Study on Mechanical Properties of Wall Panel with Insulation Decoration Structure

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Abstract. In order to explore the safety performance of the wall panel with insulation decoration structure in the actual application, some test were made. The test results of this paper show that: The rock wool with a density of 120 kg/m³ and the polyurethane with a bonding density of 50 kg/m³ are selected as the core material for the temperature retention, whose average tensile strength can reach 139.33 KPa; The mean value of single point anchoring force of 12 mm thick ceramic plate and back bolt as decorative surface is 2088.29 N, and the mean value of the structural adhesive strength between the ceramic plate and keel is 3092.07 KPa; When the uniformly distributed load on the wallboard reaches 6.53 KPa, its deflection reaches 1/180 of itself.

1. Introduction
Nowadays, due to the global energy shortage, all walks of life are promoting ecological civilization, energy saving and environmental protection. Building energy conservation is an important part of the energy-saving industry. Energy-saving buildings and industrialization of buildings have become the main theme of the development of contemporary construction industry. This article explores the mechanical properties of insulating core and keel in wallboard, and explores the bending resistance of wall panel by simulated wind pressure test.

2. Raw materials, test equipment and methods

2.1. Raw materials
The test block of rock wool composite polyurethane of different density; The rock wool composite ceramic plate; type I wall plate and type II wall plate; Among them, the keel in the I type wall panel is...
No. 5 FRP and No. 10 channel steel, the keel in the II type wall panel is No. 10 FRP No. 6.3 channel steel. The length and width of the wallboard are 3000 mm and 1200 mm; The back bolt; Bagged cement.

2.2. Test equipment
The drawing instrument of ZQS6-2000A model; Tensile testing machine; driller.

2.3. Methods
Tensile strength test of rock wool composite polyurethane: Make the adhesive composite between the test block of vertical silk rock wool with the densities of 100 kg/m³, 120 kg/m³ and 140 kg/m³ and sizes of 100mm×100mm×40mm and the rigid foam polyurethane test block with the densities of 50 kg/m³ and 60 kg/m³ and sizes of 100mm×100mm×40mm. The drawing instrument can be started and the reading displayed on the sensor can be observed, and the reading can be recorded when the test block is broken.

Tensile strength test of rock wool composite ceramic plate: According to the first test, the vertical wire rock wool with a density of 120 kg/m³ is selected as the core material for the temperature retention. 100mm×100mm×40mm vertical silk rock wool test block is bonded with a 100mm×100mm×8mm ceramic plate, the bonding strength is tested with the drawing instrument and the test data are recorded.

Connection performance test of back bolt and ceramic plate: The back bolt of is closely connected with the ceramic plate. Fix the connector of the puller on the expansion back bolt and test the connection strength between the back bolt and the ceramic plate.

Adhesion test of ceramic plate and keel: The structural adhesive is used to bond the ceramic plate with the glass fiber reinforced plastic component with the bonding area of 50 mm × 50 mm and the adhesive force of the two is tested and the data is recorded.

Bending test of wall plate: When the integrated wall panel of thermal insulation and decoration structure is used as the wall enclosure structure, the main load is the wind load. In this experiment, the average wind pressure once in 50 years at the height of 100 m in the open area of Shenyang City is the most unfavorable wind pressure. According to the standard JG/T432-2014 and execute it.

3. Results and analysis of test

3.1. Bonding performance of core material and decorative panel

| Density combination (kg/m³) | 100×50 | 100×60 | 120×50 | 120×60 | 140×50 | 140×60 |
|-----------------------------|--------|--------|--------|--------|--------|--------|
| Tensile strength (KPa)      | 114.48 | 122.37 | 139.82 | 169.59 | 218.94 | 237.75 |
|                              | 116.79 | 119.64 | 103.56 | 209.78 | 185.04 | 197.24 |
|                              | 102.46 | 102.36 | 156.32 | 204.68 | 198.74 | 197.77 |
|                              | 83.36  | 92.36  | 134.45 | 189.47 | 176.52 | 212.24 |
According to the data in table 1, Combined with the requirements of external insulation regulations for external walls and economic costs, the density of rock wool in the core material for temperature preservation is selected as 120 kg/m$^3$, and the density of polyurethane is selected as 50 kg/m$^3$.

| Number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | Average value |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|---------------|
| Tensile strength (KPa) | 97.48 | 122.76 | 156.32 | 134.65 | 201.10 | 163.36 |
|         | 98.95 | 136.48 | 130.34 | 172.08 | 149.33 | 189.36 |
|         | 67.54 | 136.07 | 171.25 | 153.57 | 215.27 | 231.28 |
|         | 67.65 | 68.44 | 118.75 | 223.99 | 189.36 | 224.87 |

The average tensile strength (KPa): 95.56, 116.78, 139.33, 183.96, 197.34, 208.79

According to the data in table 1, the experimental results meet the requirements of the 100 KPa specified value of the external insulation regulation of the outer wall.

