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Research Progress of Internal Connectors of Composite Sandwich Wallboard

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Abstract

The connector plays an important role in the composite sandwich wall panel. The selection of the connector is a factor affecting the strength and thermal performance of the composite sandwich wall panel. The type, thermal conductivity and position arrangement of connectors at home and abroad are systematically summarized, and the future development of connectors is prospected.

Keywords

Connector; Composite Sandwich Wall Panel; Thermal Conductivity; Expectation.

1. Introduction

Promoting the development of assembled buildings is an important step to promote structural reform on the supply side. The assembled building is heavy in the peripheral envelope structure, and the exterior wall panels are crucial. At present, the insulation form of exterior wall panels can be divided into external wall insulation, external wall insulation, external wall hybrid insulation, external wall self-insulation. In recent years, a number of provinces and cities have been promulgated to limit the external wall insulation documents, sandwich insulation wall panels due to the insulation material is located between the inner and outer leaf concrete slab, insulation material is protected, so as not to consider the insulation material fire, water absorption, deformation and other issues, but the traditional sandwich insulation wall panels have a large mass, to transport, construction caused a certain adverse impact[1]. In recent years, new lightweight sandwich insulation wall panels have become the trend of development. In the total energy consumption of the building, the exterior wall energy consumption accounts for the vast majority, precast concrete sandwich insulation panels as a common type of external wall panels, improve the self-insulation performance of the outside panels is the key to achieve energy saving in buildings.

Exterior insulated sandwich wall panels generally consist of an inner leaf concrete slab, an outer leaf concrete slab, and an insulation layer mechanically connected by connectors or surface bonded, with connectors being the predominant form. In the design of precast concrete sandwich insulated exterior wall panels, the connectors are an important tool to firmly connect the three layers of wall panels together and can determine the overall integrity of the wall panels, which is a crucial component in the exterior wall panels. The key to connectors in wall panels is to ensure that the panel can transfer the applied forces from one outer layer to another without causing deterioration of the insulation core. The role of connection members: 1) Connection members can effectively prevent the instability of the outer leaf wall panel under vertical loads. 2) Coordinate the deformation of the inner and outer leaf wall panels. 3) Connection members can share the shear force and participate in the force, so that the inner and outer leaf wall panels work together.

The current development of sandwich wall panel connectors can be roughly divided into two major directions, namely, shear-resistant connectors and non-shear-resistant connectors[2]. The important question facing both shear and non-shear connectors is whether they can affect the integrity of the wall panel and the thermal performance of the wall panel. However, no matter what kind of

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connections, all have their shortcomings. Therefore, the arrangement of the type and location of the connectors is particularly important. The following is a systematic summary of the connectors and a brief comparison of the advantages and disadvantages of each type of connector, and a moderate outlook.

2. Current Status of Domestic and International Research

Foreign research on non-metallic connectors, such as fiber reinforced polymers (FRP), has been conducted in the last century. In the 1980s, some countries in Europe, the United States and Australia had already started to develop and apply low thermal conductivity fiber material connectors, such as ThermomassMS/MC, a type of connector developed by Composite Technologies Corp.of the United States. After that, Japan also began to develop many different forms of non-metallic material connectors, of which FRP connectors are widely used in sandwich wall panels in Japan. China's traditional assembled insulation wall panels often use steel construction frame or steel connectors to achieve the integration of insulation structure, early to metal connectors mainly, although this connection method to ensure the mechanical properties, but the connection through the region to produce a serious cold bridge phenomenon, the external envelope of heat insulation has a negative impact. China's late development in this area of non-metallic materials, started in 2007, by Tongji University and some enterprises in Shanghai to carry out research and application of related aspects, breaking the gap in the field of sandwich wall panel joints without independent intellectual property rights[3].

