DESIGN OF HIGH THERMAL-EFFICIENT INSULATED SANDWICH WALL PANELS USING NEW-SHAPED STEEL CONNECTORS

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Abstract - Insulated sandwich wall panels (ISWPs) have been increasingly applied to building construction since they expect to enhance the thermal performance of a building in being used as building envelops. To confirm the structural capacities of ISWPs while avoiding the thermal losses, this study tries to develop high thermal-efficient ISWPs with a new-shaped steel connector that is used for integrating outer panels, main element of the ISWP. This paper describes the structural design process of ISWPs with the steel connectors for their practical applications as thermal-efficient cladding systems.

Index terms - Insulated sandwich wall panel (ISWP), New-shaped steel connector, Design process, Cladding system

I. INTRODUCTION

High thermal-efficient buildings have been promoted by the demands to the lower energy consumption [1]. Traditionally, the thermal efficiency of buildings is improved by installing additional insulation layers to the external surface of a building envelope [2-3]. Insulated sandwich wall panels (ISWPs) have gained popularities in building construction since they can enhance the thermal performance of a building. In developing high thermal-efficient ISWPs which consist of two outer panels (made of lightweight foamed concrete, LFC) separated by an inner layer of foam insulation, the ISWPs are needed to resist to applied wind loads. To do this, new-shaped steel connectors are proposed to integrate the two LFC outer panels through han inner foam insulation. This paper develops the design process of the ISWPs with the new-shaped steel connector for the practical applications as one of thermal-efficient cladding systems.

II. DEVELOPMENT OF NEW-SHAPED STEEL CONNECTORS

ISWPs can serve to resist lateral wind pressures with insulating a building when they are used for interior and exterior finishing [4]. For the development of high thermal-efficient ISWPs, the outer panels are made of LFC that assures 20 times lower thermal conductivity than typical concrete. In order to satisfy a thermal transmittance criterion prescribed in Korea energy saving design code [5], the thicknesses of components in the ISWP are, as shown in Fig. 1, determined to be 100 mm for an outer panel, 150 mm for an inner insulation and 5 mm for adhesive. The thermal transmittance of the ISWP is 0.193 W/m^{2}K which satisfies the code criterion of 0.210 W/m^{2}K.
Fig. 2 illustrates the fabrication procedure developed for the ISWP with new-shaped steel connectors. Components of theouter panels are integrated by the steel connectors which consist of a connecting rod and anchorage devices. After penetrating the connecting rod throughout anchorage devices, two outer panels and inner insulation are structurally integrated once the steel connectors are torqued until preventing relative slips between outer panels.

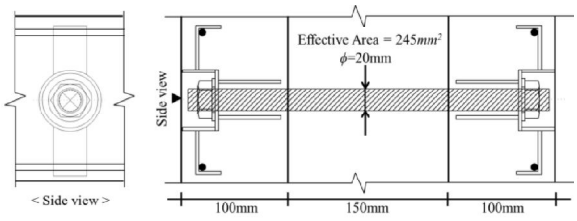


Figure 1: Configuration of anISWP with a new-shaped steel connector

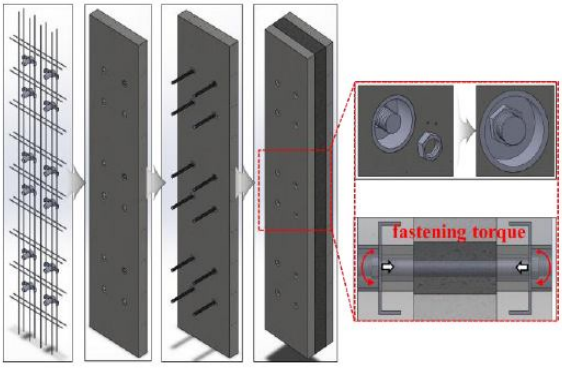


Figure 2: Fabrication procedure of proposed ISWPs

III. DESIGN OF ISWPs withNEW-SHAPED STEEL CONNECTORS

ISWPs are designed to meet non-structural load demands for building claddings. As shown in Fig. 3, a wind pressure is 3.24 kN/m^{2}for a building of which the height is 35 m and the basic wind speed is 40 m/s as prescribed in the Korean building Code, KBC 2016 [6]. The required bending moment is determined to 2.14 kN·m for a 3.0 m long and 0.6 m wide ISWP.

