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Experimental and Numerical Studies on the Behaviors of Autoclaved Aerated Concrete Panels with Insulation Boards Subjected to Wind Loading

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Abstract: Autoclaved aerated concrete panels (AACP) are lightweight elements in civil engineering design. In this paper, experiments and numerical analyses were conducted to study the flexural behavior of an enclosure system that consisted of AACPs and a decorative plate. A full-scale test was conducted to investigate the behavior of the enclosure system under wind suction. Load–deflection curves and load–strain relationships under different wind pressures were recorded and discussed. The effects of thickness, reinforcement ratio, and strength grade on the flexural behavior of AACPs were numerically investigated. Based on the numerical results, we found that the flexural behavior of AACPs can be improved by increasing the thickness or the reinforcement ratio. A comparison of finite element and theoretical results calculated using American and Chinese design formulae was conducted, and the results indicated the existing design formulae can conservatively estimate the major mechanical indices of AACPs.

Keywords: AACPs; wind suction test; numerical simulation; mechanical property; flexural behavior

1. Introduction

With the implementation of the policy for energy conservation and emission reduction, prefabricated constructions are gaining increased attention. The traditional exterior thermal insulation system usually adopts the combination of a cladding panel and a polystyrene board. This type of insulation system incurs high material costs and is prone to exterior wall detachment and burning of the construction material. Therefore, it is of great significance to develop a new assembly envelope system to solve the deficiencies of the existing system. Autoclaved aerated concrete (AAC) has the advantages of low weight, prefabrication, and good heat and sound insulation, which results in a wide prospect in engineering applications. As a lightweight element used in high-rise buildings, the wind-resistance of an enclosure system consisting of AACPs is important in engineering design, especially for buildings near coastal areas. Previous studies mainly focused on the physical properties of AAC [1–3]. However, there are only a handful studies focusing on the impact of wind pressure on the enclosure system.

A series of experimental tests were conducted by Nasim Uddin et al. [4] to investigate the flexural behavior of hybrid fiber-reinforced polymer–autoclaved aerated concrete panels (FRP-AAPCs). Their results showed that the flexural capacity of the composite FRP could be improved significantly. Benayoune et al. [5] tested a group of precast concrete sandwich composite panels and concluded that the flexural failure mode of the proposed composite panels was similar to that of conventional concrete panels. Carbonari et al. [6] experimentally investigated the flexural behavior of light-weight sandwich panels with



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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). perpendicular connectors under different boundary conditions and found that the shear connectors had only a small impact on the stiffness of the structure, whereas the failure mode was governed by the yield strength of rebars. Raj et al. [7] adopted basalt fiberreinforced composite panels as the top and bottom skins of the system. The subsequent flexural tests validated the satisfactory ductility of the proposed composite panel. Amran et al. [8] conducted six full-scale tests to study the behavior of precast foamed concrete sandwich panels (PFCSPs). The results showed that the larger the length/thickness ratio, the smaller the ultimate flexural capacity of the PFCSPs. Moreover, Pan et al. [9] conducted experimental and numerical analyses of cold-formed thin-walled steel composite walls, which were infilled with light polymer material, and concluded that the steel-strength panel species had major impact on the bending capacity of the proposed composite wall. Rozylo et al. [10,11] experimentally and numerically investigated the stability of thinwalled structures made of composite materials, in which the loss of load capacity was evaluated through three independent damage models. Zang et al. [12] experimentally studied the mechanical behavior of a CFRP laminate with cutout under free vibration and numerically investigated the effects of cutout shape, size, location, and number on free vibration. It was an effective method to study the flexural performance of an AAC wall through the abovementioned static test. As AAC are one of the most commonly used enclosure systems in high-rise buildings, it is necessary to investigate the mechanical behaviors of AAC partitions and their envelope system through the wind loading test. The application of the wind suction test, which considers the dynamic response of the assembling enclosure system consisting of an AAC wall and an insulation panel, constitutes a novelty in comparison to other similar studies.

In the present study, an assembly enclosure system that consisted of an AAC wall and an insulation plate is proposed. A full-scale wind suction test was conducted to investigate the physical behavior of the envelope system, and the deflection and strain responses of the specimen were measured during the test. Finite-element analysis was carried out to study the effects of thickness, reinforcement ratio, and compressive strength on the flexural behavior of the AAC panel. Finally, a comparison of the FE and the design results, calculated with the formulae suggested by Chinese and American standards, was performed.

