS) or polyurethane (PUR). The interface between the foam core and the face layers consists of a layer of adhesive to mainly prevent relative movements [1,2]. SIPs carry loads in a fashion similar to I-beam shapes: the face board is analogous to the flanges of the beam, carrying a majority of the moment, while the foam core behaves like the shear-carrying web [3,4]. SIPs can be used in floors, walls, and roofs for residential and light commercial buildings, as referred in Fig.1.

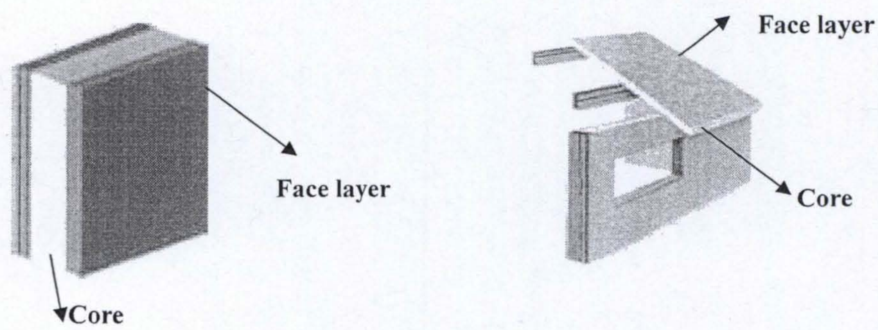

Fig.1 Structural insulated panels

GFRP (glass fiber reinforced polymer) is a composite material made of a polymer matrix reinforced with glass fiber. Their light weight, thin thickness, high strength-to-weight ratio, ease of handling and application, lack of requirement for heavy lifting and handling equipment and corrosion resistance are some factors that are advantageous in repair and retrofitting of structural members, such as beam, column and piles.

In this paper, GFRP sheets were used as strengthening materials in the sandwich panels to develop the mechanical performance of SIPs. Test programs were conducted to provide a basic understanding of this new kind of SIP panel system.

Experimental program

Materials of SIP specimens. The facer materials for SIPs in this test were fiber cement panels, each having a minimum nominal thickness of 10mm, manufactured according to the standard specifications of Thailand, TIS 1427-2547. The properties of the fiber cement panels were given in Table 1.

Table1 Mechanical properties of fiber cement sheets [5].

Thickness [mm]	Density [kg/m^3]	Compressive strength [N/mm^2]	Tensile strength [N/mm^2]		Flexural strength [N/mm^2]	Modulus of Elastic [N/mm^2]
			Along	Across		
10	1,350	12	N/A	1.39	17	7,000

The core material for SIPs in this test was EPS foam, with a minimum thickness of 75mm [6]. The properties of the EPS foam were given in Table 2. Adhesives used to structurally laminate the core to facers were Polyurethane adhesive Type II, Class 2, conforming to ASTM D2559, with shear strength of 15.40 MPa and non-uniform tear strength of 14 kN/m [8].

Table2 Mechanical properties of EPS foam [7].

Density [kg/m^3]	Compressive strength [N/mm^2]	Tensile strength [N/mm^2]	Flexural strength [N/mm^2]	Shear strength [N/mm^2]
24	0.165	0.351	0.296	0.365

In order to find the effect of GFRP strengthening on mechanical performance of SIP panels, in this test program, two type of GFRP sheets was used to pasted on the both side face of the EPS foam core, which were KNA 206 and KNA 310, product of ASKN Company in Thailand. The properties of the GFRP sheets were given in Table 3.

Table 3 Mechanical properties of GFRP sheets [9].

Type code		KNA 206	KNA 310
Yarn count [/m]	Warp	236	413
	Fill	236	413
Minimum Tensile load [kg /cm]	Warp	26	30
	Fill	26	30
Minimum Bursting strength [kg/cm^2]		14	25
Thickness [mm]		0.37	0.22
Weight [g/m^2]		145	115

Construction of specimens. Totally eighteen specimens were tested to study the mechanical performance of the new type SIP panels. The eighteen specimens were divided into two groups, used for compressive test and flexural test, respectively. Each group consisted of nine specimens fabricated from three types of SIP materials, SIP-N, SIP-206 and SIP-310, each type three specimens. SIP-N was normal SIP panel used as reference specimen. SIP-206 and SIP-310 were new type SIP materials proposed in this paper, using different GFRP sheets, KNA 206 and KNA310, respectively, pasted on both side of core foam before fiber cement panel face layer were attached on both side of the core, as shown in Fig.2. Specimens for compressive test were fabricated in cube of size 0.15m×0.15m×0.1m. Specimens for flexural test were fabricated in beam of size 0.15m×0.10m×0.7m and tested according to ASTM E72 [10].

