AN ANALYTIC STUDY ON STRENGTH CAPACITY OF STEEL CONNECTORS APPLICABLE TO INSULATED SANDWICH WALL PANELS

[1]DONG-HYEON SHIN, [2]HYUN-SOO JUNG, [3]CHAN-WOONG MOON, [4]HYUNG-JOON KIM

[1,2,3,4]Department of Architectural Engineering, University of Seoul, Korea
Email: [1]donghyeon_shin@uos.ac.kr, [4]hyungjoonkim@uos.ac.kr

Abstract - Recently building consuming energy efficiency has become a major concern to achieve environmental friendly buildings. Insulated sandwich wall panels havegained popularity because they provide thermal saving due to the presence ofa high-performance insulation layersandwiched between structural panels. As preliminary investigation forthe development ofnew high thermal-efficient ISWPs, this study carries out finite element analyses of various types of existing steel connectors that connect structural panels through an insulation layer. Based on the analytic results, strength capacities of steel connectors are summarized for the design of ISWPs.

Index terms - Insulated sandwich wall panels, Steel connectors, Strength capacity, Finite element analyses

I. INTRODUCTION

Recently, building consuming energy efficiency has become a major concern to achieve passive environmental friendly buildings [1-3]. Insulated sandwich wall panels (ISWPs) haveincreasingly gained popularity for building construction practices. ISWPs used as one of cladding systems provide thermalsaving due to the presence of a high-performance insulation layer sandwiched between the structural panels made of reinforced cement blocks. Since the insulation layer has poor strength capacity, ISWPs needs be designed to integrate two structural panels with steel connectors to resist towindloads applied to a building façade. Forpreliminary investigation for the development of a new high thermal-efficient ISWP which consistsof lightweight foamed concrete (LFC) material for structural panels and a sandwiched insulation layer, this study carries out finite element analyses of various types of existing steel connectors which are used for connecting structural panels through an insulation layer. Based on the analytic results, the strength capacities of various types of existing steel connectors are summarized for the design of the ISWPs.

II. INSULATED SANDWICH WALL PANEL

ISWPs are used for the construction of building envelopes. As illustrated in Fig. 1, they consist of two outer structural panels separated by an insulation layer. ISWPs should resist to transversewind pressure with insulating structures [4].This study uses ISWPs with a length of3,000 mm and a width of 600 mm.In order to satisfy a thermal transmittance criterion prescribed in to Korea energy saving design code [5], thicknesses of elements of the ISWPs are determined as summarized in Table 1 and the overall thickness of an ISWP is finally determined to 360 mm. The calculated thermal transmittance is 0.193 W/m^{2}K whichisless than the criterion of 0.210 W/m^{2}K prescribed in the code.

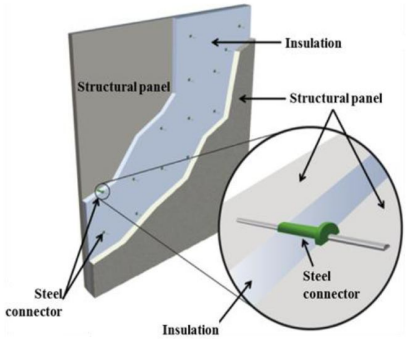


Figure 1: Typical geometry of an insulated sandwich wall panel (after Bai and Davidson, 2015)

Steel connectors are used to provide structural integrities between the outer panels throughout the composite against flexural demands [6]. Table 2 shows the configurations of several types of steel connectors considered for this study [6, 7]. The dimensions of the steel connectors are scaled to meet the size of ISWPs.