2. Materials and Methods

2.1. Specimens and Loading Protocols

Based on the dimensions (2890 mm \times 1250 mm \times 2360 mm) of the wind pressure chamber (as shown in Figure 1), a full-scale enclosure system consisting of an AAC wall and a mineral wool–aluminum plate was manufactured and tested. The AAC wall had the dimensions of 3000 mm \times 150 mm \times 2440 mm and consisted of four pieces of autoclaved aerated concrete panels (AACPs), whose transverse width was 600 mm. As shown in Figure 2, an HPB 300 steel rebar with a diameter of 6.5 mm was employed in the AACPs. The compressive strength of concrete was 3.23 MPa, determined using compression tests on 150 mm \times 150 mm \times 150 mm concrete cubes. A uniform gap of 5 mm existed between two consecutive AACPs and was filled with a masonry mortar. As shown in Figure 3a, the AAC wall was mounted in a steel frame that consisted of four rectangular steel tubes having the same dimensions through built-in anchors. The outer insulation mineral wool–aluminum plate was finally fixed on the AAC wall with the bonding mortar and anchors (Figure 3b,c).



Figure 1. Wind pressure chamber.



Figure 2. Schematic of the AACP (units: mm).



Figure 3. Assemblage of the enclosure system. (**a**) Assembly of AACPs and steel frame. (**b**) Assembly of AACPs and insulation plate. (**c**) Side view of the enclosure system.

2.2. Test Setup and Measurement Device

As specified in the technical guidelines for external thermal insulation engineering based on insulated decorative panels [13], the experimental procedures and requirements were set to be as follows.

1. The enclosure system specimen was closely installed on the wind pressure chamber, and a rubber insulation pad was adopted to ensure the tightness between the specimen and the chamber.

2. Based on the fundamental wind pressure of Zhanjiang city, China, three different levels of wind loads were successively applied to the full-scale specimen. A total of 4245 pulses with three stages were imposed cyclically on the specimen. A standard stage of wind load is shown in Figure 4, in which W denotes the design peak wind pressure. Each stage consisted of 1000, 400, 10, 4, and 1 pulses, which corresponded to 40%, 60%, 80%, 90%, and 100% of the peak pressure. Three design peak wind pressures ω of 3.50 kPa, 4.24 kPa, and 5.02 kPa, which represented the building heights of 15 m, 40 m, and 80 m (Table 1), respectively, were applied. The corresponding standard value of wind pressure can be calculated based on the load code for the design of building structures [14] as follows:

$$w_{\rm k} = \beta_{\rm gz} \mu_{\rm sl} \mu_{\rm z} w_{\rm o} \tag{1}$$

in which β_{gz} is the gust coefficient, μ_{sl} denotes the local shape coefficient, μ_z means the height variation factor of wind pressure, ω_0 is the reference wind pressure.

3. The test would be terminated if the insulated decorative panel or the anchor bolt was blown off.



(a) Pulse frequency distribution

(b) Pulse duration

Figure 4. Loading protocol.

Table 1. Calculation coefficients corresponding to different heights.

Height (m)	$eta_{ extbf{gz}}$	$\mu_{\rm sl}$	μ_z	ω_0	$\omega_{ m k}$ (kN/m²)	ω (kN/m ²)
15	1.57	-1.4	1.42	0.80	-2.50	-3.50
40	1.51	-1.4	1.79	0.80	-3.03	-4.24
80	1.47	-1.4	2.18	0.80	-3.59	-5.02

Figure 5 shows different views of the test setup. A total of eight linearly variable displacement transducers (LVDTs) were settled at the back of the AAC wall to measure the lateral deformation of the panel, as shown in Figure 6. A total of 25 strain gauges were attached to the quarter heights and the panel seams and recorded the stress responses of the AAC wall and the insulation plate (Figure 7). Fourteen strain gauges were arranged at the front and back of the AAC wall, whereas the other 11 strain gauges were mounted on the outside surface of the insulation plate.



(a) Rear view

Figure 5. Setup for the wind suction test.