3. Types and Applications of Connection Parts

The mechanical properties of sandwich wall panels depend to a large extent on the strength and stiffness of the connectors. The connectors can be divided into shear connectors and non-shear connectors according to the force characteristics. According to the material division can be divided into metal connectors, FRP connectors, combined connectors, etc.. Among them, combined wall panels must use shear connectors, and non-combined wall panels often use non-shear connectors. According to the shape characteristics can be divided into rod connectors, sheet connectors, mesh connectors, lattice connectors, etc. Among them, metal connectors will produce obvious "cold bridge" phenomenon, which is not good for heat preservation and energy saving, while FRP connectors can solve the problem of "cold bridge" and thus improve the heat preservation efficiency of insulation wall panels, but they are expensive and not corrosion-resistant and weak in shear resistance. In addition to the use of connectors to connect the inner and outer leaf wall panels, researchers have also tried to transfer forces by bonding between the insulation and concrete. However, the durability of the adhesives has not been determined, and it is unclear whether they can be relied upon in the design for long periods of time[4].

3.1 Metal Connectors

The most useful use of metal connectors in sandwich wall panels is reflected in the use of steel joist connectors alone (Figure 1) or steel joist connectors and reinforcing mesh (Figure 2). The difference between these two types is that the inner and outer leaves have longitudinal and transverse reinforcement to form a reinforcing mesh through the steel joist connectors, which enhances the integrity of the sandwich wall panel and secures the connectors during the wall panel pouring process. The steel truss connectors have good shear resistance and can resist large shear forces, but their high thermal conductivity easily causes heat loss and obvious thermal bridge effect, which significantly reduces the energy-saving insulation effect of wall panels. Table 1 summarizes the types of wall panels, types of connectors and thermal conductivity for which steel joist connectors have been used. It can be seen that the thermal conductivity of steel joist type of connectors is about 0.53-0.63W/(m·k).

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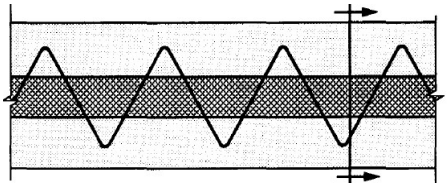

Figure 1. Steel Joist Connections

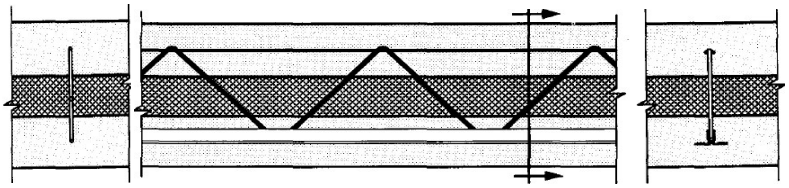

Figure 2. Steel Joist Connections

Table 1. Summary

Interior wall panels	Insulation layer	Connections	Thermal conductivity	Ref
C30 reinforced concrete	XPS insulation board	6mm of HRB400	0.63	[5]
C30 reinforced concrete	XPS insulation board	8mm of HRB400	0.534	[6]
C30 reinforced concrete	XPS insulation board	5mm of HRB400	/	[7]
C30 reinforced concrete	XPS insulation board	Steel Joist + Reinforced Steel Mesh	/	[8]
C30 reinforced concrete	XPS insulation board	Steel Joist + Reinforced Steel Mesh	0.577	[9]

3.2 Non-metallic Connectors

Most of the non-metal connectors are inorganic materials, such as fiber reinforced resin connectors - FRP (Figure 5), glass fiber reinforced resin connectors - GFRP (Figure 4), basalt fiber reinforced resin connectors - BFRP (Figure 3), carbon fiber reinforced resin connectors - CFRP (Figure 6), etc.

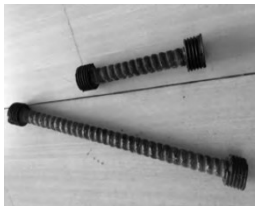

Figure 3. BFRP connection

Figure 4. GFRP connection

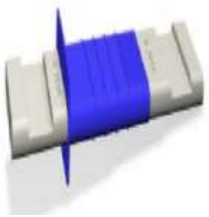

Figure 5. FRP connection

Figure 6. CFRP connection

The non-metallic connectors are widely used at this stage due to their low thermal conductivity and light weight, and they show good performance in the thermal aspects of wall panels and significantly improve the "thermal bridging" phenomenon caused by metal connectors, but their shear resistance and corrosion resistance are not good compared with metal ones, and their cost is high. Table 2 summarizes the types of wall panels where non-metallic connectors are used, the types of connectors,

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and the thermal conductivity. It can be seen that the thermal conductivity of non-metallic connectors is about 0.414-0.520 W/(m·k).

