Study on Flexural Performance of Integral Ceramic Wool-AAC Composite Wall Panel

Diqing Wang

College of Civil and Architectural Engineering, North China University of Science and Technology, Tangshan, Hebei, 063210, China

Abstract

To study the flexural performance of ceramic wool autoclaved aerated concrete composite wall panels (ceramic wool-AAC composite wall panels for short), four-point bending tests were conducted on the composite wall panels. The failure load of the panels was the measured value corresponding to the failure criteria specified in the code. The influences of structural forms on the flexural capacity, deflection, mid-span strain, interlayer slip and failure phenomena of the wall panels were discussed. The research results provide a theoretical basis and experimental data support for the design and application of ceramic wool-AAC composite wall panels.

Keywords

Ceramic Wool; Autoclaved Aerated Concrete; Four-point Bending Test; Mechanical Properties.

1. Introduction

In the field of modern architecture, the performance requirements of building materials are constantly improved, which should not only meet the demand of energy saving and environmental protection, but also have good mechanical properties and construction convenience. [1] As an enclosure component in prefabricated building systems, prefabricated composite exterior wall panels feature energy saving, thermal insulation, sound insulation and fire resistance.[2]

Compared with traditional walls, they are lighter in self-weight and allow faster construction. Research and development on prefabricated composite exterior wall panels started earlier in foreign countries, and mature technologies and complete specifications have been formed in the United States, Japan and Europe. In recent years, the development of green buildings and construction industrialization in China has promoted the application and development of prefabricated composite exterior wall panels.[3]

In the practical application of composite wall panels, the flexural performance of the whole panel is directly related to the wall’s ability to bear vertical and horizontal loads during actual service. Therefore, an in-depth study on the flexural performance of ceramic wool-AAC composite wall panels is of great practical significance.[4]

2. Test Overview

Aiming at the different thicknesses of autoclaved aerated concrete on the inner and outer sides of ceramic wool-AAC composite exterior wall panels, four-point bending tests were carried out to explore the mechanical properties and failure mechanism of the panels, including the flexural capacity and deflection of the panels, mid-span strain, interlayer slip of each layer and failure phenomena of the panels.

2.1. Specimen Design

Two groups of specimens were designed with the dimensions of 4200mm×600mm×(200, 300)mm (length×width×thickness). The specimens were made of autoclaved aerated concrete with a compressive strength grade of A3.5, ceramic wool and steel wire mesh frames. The steel wire meshes on both sides of the steel wire mesh frame had a mesh size of 50mm×50mm and a wire diameter of 3mm, the diagonal wire diameter was also 3mm, and the standard value of the tensile strength of the steel wire was 550N/mm^2. The detailed specifications of the specimens are shown in Table 1.

Table 1. Specifications of Specimens for Joint Bearing Capacity Test

Specimen No.	Specification(mm)	Structural Form	Quantity
LA3.5-200	4200×600×200	60mm-thick autoclaved aerated concrete on both inner and outer sides, 80mm-thick insulation layer	3
LA3.5-300	4200×600×300	60mm-thick autoclaved aerated concrete on both inner and outer sides, 80mm-thick insulation layer	3

2.2. Test Device and Measurement Scheme

The specimens were placed horizontally during the test. To simulate the uniformly distributed load borne by the panels, vertical loads were applied at the quarter points of the net span of the panels, and the vertical loads acted on the panels through distribution beams.

This test mainly measured the deflection, displacement and mid-span strain of the panels. There were 7 strain gauges arranged on the specimens of the LA3.5-200 group and 9 strain gauges on those of the LA3.5-300 group. Displacement gauges were installed at the mid-span, west edge and east edge of the specimens respectively.

2.3. Loading Scheme

The specimens to be tested shall be stored under the test conditions for no less than 24 hours, and the measurement and test can be carried out only after the state of the specimens is basically consistent with the laboratory conditions. First, the specifications of the panels (accurate to 1mm), the self-weight of the panels (accurate to 10N, see Table 3.1) and the total weight of the pressure steel plates, rollers and crossbeams used for loading (accurate to 10N) shall be measured and recorded. After the panels are placed stably, electronic displacement gauges shall be installed and their initial readings reset to zero, followed by a 2-minute no-load standing period before uniformly distributed loads are applied to the specimens in stages. In the early stage of the test, loads are applied in force stages with 1kN per stage and a loading rate of 1kN/min. In the later stage, when the load-displacement curve shows an obvious inflection point, the component undergoes large deformation or the deflection reaches L/200, loads are applied in displacement stages with 1mm per stage and a loading rate of 1mm/min. For the test measuring residual deformation, the load shall first be applied to the serviceability state, then the load shall be removed and re-applied until the specimen fails. When the first crack appears on the specimen during loading, loading shall be suspended to read and record the measured values of the concentrated load, mid-span deflection and support displacement at both ends at the initial cracking stage. After a 5-minute standing period, if the specimen is not damaged, continue loading to the ultimate load. Loading shall be stopped immediately, the measured failure load shall be recorded and the test shall be terminated when any of the following three phenomena occurs: the maximum crack width of the main tensile steel bar reaches 1.5mm or the deflection reaches 1/50 of the span (take 1.20), the autoclaved aerated concrete at the compressed part is damaged (take 1.30), or the main tensile steel bar is broken (take 1.60). The crack development law and the load-displacement curve shall be observed throughout the test, and loading shall be stopped when the load-displacement curve enters the descending section, the specimen is damaged and the load drops to 85% of the ultimate load. It should be noted that the load acting on the specimen consists of two parts: the load applied by the loading device and the self-weight of the specimen.