(b) Side view



Figure 6. Position of the LVDT.



Figure 7. Arrangement of the gauges.

3. Results

As seen in Figure 8, no cracking of the decorative plate and pulling out of the connection between the AAC wall and the decorative panel were observed. Figure 9 shows the deflection curves of the W-4, W-5, and W-6 measurement points, which were located at the half-height of the AAC wall. It can be seen in Figure 9 that the deflections at W-4 were slightly greater than those at W-5 and significantly greater than those at W-6 during the test. The reason may be that the wind pressure applied on the specimen was not even, which caused the specimen to turn towards the right edge. Figure 10 presents the deflection responses of all measurement points under the highest level of wind pressure (Level 3). The maximum deflections of all measurement points were greater than 2.3 mm. However, the maximum deflection of W-6 was 1.4 mm. This indicated that a rotation around the right support was indeed caused by the wind load during the test.



Figure 8. Inside view after the test.



Figure 9. Deflection histories of the measurement points at half-height of the specimen.



Figure 10. Deflection histories of all measurement points.

Figure 11 shows the envelope strain responses at the center of the decorative panel during the last stage of the wind pressure test (Level 3). It can be drawn from Figure 11 that

the strain gradually raised with the increasing of the wind suction until the peak strain was achieved. However, the strain curve in the descent stage and that in the ascent stage were not symmetric with respect to the peak point. The reason may be that plastic strain was induced with the increase of the wind load. No fracture was observed on the weatherproof sealant near the seams after the test. Moreover, the flexural strain reached the maximum value of 500 at Y-9 under the peak wind suction, which indicated that the control point was on the outer surface of the central area for the two-way panel.



Figure 11. Envelope strain responses of the decorative panel.

4. Numerical Simulations

The failure mode of the assemble enclosure system was not examined due to the limited loading capacity of the wind pressure chamber, although the real responses of the enclosure system were obtained through the wind suction test. Thus, it is necessary to further investigate the mechanical behavior of the envelope system based on the finite element simulation. This section mainly focuses on the wind-resistant behavior of the AAC wall; the effect of the insulation panel was ignored due to the difficulties in accurately modeling the interaction between the built-in anchor and the panel. As the main bearing part of the enclosure system, the AAC wall can be regarded as a pure bending element under wind suction [5,7]. Therefore, static analyses in a four-point loading were adopted here.

4.1. Model Description

Finite element analysis was performed on the AACP using the software package ABAQUS [15]. According to the requirement of Autoclaved aerated concrete slabs [16], five different thicknesses (150 mm, 175 mm, 200 mm, 250 mm, and 300 mm), three reinforcement ratios ($\rho = 0.2\%$, 0.3%, and 0.4%), and three strength grades (A3.5, A5.0, and A7.5) of concrete were adopted. Thus, a total of 18 AACP specimens were considered in the current numerical study.

All the numerical models consisted of a piece of AACP with the dimensions of $3800 \text{ mm} \times 600 \text{ mm} \times 300 \text{ mm}$ and four rigid cushion blocks (Figure 12), and the detail of the AAC model is presented in Figure 13. The cushion blocks were connected to the AACP using the tie constraint, and the embedded region was used to simulate the interaction between the AAC and the internal rebars. Two of the cushion blocks were assembled at one quarter point of the specimen, while the others were arranged at the ends of the AACP, as shown in Figure 12. Fixed and simple constraints were adopted at the bottoms of the left and right cushion blocks, respectively, and the horizontal distance between them was 3400 mm. The lateral displacement was applied on the AAC panel through two reference points, which was coupled with the upper surface of the top cushion blocks. Both the AACP and the cushion block were modeled using eight-node brick solid elements with the reduced-integration technique (C3D8R), whereas the two-node linear truss elements (T3D2) were used for the rebars inside the concrete panel. The mesh size of 50 mm was used

for the AACP and the cushion blocks, and that of 10 mm for the embedded rebars. The 'Concrete Damaged Plasticity' material model was adopted for the AAC. The parameters of the 'Concrete Damaged Plasticity' material model are listed in Table 2. The elastic perfectly plastic model with a yield stress of 350 MPa was considered for the rebar. The other material properties of AACP are presented in Table 3 [17]. Mesh analysis was conducted to consider the effect of mesh density on the simulation results. As shown in Figure 14, the flexural response of the model with a mesh density of 25 mm was almost identical to that of the model with a density of 50 mm. Thus, the mesh size of 50 mm was utilized to avoid complex calculations in the subsequent parameter analyses.