Table 2. Summary

Interior wall panels	Insulation layer	Connections	Thermal conductivity	Ref
C30 reinforced concrete	XPS insulation board	6mm of BFRP	0.434	[10]
C30 reinforced concrete	XPS insulation board	20mm of FRP	0.414	[11]
C30 reinforced concrete	XPS insulation board	FRP rod type	0.520	[12]
C40 reinforced concrete	EPS insulation board	GFRP rod type	0.511	[13]

4. Arrangement of Connection Parts

The location and manner in which the connections are arranged in the sandwich wall panels are also particularly important. Charter Dong[1]proposed that when FRP occupies a sufficient volume percentage in the concrete slab on both sides, there will also be a reduction in the thermal conductivity of the sandwich wall slab. Han Pengtao [4]experimentally concluded that the arrangement spacing of steel trusses has a great influence on the flexural load bearing capacity of wall slabs, and when the arrangement spacing of steel trusses was reduced from 750 mm to 300 mm, the ultimate load in normal use was increased by about 61% respectively, and for wall slabs with only GFRP connections configured with non-metallic material connections, the smaller the GFRP arrangement spacing, the better the flexural performance of the wall slabs, but the arrangement reached a certain However, after the arrangement reaches a certain spacing, the bending bearing capacity of the wall panel is improved very little, which can be approximated as the bending bearing capacity of the wall panel is no longer improved. The sandwich external wall panel has the highest improvement in the horizontal arrangement spacing from 500×300 to 400×300; and the highest improvement in the vertical arrangement spacing from 300×400 to 300×300. Yang Yutong [10]proposed to arrange the BFRP connectors at 45° to the panel, which can achieve a small heat flow density of the inner and outer leaf wall panels and a small heat flow density of the connectors. Bu Yingqiao[13]proposed that the load carrying capacity of the connector arrangement when the spacing reaches 400 mm is not much different from the load carrying capacity when the arrangement spacing is 300 mm, and the connector arrangement can be made according to 400 mm spacing. Table 3 summarizes the arrangement spacing and arrangement method of connectors.

Table 3. Summary

Connections	Layout spacing mm	Layout	Ref
Metal material connectors	300	Vertical distribution	[4]
Non-metallic material connectors	400×300 300×300	Transverse (45°) Longitudinal (45°)	[4,10]
Non-metallic material connectors	400×300 400×300	Transverse (45°) Longitudinal (45°)	[14,10]

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5. Arrangement of Connection Parts

In summary, metal connectors have better shear resistance and corrosion resistance, but their high thermal conductivity leads to a significant drop in energy efficiency of the wall panel, which can easily cause the wall panel "thermal bridge" effect, while non-metallic connectors have a small thermal conductivity of their own, thus making up for the shortcomings of metal connectors, but their own materials lead to their shear resistance, corrosion resistance The material itself leads to poor shear resistance, corrosion resistance, and high price. In the experiment of J. Gu[2], a connection is proposed which is composed of steel plate, insulating plastic and plastic sleeve. A layer of insulating plastic is added to the steel plate. Dong Charter[1]out the combination of FRP and steel reinforcement using research found that the heat transfer coefficient of 0.54 W/(m-k) of the combined connection of FRP material coated on the exterior of the steel reinforcement is slightly higher than the thermal conductivity of the 15 mm FRP connection, reducing the thermal conductivity of 0.6120.54 W/(m-k) when the steel reinforcement is used as the connection, but the shear resistance is greatly improved, which is because in the heat transfer process, different substances affect each other, and when the volume of the two substances of the combined connector is the same, the contact area between the outer ring and the surrounding substances is greater, and thus the degree of influence is greater, resulting in a lower heat transfer coefficient for FRP wrapped steel. Therefore, the combined use of metal-like connectors and inorganic materials not only overcomes the problem of insufficient shear resistance of the connectors, but also ensures the thermal performance of the wall panels, which will provide good prospects for the future development of the connectors.

Acknowledgments

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