Components	THK., mm	Thermal Conductivity, W/mK
Outer Structural panel	100	0.100
Adhesive	5	0.353
Inner insulation	150	0.050
Adhesive	5	0.353
Outer Structural panel	100	0.100
Thermal transmittance, W/m^{2}K	0.193	

Table. 1 Thickness and Thermal conductivities ofelements of an ISWP

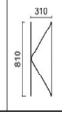
Type	Pin	Clip	Grid	Truss
Shape				
Height, mm	310			
Width, mm	65	213	425	810
Thickness, mm	19	13	2	6
Material	Structural steel (SS400), Stainless steel (S304L)			

Table. 2 Dimensions of steel connectors for ISWPs

III. FINITE ELEMENT ANALYSES OF STEEL CONNECTORS

The steel connectors embedded into ISWPs should have proper strength capacity to limit relative slipsbetween the outer panels.The strength capacities of the steel connectors selected for this study are analytically evaluated.

3.1. Description of FEA

Acommercial software, ABAQUS 6.10 [8] is used to conduct a finite element analysis (FEA). The analytic modelsemphasize the region of steel connectors to optimize computation time with reasonable resolution of results. The steel connectors are modelled using C3D8R solid elements which are capable to capturing theelasto-plastic behavior. Material properties for definingstress-strain relations are summarized in Table 3.

Property	Structural steel	Stainless steel
Yield strength, MPa	235	241
Elastic modulus, GPa	205	190
Poisson's ratio	0.300	0.265

Table. 3 Material properties of steel connectors

The model is also established to capture strain hardening after yield strength (F_y) and strength and stiffness degradation after nominal tensile strength (F_u).The embedded lengths of the steel connectors are assumed to be 80mm. Shear deformations are imposed toISWPs.

3.2. Results of FEA

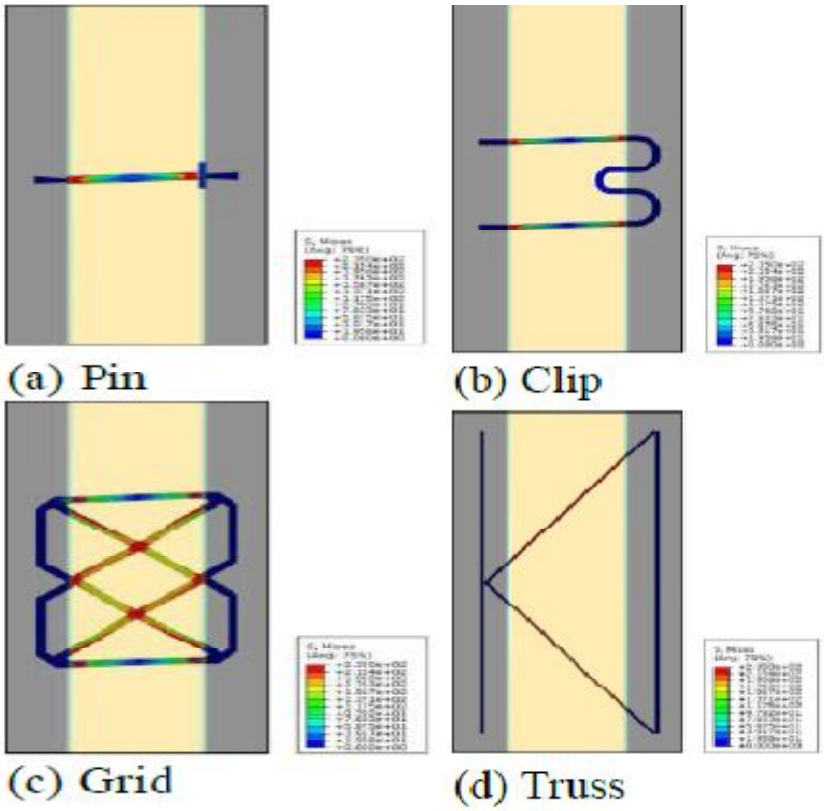
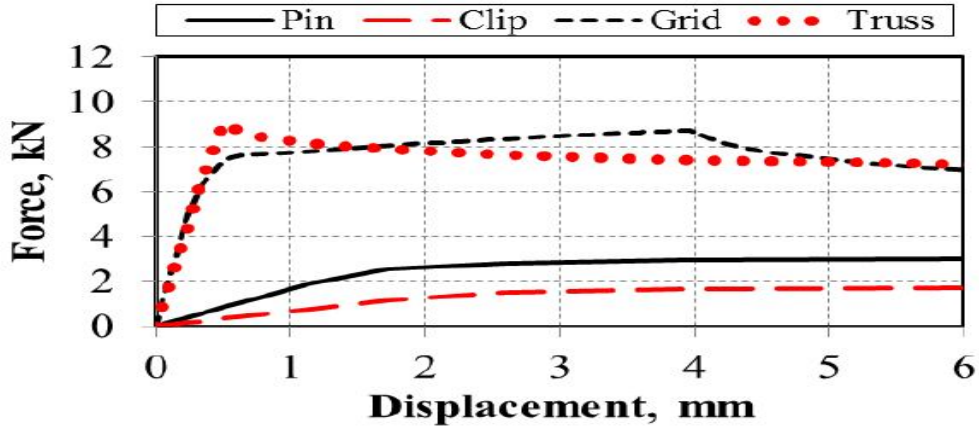
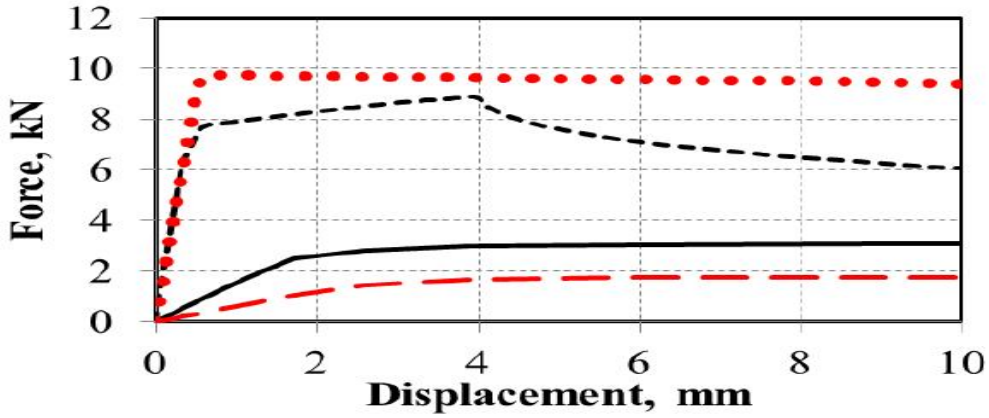


