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Finite Element Analysis and Optimization of PDCPD New Material Wall Formwork

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Abstract

Thermosetting polydicyclopentadiene (PDCPD) is a new material with high performance, which is expected to replace the traditional steel in the application of cast-in-place formwork components in house construction. In this paper, the finite element model is established by Abaqus to simulate and analyze the floor formwork with the largest size and span in the engineering example, so as to verify the feasibility of this component. The results show that the strength of the floor formwork meets the requirements under the vertical pressure of concrete, but its deformation does not meet the requirements. Therefore, the design optimization is carried out on the basis of the original design, and the main longitudinal ribs are reinforced with steel plates along the span direction. The verification results show that the optimization scheme is suitable.

Keywords

PDCPD; Wall Formwork; Finite Element Analysis; Steel Rib Strengthening.

1. Introduction

In 2021, the output value of the domestic construction industry is 8.4 trillion yuan, an increase of 1.41 times compared with 2012, and China has been transformed from a construction country to a construction power and continues to develop [1]. Traditional building materials such as steel and concrete will produce a lot of construction waste and consume a lot of non-renewable resources in the process of use, which brings huge environmental pressure. Therefore, it is imperative to develop green, low-carbon and energy-saving new building materials[2].

High-performance new materials help the traditional building industry to develop in the direction of green consumption reduction, energy saving and environmental protection. Among them, thermosetting polybicyclopentadiene (PDCPD), as a composite material, shows higher interlamellar fracture toughness and less damage development during load holding, effectively prolonging fatigue life, and significantly improving compressive strength and compression properties. This material has a broad application prospect in the field of housing construction instead of traditional steel formwork.[3],[4]

2. Engineering Background

The project example selected in this paper is a commercial housing on the first floor, which is cast in situ as a whole and adopts a new type of PDCPD wall template. According to the analysis of the installation structure of the floor template, the floor template with the largest size and span is selected for analysis. The location of the selected template is shown in Figure 1. The total length of the position is 5800 mm, the width is 1800mm, and there are 8 templates, among which the size of the template is 800×1800mm. The size of the template is 700×1800mm, and

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the thickness of the template panel is 4mm, the thickness of the long rib is 10mm, and the thickness of the short rib is 15mm.

Figure 1. Calculating the position of the floor template (unit: mm)

3. Finite Element Model and Parameter Setting

3.1. Establishment of Finite Element Model

The numerical calculation model of the template was established by using the common finite element software ABAQUS and ANSYS. The PDCPD template was simulated by shell element, and the bolted connection between the templates was simulated by node coupling. The wall template model was divided into 14,275 and 13,650 nodes. The four sides of the eight templates are supported on the wall and the temporary support beam respectively, so they can be regarded as the support conditions of four simple supports. Therefore, the boundary conditions of the finite element model are as follows: the four sides of the template constrain the displacement of all nodes in the Dz direction. The finite element model of the wall template is shown in Figure 2[5].

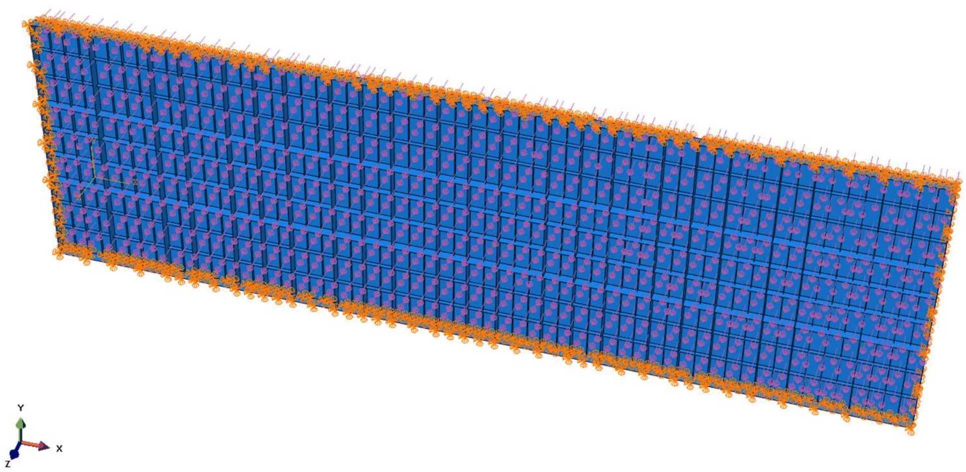

Figure 2. Finite element model of floor template

3.2. Material and Action Value

The elastic modulus of PDCPD is 1.8~2.1GPa, the density is 1.03 kg/m^3, the tensile strength is 46~52 MPa and the bending strength is 70~80 MPa.

