

Experimental Study on Composite Light-weight Microporous Concrete Cladding Panels

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Abstract. A new type of composite light-weight microporous concrete cladding panel was developed, with the compound function of retaining and heat preservation. Two specimens of the new cladding panel and connection detailing were made for out-of-plane bending experiment. The results indicate that the new cladding panel and its connection detailing are of sufficient stiffness, bearing capacity and deformability under wind load and out-of-plane seismic action.

1. Introduction

A new type of light-weight microporous concrete was developed, with satisfactory heat preservation property and acceptable compressive strength when used as retaining structure [1]. Precast concrete cladding panel is a significant precast concrete product, with the benefits of decreased on-site wet work burden, such as masonry and plastering, high construction efficiency and reduced construction waste [2].

Currently, the general solution of a precast cladding panel with combined functions of retaining and heat preservation is sandwich panels made of two layers of normal concrete and organic heat-insulating material in the middle[3][4]. Cladding panels made of inorganic material have better durability and fire-resistance performance, and are adaptive to simplified connection detailing. This paper introduces the experiment on a new kind of cladding panel, with compound functions of retaining and heat preservation, together with its connection detailing. Out-of-plane bending experiments on the cladding panel specimens were conducted to test their performance under wind load and out-of-plane seismic action.

2. Design and Construction of the Cladding Panel

The composite cladding panel has two layers, namely, the normal concrete layer on the outdoor side and the light-weight microporous concrete layer on the indoor side. Truss bars are designed through the interface of the two layers connecting the two layers, with the purpose of bearing the shear force induced by gravity load in real conditions and preventing relative deformation. The profile and reinforcement of the cladding panel specimen are shown in figure 1.

Figure 2a is the front view of dry connection. Figure 2b gives a detailed view of the connection between the panel and the beam. The panel is wet connected on the top side and dry connected on the bottom side. Two rows of protruding reinforcement steel stretches into the cast-in-place layer of the beam. The upper row is used as connection rebar and the lower row of rebar is designed to resist vertical shear force between the panel and the beam. The connection is dry joint which allows for relative horizontal slip under in-plane seismic action. Embedded parts are designed to adjust height of the panel (figure 2c). For the specimen, a composite beam is designed to simulate the actual boundary condition.



On the dry connection side, the embedded parts on the cladding panel are welded to the concrete blocks by steel angles.

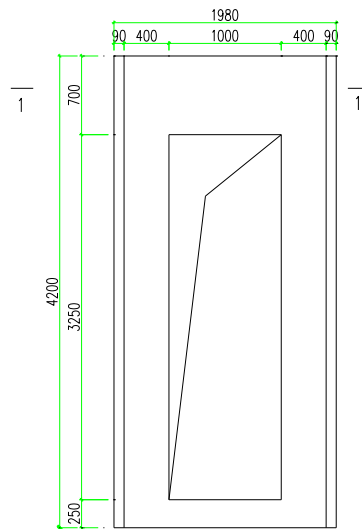


Figure 1a. Façade profile

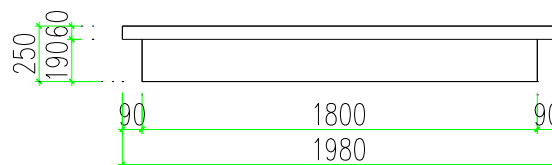


Figure 1b. Reinforcement drawing

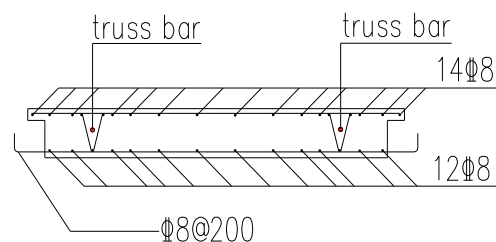


Figure 1c. Reinforcement

Figure 1. Dimensions and reinforcement of cladding panel

When manufactured in the factory, the panel mold was placed horizontally and the normal concrete, with relatively high density, was placed at the bottom layer. Two cladding panel specimens, numbered Plate A and Plate B, were produced, with the same detailing but different production process. For Plate A, the two layers of concrete were cast continuously, that is, the light weight concrete was cast before initial set of the normal concrete at the bottom layer. While for Plate B, the light-weight concrete was cast after the normal concrete had been hardened and its surface had been roughened.