Figure 2: Deformed shapes and stress contours of steel connectors

Fig. 2 presents the deformed shapesandstress contours of steel connectorsat maximum deformations. The maximum stresses are observed at the both ends of the pin- and clip-typed steel connectors which are governed by the flexural behavior. For the grid- and truss-typed steel connectors,axial deformations at their diagonalelements are pronounced. The initial stiffness and yield strength of the grid- and truss-typed steel connectorsare larger than those of the pin- and clip-typed ones, as shown in Fig. 3.



(a) Structural steel



(b) Stainless steel

Figure 3: Force-deformation relations of steel cor

The strength capacities of the steel connectorsare summarized on Table 4. The grid- and truss-typed steel connectorspossesses 2 ~ 3 times larger strength capacities than the pin- and clip-typed steel connectors.

Type	Structural steel	Stainless steel
Pin	2.8	3.1
Clip	1.8	1.8
Grid	7.2	7.8
Truss	8.8	9.7

Table. 4 Strength capacity of steel connectors (unit:kN)

CONCLUSION

This paper makes an effort to analytically evaluate various types of existing steel connectors applied to ISWPs. Based on the analytic results, structural behaviors and strength of steel connectors were investigated.The flexural behavioris critical to the pin- and clip-typed steel connectors, whereas the grid- and truss-typed steel connectors are governed by axial deformations. The grid- and truss-typed steel connectorspossesslarge strength capacities compared with the pin- and clip-typed steel connectors.

ACKNOWLEDGEMENT

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