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The floor formwork mainly bears the dead weight and the wet weight of concrete pouring, the bulk weight of concrete is 26kN/m^3, the thickness of the floor concrete is 150mm, the dead weight of the floor formwork is recorded as G_1, the dead weight of reinforced concrete is recorded as G_2, and the uniform load of construction personnel and equipment is G_3=2.5kN/m^2, then the effect value of the finite element calculation is:

Standard dead load: $F_1 = G_1 + G_2$

Standard live load: $F_2 = G_3$=2.5kN/m2

Constant load: $F_c = 1.2\times F_1$, used for deflection calculation

Live load: $F_L = 1.4\times F_2 = 1.4\times 2.5 = 3.75$kN /m^2

Total load: $F = F_c + F_L = 1.2\times F_1 + 3.75$

According to the original design drawings, the standard dead load is calculated: F_1=3.9kN/m^2, $F_c = 1.2\times F_1$=4.68kN/m^2, $F = F_c + F_L = 1.2\times F_1 + 3.75$=8.43kN/m^2.

3.3. Limit of Template Deformation

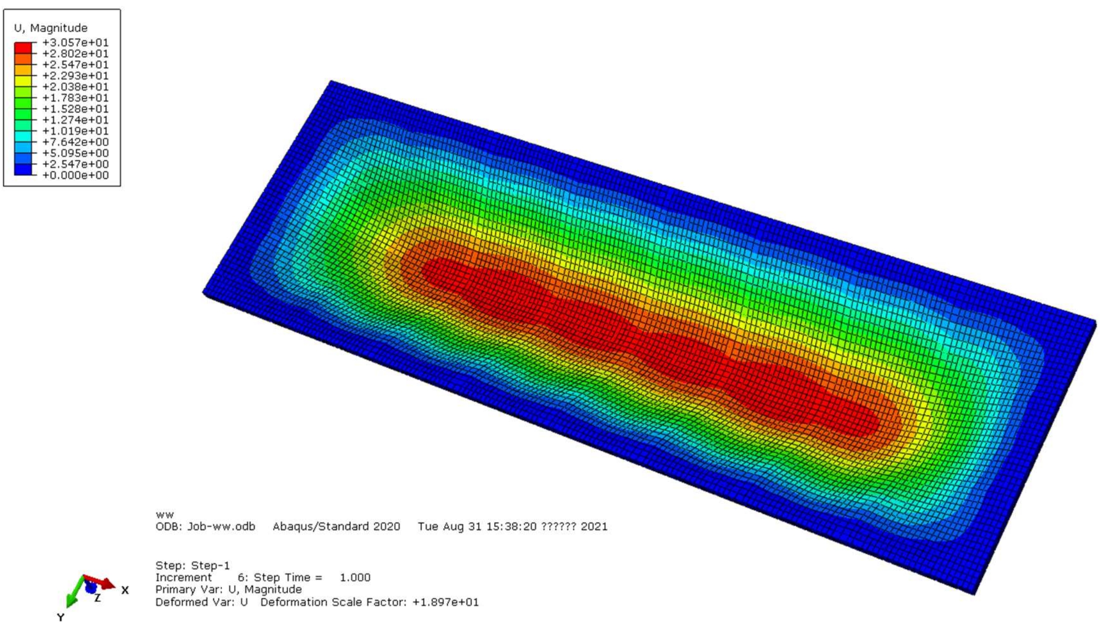
According to the "Concrete Structure Engineering Construction Code" (GB50666-2011)[6], the limit value of formwork deformation is determined according to article 4.3.9, that is, for the floor formwork of this analysis, the deflection shall not be greater than L/400 of the calculated span of the formwork member, and the calculated span of the formwork is the horizontal spacing between the vertical supports, so the deflection f of the formwork should meet:

$$f \le L/400$$

4. Calculation Results and Optimization Scheme

4.1. Deformation

The deformation of the floor formwork under the vertical pressure of concrete is shown in Figure 3. It can be seen that the larger deformation value of the template is located in the middle region, and the maximum displacement value is 30.6mm. The L value of the template is 1800mm, so f > L /400=1800/400=4.5mm, which does not meet the requirements.