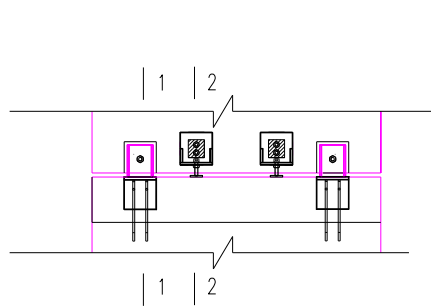
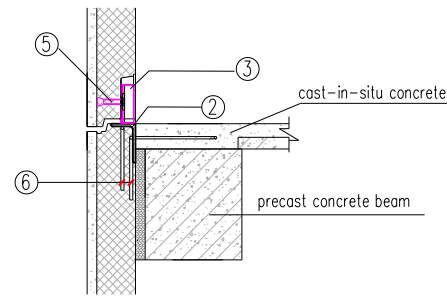
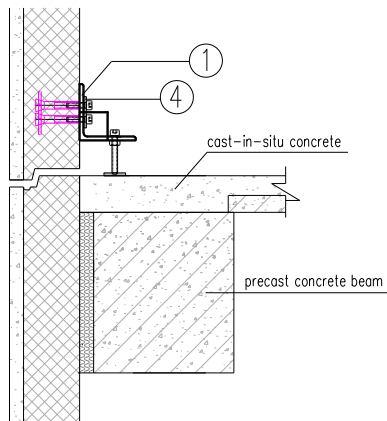
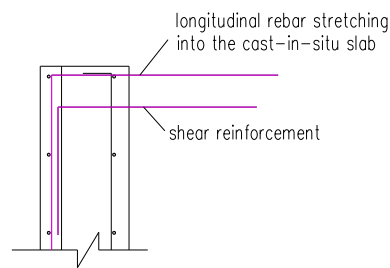
**Figure 2a.** Front view of the dry connection detailing**Figure 2b.** Section 1-1**Figure 2c.** Section 2-2**Figure 2d.** Detailing of wet connection

Figure 2. Connection detailing of the cladding panel (①-temporary steel angle for height adjustment, ②-protection steel angle at the top of the cladding panel, ③-channel steel, ④-double nuts, ⑤-anchorage rebar, ⑥-U-shaped rebar used to fix protection steel angle)

The compressive strength of light-weight microporous concrete is designed as LC10, and the normal concrete is designed as C30. According to Chinese design code [5], the characteristic compressive strength of light-weight and normal concrete are 10 MPa and 30 MPa, respectively. The compressive strength, modulus of elasticity and splitting strength of light-weight concrete were tested and the results are shown in table 1. The test results of rebar and normal concrete are in table 2.

Table 1. Material test results of light-weight microporous concrete.

	Cubic compressive strength / MPa	Axial compressive strength / MPa	Splitting tensile strength / MPa	Modulus of elasticity/ (10^4 N/mm ²)
Plate A	12.48	11.37	1.08	0.7974
Plate B	13.74	12.23	1.10	0.7458

Table 2. Material test results of rebar and normal concrete.

	Normal concrete		Rebar	
	Cubic compressive strength / MPa	Modulus of elasticity / (10^4 N/mm ²)	Yielding strength / MPa	Tensile strength / MPa
Plate A	36.3	3.22	452	651
Plate B	35.6	3.16		

3. Experimental equipment and loading condition

The loading equipment includes one actuator and three degrees of rigid distributing beam, in total, eight loading points on the panel to simulate uniformly distributed load on the surface of the cladding panel. The pressure was designed on the surface of light-weight concrete so that the light weight concrete, which has low compressive strength compared to that of normal concrete, was in compressive stress. Figure 3 shows the loading equipment and condition.

The loading was monotonic, and the control method was coupled force-displacement method. Force control method was adopted first with each increment of 5 kN, and was replaced by displacement control method after yielding of the specimen, and each increment was changed to 1.0 times the yielding deformation correspondingly.