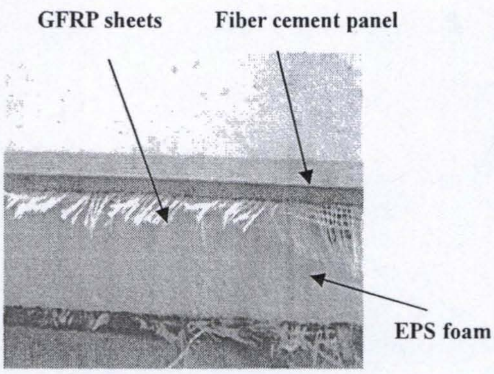

Fig.2 SIP-206, SIP-310 panels

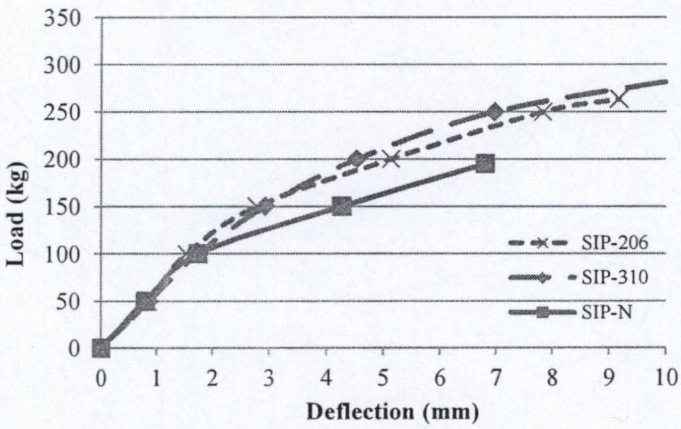

Fig.3 Load-deflection curves

Results and Discussion

Compressive test. The compressive strength of specimen SIP-N, SIP-2-6 and SIP-310 were 33.71kg/cm^2, 38.45 kg/cm^2 and 41.8 kg/cm^2, respectively. The typical failure mode was the cracking of interface between core and facers.

Flexural test. The flexural strength of specimen SIP-N, SIP-206 and SIP-310 were 11.7 kg/cm^2, 15.8 kg/cm^2 and 17.2 kg/cm^2, respectively. Shear cracks were observed in the foam in specimen SIP-N, which indicated that the failure mode was shear failure. In specimen SIP-206 and SIP-310, there are also shear cracks appear in the foam while some flexural cracks were observed in the face board in the middle span. It can be concluded that GFRP sheets inside of SIP effectively helped to resist tensile stresses in the face layer and shear stresses in the core.

The relationship of flexural loads and deflections at mid-span of tested beams were plotted in Fig.5. All the specimens showed plastic properties after beginning elastic stage. Compared to SIP-N panel, SIP-206 and SIP-310 behaved better ductility with a fairly large range of non-linear behavior. The deflection at failure for SIP-206 was 6.8mm. The deflection at failure for SIP-206 and SIP-310 was 9.17 mm and 10.47 mm, respectively. It could be seen that the GFRP sheets strengthened inside significantly affect the ductility and deflection of the SIP panels. The higher the tensile strength of GFRP was, the more significant the effect. At the same loading level, the deflection of SIP-206 and SIP-310 were less than that of SIP-N, which indicated that the stiffness of new GFRP SIPs is also increased.

Summary and conclusions

In this paper, a new kind of SIP system was proposed in order to develop the mechanical properties of SIPs. GFRP sheets of different tensile strength were pasted between face and core layer of original SIPs. This GFRP SIP system offers numerous advantages over the original types of SIPs. The advantages include the light weight, thin thickness, lower cost, fire resistance and ease of manufacturing. Experimental programs were performed to study the compressive and flexural behavior of this new SIP system. The results of the study indicated that the GFRP SIP system has higher load carrying capacity. GFRP SIPs behave better ductility and larger deflections at failure. The stiffness of GFRP SIPs is also increased. Further study should be focus on the performance of walls, roofs and the durability of this new kind of SIP system.

Acknowledgements

The authors would like to give great acknowledgement to Energy policy and planning office, Ministry of Energy, Thailand.

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