3. Test Results and Analysis

3.1. Test Phenomena and Failure Characteristics

In the integral bearing capacity test of ceramic wool-AAC composite exterior wall panels, the test phenomena of the six specimens of LA3.5-200 and LA3.5-300 were basically the same. At the initial loading stage, the mid-span deflection changed slightly with no obvious test phenomena observed. As the stress increased, the specimens occasionally made a banging sound in the middle loading stage, and the acquisition instrument showed corresponding instantaneous numerical changes, but no obvious cracks were found on the specimens. From the images captured by the camera, it can be seen that the bending deformation of the specimens at the late stage of the test was obvious compared with that at the initial stage, with mid-span settlement occurring. The test was terminated due to the brittle failure of the specimens, which was accompanied by an instantaneous through crack at the bottom of the panel extending to the side of the panel, and the longitudinal steel wires inside the concrete were broken. The failure areas were all between the mid-span and the quarter points on both sides of the panel, and no slip was found between the inner and outer leaf wall panels and the internal ceramic wool.

3.2. Analysis of Load-Strain Curves

In the integral bearing capacity test of ceramic wool-AAC composite exterior wall panels, the load-strain curves of the six specimens of LA3.5-200 and LA3.5-300 showed similarity, so the curve of specimen LA3.5-300-2 was selected for analysis. Due to the small thickness of concrete on both sides of the ceramic wool, the panel could not bear a large bearing capacity. When the bearing capacity reached 10.43kN, the middle part of the panel mid-span was damaged first, leading to abrupt changes in the strain values of all parts at the mid-span, and the concrete mortar at the positions of strain gauges 4, 5 and 6 ceased to work. This was the first failure of the specimen, and the bearing capacity at this time was named the local failure bearing capacity. After that, the specimen was divided into two working areas: the mortar at the top strain gauge and strain gauge 1 in the upper part remained as the compressed zone unchanged, while the mortar at strain gauges 2 and 3 turned into the tensile zone with the strain values abruptly changing to positive values; the mortar at strain gauge 7 in the lower part became the area near the neutral axis, and the bottom strain gauge remained as the tensile zone unchanged. With the continuous increase of bearing capacity, the specimen suffered brittle failure and the test was terminated, with the ultimate bearing capacity being 18.66kN.

3.3. Analysis of Load-Deflection Curves

In the integral bearing capacity test, specimens LA3.5-200-3 and LA3.5-300-1 were selected as the research objects for the analysis of mid-span stress-deflection curves. The mid-span deflection increased gradually with the increase of stress, and the mid-span displacement reached the maximum when the test reached the ultimate bearing capacity. It is worth noting that during the loading process, every time the specimen made a banging sound, the stress would slightly flatten or decrease a little, and then increase gradually. However, the overall performance was that the stress changed proportionally with the mid-span deflection, and the curvature of the curve increased gradually.

For the analysis of east/west side stress-deflection curves in the integral bearing capacity test, specimens LA3.5-200-1 and LA3.5-300-3 were selected as the research objects. The vertical displacement on the east side was less than 1.5mm and that on the west side was also less than 1.5mm, indicating that the supports at the hinged supports on both sides were very stable, with no obvious slip and deformation phenomena observed.

4. Conclusion

In the integral bearing capacity test, it was found that the ceramic wool-AAC composite panels had no obvious ductile change and suffered brittle failure. The ultimate load of the integral panel was generally higher than that under bolt connection, indicating that the composite panels had a high compatibility with bolts. The flexural performance of the 300mm-thick specimens was greatly improved compared with the 200mm-thick specimens, with the local failure bearing capacity increased by 120% and the ultimate bearing capacity increased by 92%. Therefore, appropriately increasing the panel thickness has great application value.

Acknowledgments

Tangshan Huaxian Technology Co., Ltd.

References

[1] Małyszko L, Kowalska E, Bilko P. Splitting tensile behavior of autoclaved aerated concrete: Comparison of different specimens' results. Construction and Building Materials, 157, 1190–1198.

[2] Liu Y, Chen G, Wang Z, et al. On the Seismic Performance of Autoclaved Aerated Concrete Self-Insulation Block Walls[J]. Materials, 2020, 13(13): 2942-2942.

[3] Rahman R A, Fazlizan A, Asim N, Thongtha A . A Review on the Utilization of Waste Material for Autoclaved Aerated Concrete † Production. Journal of Renewable Materials, 9(1), 61–72.

[4] Shon, C S, Mukangali I, Zhang D, Ulykbanov A, Kim J. Evaluation of Non-Autoclaved Aerated Concrete for Energy Behaviors of a Residential House in Nur-Sultan, Kazakhstan. Buildings, 11, 610.