Figure 12. Finite element model of the specimen.





Tal	ole	2.	Parameters	of the	concrete	damaged	p	lasticity mode	l.
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ψ	ϵ	σ b0/ σ c0	K	μ
30°	0.1	1.16	0.6667	0.0005

Note: ψ is the dilation angle, ϵ is the flow potential eccentricity, σ_{b0}/σ_{c0} is the ratio of the initial equibiaxial compressive yield stress to the initial uniaxial compressive yield stress, K is the ratio of the second stress invariant on the tensile meridian to that on the compressive meridian, and μ is viscosity.

Table 3. Material properties from the coupon tests.

Category/Material	Elastic Modulus	Yield Strength	Tensile Strength	Compressive	Poisson's Ratio
Grade	(×105 MPa)	(MPa)	(MPa)	Strength (MPa)	
AAC Rebar	0.02 2.10	- 350	0.28	2.88	0.2 0.3



Figure 14. Mesh analyses results for the AACP.

Based on the modeling strategy described above, Figures 15 and 16 show the calibrated load–deflection responses and the simulated flexural behavior of model S3-A77-1 from the Chen's experimental results [17]. The maximum error of flexural stiffness between the numerical analysis results and the test results was less than 10%, and that of ultimate flexural capacity between the two analyses was less than 8%.



Figure 15. Calibrated load–deflection curves for the AACP.



Figure 16. Flexural behavior of the numerical model S-A77-1 [17].

4.2. Thickness of the AACP

In this section, the effect of the thickness of the AACP on the flexural behavior of AACPs was numerically studied. Fifteen finite element analyses were performed on the AACPs, including different thicknesses and reinforcement ratios. Three common reinforcement ratios ($\rho = 0.2\%$, 0.3%, and 0.4%) were chosen for the AACP models. The moment–curvature curves of the models are shown in Figure 17. It can be seen from Figure 17 that, with the increase in thickness, the cracking moment and the ultimate flexural capacity of the AACPs increased. When the thickness exceeded the value of 200 mm, there was an apparent increase in the ultimate flexural capacity for the three groups of models. Moreover, increasing the thickness also improved the flexural stiffness of the AACPs, as seen in Figure 17.



Figure 17. Effect of the thickness of the AAC wall.

4.3. Reinforcement Ratio

As mentioned in Section 4.2, three types of reinforcement ratios were considered in the current study. Figure 18 presents the moment–curvature responses of 15 numerical models. Obviously, flexural stiffness, cracking moment, and ultimate flexural capacity can be enhanced with the increase of the reinforcement ratio. Figure 19 shows the curves of cracking moment vs. thickness and ultimate flexural moment vs. thickness of finite element models. It can be seen from Figure 19 that the relationship between the cracking moment and the thickness was not linear, and neither was that between the ultimate flexural capacity and the thickness. When the thickness was increased to 200 mm, there was an apparent increase in the slope of the first curve. When the thickness reached the value of 175 mm, a slight change in the slope of the last curve was observed. Therefore, it is a cost-effective recommendation that the thickness of the AACP should be greater than 200 mm in the design to improve its flexural behavior.





Figure 18. Effect of the reinforcement ratio.



Figure 19. Comparison of the cracking moment (and ultimate flexural capacity) among the AACPs with different thicknesses.

4.4. Strength Grade of AAC

Three numerical models with different strength grades (A3.5, A5.0, and A7.5) were established to investigate the effect of the strength grade on the flexural behavior of the AACP. Figure 20 shows the moment–curvature curves of the three models. It can be seen from Figure 20 that the strength grade had little effect on the flexural behavior of the AACP. With the increase in the strength grade, the flexural stiffness of the AACP improved, whereas the cracking moment increased from 2.58 kN·m to 2.85 kN·m, indicating an enhancement of around 10.5%. The flexural capacity of AAC slab also increased from 10.16 kN·m to 10.61 kN·m, indicating an enhancement of about 4.4%. Therefore, it can be concluded that the thickness and reinforcement ratio are the main parameters affecting the flexural performance of the AACP.