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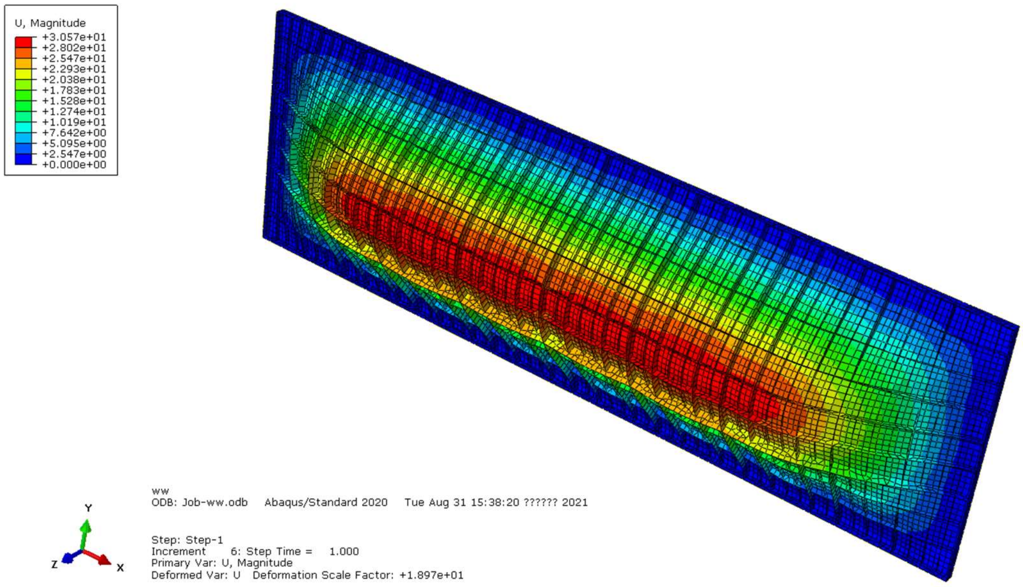

Figure 3. Calculation results of template deformation

4.2. Stress

The stress of the floor formwork under the vertical pressure of concrete is shown in Figure 4. It can be seen that the maximum stress of the template is 29.3MPa, which is located at the junction between the longitudinal rib and the transverse rib and the edge, and its value is less than the tensile and compressive strength of PDCPD material, and the strength meets the requirements.

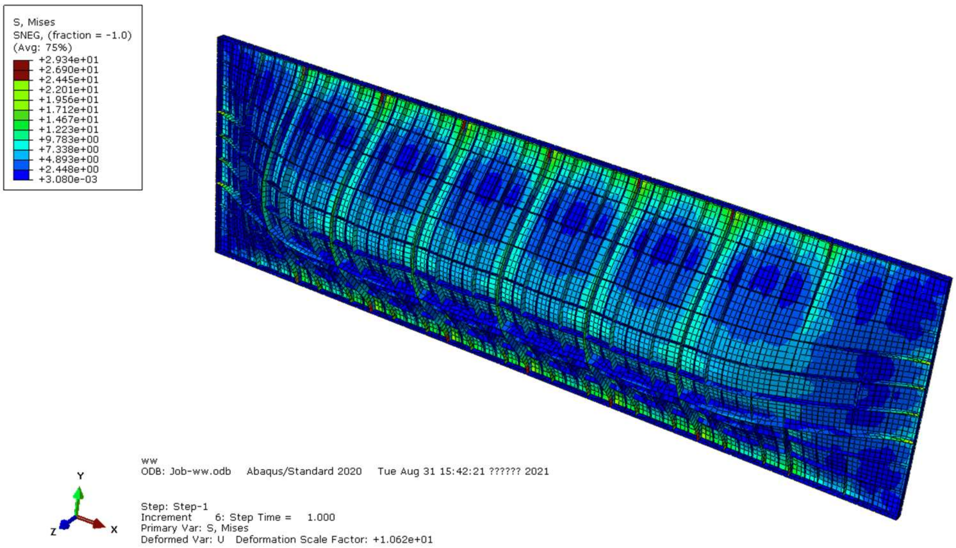

Figure 4. Calculation results of template stress

4.3. Optimization Scheme

The thickness of the panel of the original design template is 4mm, the thickness of the long rib is 10mm, and the thickness of the short rib is 15mm. The height of the floor is set according to the primary and secondary rib arrangement in the given length and width direction. In the optimized working condition, the main longitudinal ribs will be strengthened with steel plates along the span direction. The reinforced steel plate is 70mm high and 12mm thick, and the rest will remain unchanged in the original design structure. At this time:

standard dead load: F_1=4.06kN/m^2;

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constant load: $F_c = 1.2 \times F_1 = 4.87 kN/m^2$;
total load: $F = F_c + F_L = 1.2 \times F_1 + 3.75 = 8.62 kN/m^2$.