3.2. Decorative panel and keel connection performance

| Number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10 | Average value |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|---------------|
| Tensile force (N) | 1520.22 | 1860.47 | 2120.95 | 1245.39 | 1426.72 | 2966.19 | 1932.34 | 2547.73 | 2653.44 | 2088.29 |

| Number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10 | Average value |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|---------------|
| Tensile strength (KPa) | 2662.00 | 2844.83 | 3091.17 | 3551.25 | 3306.17 | 3029.84 | 3136.83 | 2780.33 | 3381.17 | 3137.08 | 3092.07 |

According to the data in table 3, the average tensile strength of the back bolt connected with 12mm ceramic plate can reach 2088.29 N and the average value of bonding strength of ceramic plate and FRP is 3092.07 KPa. In the insulation decoration structure integrated wall plate, 5 ceramic boards are laid flat, and 4 back bolts are mounted on each ceramic board, meet the requirements of the external insulation regulation of the outer wall. The bonding area between the ceramic plate and the keel is 0.3 m$^2$, therefore, the connection strength between the ceramic plate and the keel reached 269.27 KPa. And together with the bonding strength of rock wool and ceramic plates, which means that the strength of the connection among the ceramic plate, insulation materials and the keel in a wall panel can reach 397.61 KPa, meet security needs.
### 3.3. Bending resistance of wall plate

| Load(kg) | Deflection(mm) | Type I wall plate | Type II wall plate |
|----------|----------------|-------------------|--------------------|
| 0        | 1              | 1                 | 1                  |
| 600      | 2              | 2                 | 2                  |
| 1200     | 4              | 3                 | 3                  |
| 1800     | 9              | 6                 | 6                  |
| 2400     | 19             | Destroyed         |                    |

In experiment, the load of type I wall plate reaches 2400 kg, but type II wall plate is damaged, the reason is that channel steel is small. The theoretical calculation of this part is carried out below.

First, I type wall panel is used as the analysis object. Keel is a two-phase composite, assuming that its modulus of elasticity is \( E_c \); FRP elastic modulus is \( E_m \); Volume rate is \( V_m \); The modulus of elasticity of the channel is \( E_p \); Volume rate is \( V_p \); Without considering Poisson's ratio, And both are in line with the tandem model, then the calculation formula of the keel elastic modulus is:

\[
E_c = \frac{E_m E_p}{E_m V_p + E_p V_m}
\]

\( E_m = 2.2 \times 10^4 \text{MPa} \); \( E_p = 2.06 \times 10^5 \text{MPa} \); \( V_m = 33\% \); \( V_p = 67\% \); Substituting values to formulas:

\( E_c = 5.48 \times 10^4 \text{MPa} \). The keel and ceramic plate combination also conforms to the tandem model, use the above formula again to calculate, Elastic modulus is \( E_d = 2.12 \times 10^5 \text{MPa} \). After calculation, the elastic modulus of type II wall plate is \( E_d = 1.68 \times 10^5 \text{MPa} \).

Next, calculating the mid-span deflection of a single-span simply supported plate under the uniform load of I wall plate:

\[
f = \frac{5W_f L^4 B}{384E_f I_0} (1+k)(1-\beta)
\]

\[
k = \frac{9.6E_f I_0}{L^2 G_c A_c}
\]

\[
\beta = \frac{I_f}{I_f + \frac{I_0}{1+k}}
\]
The model is in the form of a sandwich, the keel volume is included in the panel volume. The volume of keel is $3.7 \times 10^7 \text{mm}^3$. After the panel volume is included, the thickness of the panel is increased by 6 mm. According to the formula: $L = 3000 \text{mm}; B = 1200 \text{mm}; e = 75 \text{mm}; t = 15 \text{mm}; G = 1.7 \times \rho / 100$; 

$\rho = 120 \text{kg/m}^3; L_o = Bte^2 / 2 = 5.06 \times 10^7 \text{mm}^4; L_f = Br^3 / 6 = 6.75 \times 10^5 \text{mm}^4; W_k = 6.67 \times 10^{-3} \text{MPa}$; 

$E_d = E_f = 2.12 \times 10^5 \text{MPa} ; A_k = Bd = 1.8 \times 10^5$ ; Substituting values into formulas: $k = 31.5, \beta = 0.3, f = 17.55 \text{mm}$. According to this algorithm, the value of type II wall plate is 16.95 mm. The calculated result is very close to the test result, so the test is feasible.

The calculation formula of the maximum wind pressure of the insulation system of the external wall is:

$$\omega_k = \beta \mu \mu_\omega \omega_o \quad (5)$$

Take the coefficient according to the specification GB50009-2012 and substituting the coefficient of Shenyang City into the formula: $\omega_k = -2.54 \text{KN/m}^2$ (Reverse wind pressure).

This value is less than the value in the test, therefore, the wallboard has strong safety performance.

4. Conclusion
(1) The way to meet the economic cost requirements of mechanical requirements is that the density of rock wool is 120 kg/m$^3$ and the density of polyurethane is 50 kg/m$^3$.
(2) The connection strength among the ceramic plate, insulation materials and the keel in a wall panel can reach 397.61 KPa, meet the requirements of the regulations.
(3) Ability to withstand wind loads of type I wall plate is 6.67 KN/m$^2$ the load when II wall plate is destroyed is 5.55 KN/m$^2$, exceeding the standard value that is 2.54 KN/m$^2$.

5. Reference lists
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