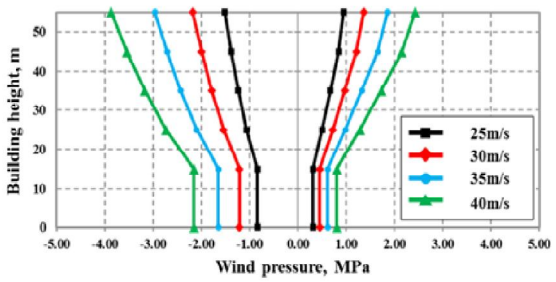


Figure 3: Distribution of wind pressures along building height

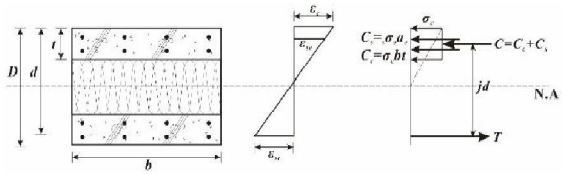


Figure 4: Strain distribution and internal forces

Fig. 4shows internal forces of the ISWP whered is a depth of neutral axis, ε_c is a strain of compressive surface, and ε_{st} is the strain of tensile rebar.Theinternal forces are estimated by multiplying the sectional area of an outer panel and tensile rebarsby the corresponding stresses. The allowable bending moment, M_n of the ISWP isdetermined as the lesser of 1) an allowable bending moment, M_{nt} computed from the allowable tensile stress of a rebar,and 2) an allowable bending moment, M_{nc} calculated from the allowable compressive stress of LFC. The values of M_{nt} and M_{nc} are calculated from:

$$M_{nc} = C_c(d - \frac{t}{2}) + C_s(d - d_c) \quad (1)$$

$$M_{nt} = Tjd \quad (2)$$

where C_c is the compressive force of an outer panel, C_s is the compressive force of rebar in compression zone, T is tensile force in the rebar in tension zone, d_c is the depth to the compressive rebar, t is the thickness of LFC and jd is the lever arm of internal forces.The compressive strength of LFC and the yield strength of a rebar are, respectively,4 MPa and 240 MPa. Since it is effective that the ISWP resists to the external forces as a fully composite section, the steel connectors are placed to provide sufficient capacity against shear demands. The shear demand, V_{req} can be computed using two methods:

1. Method 1: Shear demand is computed from the maximum compression or tension force at the maximum moment region [7].
2. Method 2: Shear demand is computed from the vertical shear acting on the panel [8]

This study conservatively determines 19.2 kNas the shear demand on the ISPWaccording to theMethod 2.

For a fully composite section,the strength capacity, V_{cap} = 1.7 kN of aϕ20 mm diameter steel rod used for a steel connectoris obtained from:

$$V_{cap} = \frac{2F_y Z}{L} \quad (3)$$

where F_y is the yield strength of structural steel, Z is the plastic section modulus, and L is the length of the steel connector (150 mm). Finally, the required number, N_{req} of steel connectors is computed from:

$$N_{req} = V_{req} / V_{cap} \quad (4)$$

To develop a fully composite section, twelve steel rods are required for the steel connectors. The steel connectors are arranged with double rows of 300 mm spacing, as shown in Fig. 5.

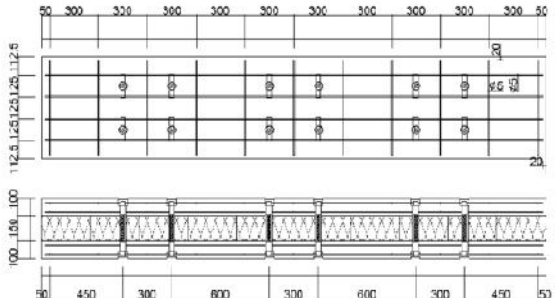


Figure 5: Reinforcement details and layout of steel connectors

CONCLUSION

This paper makes an effort to develop a high thermal-efficient insulated sandwich wall panel and design method for the practical application of cladding systems. The outer panels made of lightweight foamed concrete areused for load-carrying components. A new-shaped steel connector is proposedto integrate the two outer panels. Using basic solid mechanics, the calculating procedure of the flexural and shear resistances of the ISWP are presented.

ACKNOWLEDGEMENT

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