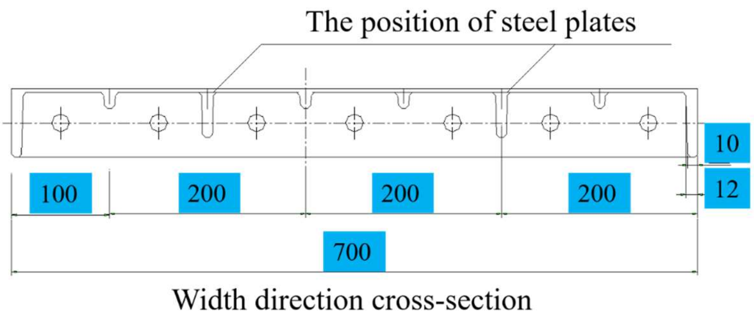

Figure 5. Schematic diagram of reinforced steel plate

The stiffness of the reinforced model was checked. Under constant load F, the deformation of the template was shown in Figure6. It can be seen that the larger deformation value of the template is located in the area of the secondary side plate, and the maximum displacement value is 2.4mm. The L value of the template is 1800mm, so f < L /400=1800/400=4.5mm, and the stiffness meets the requirements.

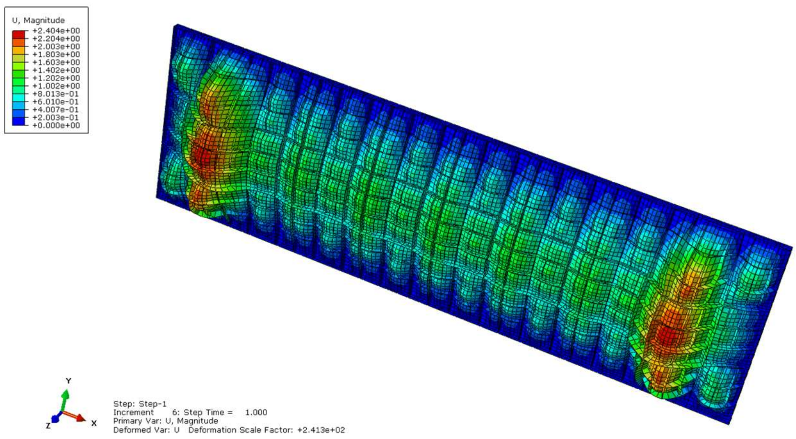

Figure 6. Calculation results of template deformation in optimization scheme

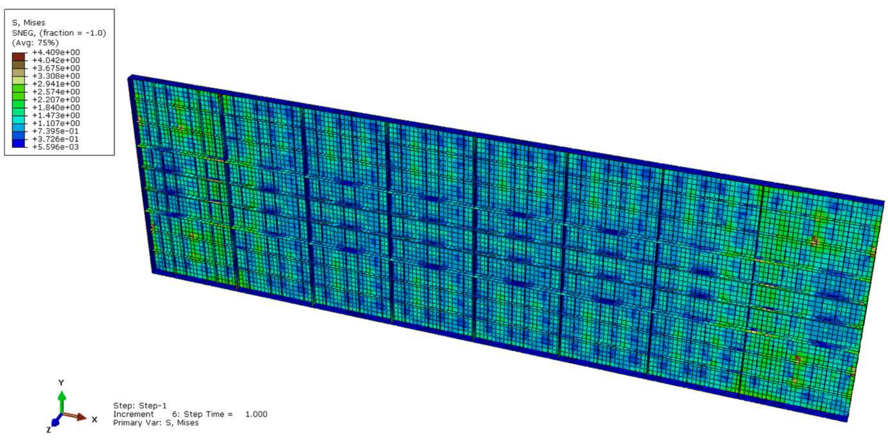

Figure 7. Calculation results of template stress in optimized working conditions

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The strength of the reinforced model was checked and calculated. Under the action of total load F, the stress of the template was shown in Figure7. It can be seen that the maximum stress of the template is 65.3MPa, which is located on the steel rib, far less than the yield strength of the steel. The stress of PDCPD floor and panel is relatively small, the maximum is 4.4MPa, which is less than the bending strength of PDCPD material, and the strength meets the requirements.

5. Conclusion

The finite element model of PDCPD wall formwork in an engineering example is established by using Abaqus, and the feasibility of this component is verified. The simulation results show that the maximum stress of the floor formwork is 29.3MPa under the action of vertical concrete pressure, which is located at the junction of longitudinal rib, transverse rib and edge, and the strength meets the requirements. However, the larger deformation value of the template is located in the middle region, and the maximum displacement value is 30.6mm, which exceeds the specification requirements.

On the basis of the original design, an optimization scheme was proposed to strengthen the main longitudinal ribs along the span direction with steel plates. The verification results showed that the maximum displacement value of the optimized model was 2.4mm and the maximum stress was 65.3MPa. The stiffness and strength of the optimized model met the requirements of the specification, and the applicability of the optimized scheme was good.

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