Finite Element Simulation of PVC Ecological Wood Composite Wall under Horizontal Load

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Abstract. PVC ecological wood is applied to the load-bearing wall structure of building engineering, it is necessary to design the wall structure to meet the bearing capacity requirements. According to the requirement of energy saving, this paper designs the composite wall of low-rise residential application of light steel structure in cold area, and carries on the finite element simulation analysis under the horizontal load, which provides the theoretical basis for the application of PVC ecological wood composite wall.

Keywords: Ecological Wood, Composite Wall, Wind Load, Deformation

1. Introduction

PVC ecological wood is a profile made of more than 80% wood flour and PVC particles and a part of polymer materials. It is melted and then extruded at high temperature. It is formed in one time without secondary painting, and has various colors. As a substitute for traditional wood and metal materials, it has good moisture-proof, acid-alkali-resistant, antifungal, anti-static, moth-proof properties, and has the advantages of eco-environmental protection, pollution-free, pollution-free, recyclable, and has been widely used in villas, residential areas, garden landscape and so on[1]. PVC ecological wood has the appearance of solid wood, and it is applied to the wall panel of light steel structure buildings. It can not only be used as a structural cladding panel to participate in the stress of the structure, but also can be used as a decorative plate for the house, integrating structure and decoration. In one body, the combined wall that forms the whole room can be produced in the factory and installed on site, and then realize the development of building components, industrialization and industrialization, convenient construction, green environmental protection, and good social and economic benefits.

2. Wall Structure

PVC ecological wood is used in low-rise buildings with light steel structure. According to the design standard of 65% energy saving in cold area, the heat transfer coefficient of exterior wall of 3 stories and below is not greater than that of building 0.35 W/m².K, light steel keel is used as the skeleton, the combined wall cross section structure is designed[2-4], as shown in figure 1. The order from inside to outside is: 20 mm thick PVC ecological wood interior decoration board, 0.1 mm waterproof film, 12mm thick OSB board, 170 mm light steel skeleton (filled with insulating rock wool), 12mm...
thick OSB board, 0.1 mm breathable film, 12mm thick ecological wood exterior decoration panel.

![Diagram](image)

**Figure 1.** Schematic diagram of wall structure

The light steel framework, the OSB panel and the light steel framework, and the PVC interior panel and the OSB panel are connected by self-tapping screws; the PVC exterior panel is connected to the light steel framework through a reliable independent connector to form a whole. The light steel keel wall and the main frame are connected to the frame beam by angle steel welded to the frame beam and bolts. Therefore, the combined whole can be regarded as one monolithic plate for research in which two opposite sides are simply supported and two opposite sides are free

3. Calculation of Horizontal Load of Composite Wall

The PVC ecological wood composite wall is mainly used in the seismic fortification intensity 8 degree area, the low-rise light steel frame structure house, this paper aims at the standard layer height 3m and three-story light steel frame structure civil building exterior wall, the common wall size 3.6m×3.0m carries on the force analysis[5]. The wall facade construction is shown in figure 2.

![Diagram](image)

**Figure 2.** Composite wall construction facade

3.1 Wind Load Calculation

Because the composite wall belongs to the enclosure structure and is a non-structural member, the standard value of wind load calculated according to the Code for Building Structural Load (GB 50009-2012)[6] should be calculated according to the following formula:

\[ W_k = \beta_{gz} \mu_{sl} \mu_z W_0 \]  

(1)

In the formula, \( W_k \): Standard value of wind load, kN/m²; \( \beta_{gz} \): gust coefficient at height \( z \); \( \mu_{sl} \): Local body type coefficient of wind load; \( \mu_z \): coefficient of variation of wind pressure height; \( W_0 \): Basic wind pressure, kN/m²; According to the rough ground, it is classified as Class B. Checking the "Building Structure Load Code" (GB 50009-2012) shows that \( \beta_{gz} = 1.70 \), \( \mu_{sl} = 1.0 \), \( \mu_z = 1.0 \), \( W_0 = 0.65 \text{kN} / \text{m}^2 \),
then \( W_b = 1.11 \text{kN} / \text{m}^2 \). The load partial coefficient is 1.4, and the design value of wind load \( W = 1.55 \text{kN} / \text{m}^2 \).