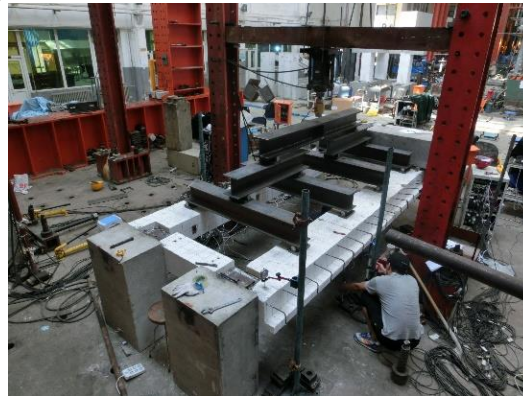


Figure 3. Loading equipment and condition

4. Experiment results

The main experimental results are shown in table 3. The phenomena was almost the same for Plate A and Plate B before reaching extreme state. In initial state of loading, the load-displacement curve was linear and the specimen was in elastic state. Visible cracks first occurred at the mid-span near the dry connected side, and it was transverse crack due to bending moment (figure 4). The cracks gradually grew wide and more cracks were observed as the load was increasing. The section stiffness decreased greatly and the crack was distributed widely and evenly in a wide range. Figure 4 was the crack distribution of Plate A before extreme state. No relative slip was observed at the interface of light-weight concrete and normal concrete. Most cracks at the bottom of specimen propagated to the two side surfaces and were able to penetrate the interface, indicating that the composite cladding panel was of desirable integrity. Figure 5 gives the load-displacement curves of the two specimens. The maximum deflection was obtained from the position about 3/8 span from the dry connected side. Obvious deformation and ductile failure mode were observed during the experiment.

The failure mode of Plate A was propagation of diagonal crack at the dry connection side and crushing of light-weight concrete. While the failure of Plate B was due to premature crushing of concrete block serving as the boundary connection of dry connection, with angle steel welded to the cladding panel.

Table 3. Experimental results.

	Yielding Capacity /kN	Yielding Displacement /mm	Ultimate Capacity /kN	Ultimate Displacement /mm
Plate A	113	32	172	120
Plate B	115	22	154	60

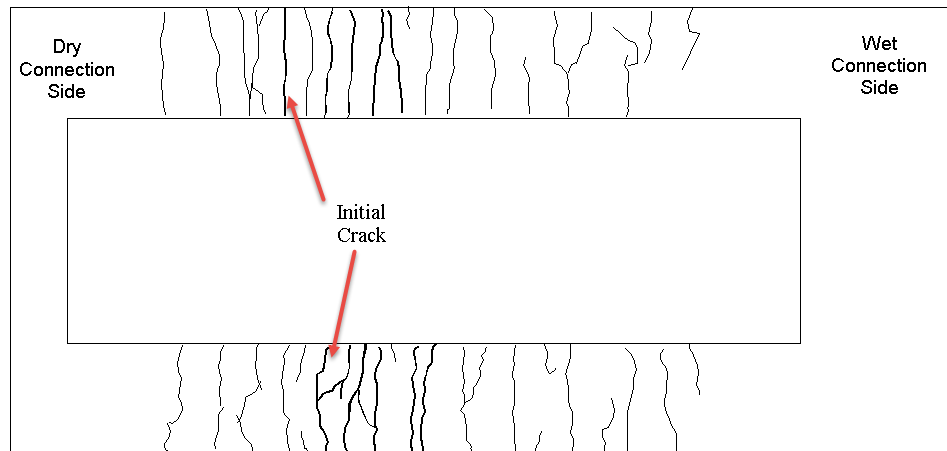


Figure 4a Crack distribution at the bottom of Plate A.



Figure 4b. Crack distribution at the two lateral surfaces of Plate A.

Figure 4. Crack distribution of Plate A.

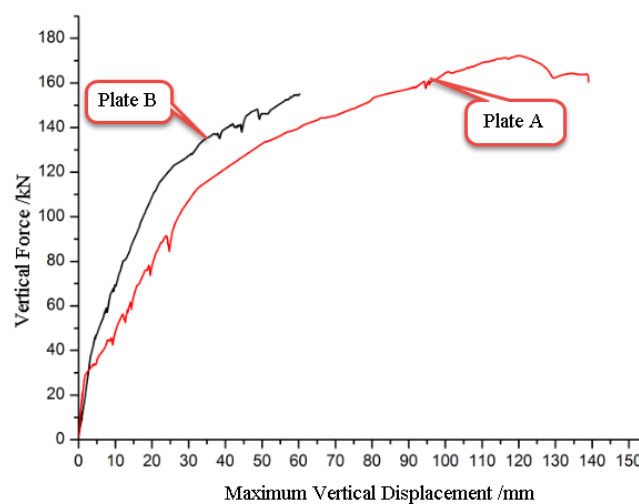


Figure 5. Comparison of Load-displacement curves

5. Conclusions and Suggestions

The novel composite light-weight microporous cladding panel, together with its emulative cast-in-plane and dry connections, are of satisfactory ductility, sufficient stiffness and bending capacity under wind load and out-of-plane earthquake action. Satisfactory bending compatibility between the two layers was observed, indicating that the effect of separate casting construction could be neglected. Separate casting construction is recommended under the situation of line production, for efficiency consideration.

Acknowledgements

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