Figure 20. Effect of the strength grade.

4.5. Comparison of the Theoretical and Finite Element Results

As specified in the Chinese code for the design of concrete structures [18], the flexural capacity of concrete can be estimated using Equation (2)

$$M \le \alpha_1 f_c b x (h_0 - x/2) \tag{2}$$

where *b* represents the width of the AACP, h_0 denotes the effective height of the crosssection of the slab, f_y is the design value of the tensile strength of the longitudinal rebar, f_c is the design value of the compressive strength of the AAC, and A_s is the cross-sectional area of the longitudinal rebar. The depth of the compression zone *x* can be obtained by solving Equation (3)

$$\alpha_1 f_{\rm c} b x = f_{\rm v} A_{\rm s} \tag{3}$$

where $\alpha_1 = 1.0$ when the strength grade of concrete is less than C50.

According to the Chinese JGJ/T 17-2020 standard [19], the flexural capacity of the AACP can be determined using Equation (4)

$$M \le 0.75 f_{\rm c} b x \left(h_o - \frac{x}{2}\right) \tag{4}$$

It is apparent that the difference between Equations (2) and (4) is the coefficient α_1 .

American RILEM [20] proposed a design correlation for calculating the flexural capacity of the AACP, as given by Equation (5)

$$M = f_{\rm c}bh^2 \left[\alpha s(1 - \beta s) + c' \left(1 - \frac{d_2}{h} \right) \right]$$
(5)

where $\alpha = 1 - \frac{(1-s)k}{s} \le \alpha_{\max} = 0.667$, $s = \frac{k+c-c'}{1+k}$, $k = \frac{\varepsilon_{cy}}{2\varepsilon_{su}}$, $c = \frac{A_s f_y}{b h f_c}$, $c' = 0.75c \left(\frac{A_s'}{A_s}\right)$, $\beta = \frac{2k(1-s)[-1+2k(1-s)/(3s)]+s}{2s-2k(1-s)} \le \beta_{\max} = 0.361$, d_2 and h represent the depth of compressive and tensile rebars, respectively, ε_{cy} represents the maximum compressive strain of concrete, ε_{su} denotes the ultimate tensile strain of the rebar, and A_s'' is the cross-sectional area of the longitudinal compressive rebars.

Figure 21 shows the comparison of the ultimate flexural capacities of the finite element results and the theoretical ones as calculated using the American and Chinese specifications [18–20]. It can be seen from Figure 21 that the three design correlations can conservatively estimate the ultimate flexural capacities of AACPs. The calculated results obtained using Equation (4) were the closest to the simulated results, with a maximum error of 27%. Moreover, Equation (4) resulted in the lowest evaluation of the ultimate flexural capacity, with a maximum error of 50%.



Figure 21. Comparison of different correlations for the flexural capacities of AACPs.

As specified in the Chinese code for the design of concrete structures [18], the cracking moment of concrete M_{cr} can be estimated using Equation (6)

$$M_{\rm cr} = M_{\rm c} + M_{\rm s} = \frac{1}{2} f_{\rm t} b \frac{h}{2} (h - 2 \times \frac{1}{3} \times \frac{h}{2}) + \sigma_{\rm s} A_{\rm s} (h - 2\alpha_{\rm s})$$
(6)

where E_s and E_c denote the elastic moduli of the rebar and concrete, respectively, α_s represents the distance between the resultant point of tensile reinforcement and the edge, and σ_s is the stress of the rebars, which is calculated by Equation (7)

$$\sigma_{\rm s} = E_{\rm s}\varepsilon_{\rm s} = \frac{E_{\rm s}}{E_{\rm c}}\frac{h_0}{h}f_{\rm t} \tag{7}$$

Figure 22 shows that the cracking moments of all the numerical models were greater than those obtained using Equation (6), and the maximum error between the theoretical results and the FE ones was less than 25%. Therefore, Equation (6) can be used to estimate the cracking moment of the AACP.



Figure 22. Comparison of the cracking moments calculated by the theoretical and the FE methods.