### 3.2 Calculation of Seismic Action

PVC the ecological wood composite wall as the enclosure structure, the equivalent lateral force method can be used to calculate its seismic action according to the code [7], and applied to the center of gravity of non-structural members in the form of concentrated force. The calculation formula is as follows:

\[
F = \gamma \eta_1 \zeta_1 \alpha_{\text{max}} G
\]  

(2)

In the formula, \( \gamma \): non-structural component; \( \eta \): non-structural component category coefficients; \( \zeta_1 \): State function; \( \zeta_2 \): Position function; \( \alpha_{\text{max}} \): Maximum seismic impact coefficient; \( G \): nonstructural component gravity, unit kN.

The maximum seismic fortification intensity is 8 degrees, the design basic acceleration is 0.20g, \( \alpha_{\text{max}} = 0.24 \); the seismic fortification category of the enclosing structure in residential buildings is not lower than the standard fortification category, and the key fortification category is taken, which is the category B standard, so \( \alpha_{\text{max}} = 1.4 \); Wall protection \( \gamma = 0.9 \); the wall is a prefabricated component \( \zeta_1 = 2.0 \); the wall takes the uppermost layer \( \zeta_2 = 2.0 \); G is the gravity of the wall, and \( G = 4.1 \text{kN} \); then \( F = 1.4 \times 0.9 \times 2.0 \times 2.0 \times 0.24 \times 4.1 = 4.96 \text{kN} \), the design value of horizontal seismic action \( F_d = 1.3F = 6.45 \text{kN} \), which is reduced to the equivalent uniform load of 0.60kN / m\(^2\) on the wall. The design value of earthquake action is smaller than the design value of wind load, so the design value of wind load is used as the most unfavorable uniform load value for calculation.

### 4. Finite Element Simulation Analysis of Composite Wall under Horizontal Load

#### 4.1 Finite Element Modelling

The material parameters of the composite wall are shown in Table 1.

**Table 1** Finite element simulation material parameter table

| Materials          | Density (kg/m\(^3\)) | Specific heat capacity (J/kg.K) | Thermal conductivity (W/m.K) |
|--------------------|----------------------|--------------------------------|-----------------------------|
| PVC Ecological Wood| 1300                 | 1500                           | 0.18                        |
| Light steel keel   | 7900                 | 480                            | 58                          |
| Rock wool          | 70                   | 840                            | 0.05                        |

The finite element simulation uses ABAQUS software, the PVC ecological plank and keel are simulated by S4R shell element, and the self-tapping screw connection is simulated by strengthening constraint Tie constraint, that is, the surface-to-face connection is used where the two sides of the ecological plank intersect with the keel, thus limiting the consistency of X、Y、Z direction displacement. The vertical keel and the heaven and earth keel are connected by Tie connecting the outer intersecting line to simulate the self-tapping screw action. The boundary condition is set to limit the displacement of the X、Y direction on one side of the keel and the displacement of the X、Y、Z on one side, and to simulate the hinge condition of the outer hanging wall. the finite element model is shown in Figure 3.
4.2 Finite Element Analysis of Internal Wall Force and Deflection

Finite element analysis shows the stress cloud diagram of the PVC plate on the outside of the composite wall is shown in Fig. 4 a, and the displacement cloud diagram is shown in Fig. 4 b; the stress cloud of the PVC inner plate of the composite wall is shown in Fig. 5 a, and the displacement cloud picture is shown in Fig. 5 b.

![Cloud diagram of stress and displacement of external side plate of composite wall](image)

**Figure 4** Cloud diagram of stress and displacement of external side plate of composite wall

![Cloud diagram of stress and displacement of inner side plate of composite wall](image)

**Figure 5** Cloud diagram of stress and displacement of inner side plate of composite wall

It can be seen from the figure that the area with the largest stress on the outside plate is the middle of the first span, the stress is 1.641N/mm², and the mid-span deflection is 5.0 mm. The area near the inner plate and the keel has greater stress, about 0.3537N/mm², and the displacement can reach 1.69mm. And it can be seen that the deflection of the inner plate is almost the same as the deflection of the keel [8-9]. It can be speculated that the deflection of the inner plate is caused by the deflection of the vertical keel, which causes the internal force of the inner plate. It is speculated that the force transmission sequence of the wall is the outer plate-vertical keel-inner plate. Considering that the outer plate is relatively stressed and deformed, the thickness of the outer plate can be thickened to reduce the deformation of the wall [10].
5. Conclusions
Through the structural design of the common engineering size PVC ecological wood light steel keel composite wall, the most dangerous stress is determined by theoretical calculation, and the finite element simulation is carried out. The research shows that: the Composite wall can be met in areas with 8-degree fortification intensity.

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