According to the technical specification for application of autoclaved aerated concrete [19], the flexural stiffness B_s of an AACP is expressed by Equation (8)

$$B_{\rm s} = 0.85 E_{\rm c} I_0 \tag{8}$$

where I_0 denotes the moment of inertia of AACP. Figure 23 presents the comparison of the flexural stiffnesses calculated by the numerical modeling and the theoretical method [19]. It can be seen from Figure 23 that the maximum error between the results obtained by the two strategies was less than 30%, and the simulated results were greater than the designed ones. Therefore, Equation (8) can be used to evaluate the flexural stiffness of an AACP. This paper mainly focused on the effects of thickness, reinforcement ratio, and strength grade on the flexural behavior of AACPs. Therefore, it should be noted that the specimen parameters should be within the range selected in this paper, when referring to the results of this paper. Future concerns should be paid to the effects of concrete cover thickness and reinforcing bar strength, and the effect on the flexural behavior of AACPs should be another key issue.



Figure 23. Comparison of the flexural stiffnesses.

5. Conclusions

In this study, a full-scale wind pressure test and a series of finite element analyses were conducted to investigate the flexural behavior of the assembled enclosure system. Based upon the results, following conclusions are drawn.

The assembly enclosure system consisting of the AACPs and a decorative plate exhibited good wind-resistant performance. There was no cracking of the decorative plate and no pulling out of the connection between the AAC wall and the decorative panel during the test. The control point of the decorative panel was at the center of its outside surface. The finite element results showed that the thickness of the AACP and the reinforcement ratio had major effects on the flexural behavior of the AACP, while the strength grade of AAC had little impact. The major performance indices of the AACP can be improved with the increase of thickness or of the reinforcement ratio. The current Chinese and American standards can conservatively estimate the flexural stiffness, cracking moment, and ultimate flexural capacity of an AACP. The flexural capacity of an AACP can be evaluated by the design formula proposed by American RILEM with a maximum margin of 27%. Using the equation recommended by the Chinese code for the design of concrete structures it is possible to assess the cracking moment of an AACP with a maximum error of 25%. According to the technical specification for application of autoclaved aerated concrete, the maximum error on the flexural stiffness of the AACP between the theoretical and finite element results was less than 30%.

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References

- 1. Shi, C.J.; Fouad, F.H. *Autoclaved Aerated Concrete-Properties and Structural Design*; Special Publication; American Concrete Institute: Farmington Hills, MI, USA, 2005; Volume 226.
- 2. Ferretti, D.; Michelini, E.; Rosati, G. Mechanical characterization of autoclaved aerated 2 concrete masonry subjected to in-plane loading: 3 experimental investigation and FE modeling. *Constr. Build. Mater.* **2015**, *98*, 353–365. [CrossRef]
- Wakili, K.G.; Hugi, E.; Karvonen, L.; Schnewlin, P.; Winnefeld, F. Thermal behaviour of autoclaved aerated concrete exposed to fire. *Cem. Concr. Compos.* 2015, 62, 52–58. [CrossRef]
- 4. Uddin, N.; Fouad, F.; Vaida, U.K.; Khotpal, A.; Serrano-Perez, J.C. Structural Characterization of hybrid fiber reinforced polymer (FRP)-autoclave aerated concrete (AAC) panels. *J. Reinf. Plast. Compos.* **2006**, *25*, 981. [CrossRef]
- Benayoune, A.; Abdul Samad, A.A.; Trikha, D.N.; Ali, A.A.; Ellinna, S.H.M. Flexural behaviour of pre-cast concrete sandwich composite panel-Experimental and theoretical investigations. *Constr. Build. Mater.* 2008, 22, 580–592. [CrossRef]
- 6. Carbonari, G.; Cavalaro, S.H.P.; Cansario, M.M.; Aguado, A. Flexural behaviour of light-weight sandwich panels composed by concrete and EPS. *Constr. Build. Mater.* **2012**, *35*, 792–799. [CrossRef]
- Raj, S.; Kumar, V.R.; Kumar, B.B.H.; Gopinath, S.; Iyer, N.R. Flexural studies on basalt fiber reinforced composite sandwich panel with profile sheet as core. *Constr. Build. Mater.* 2015, *82*, 391–400. [CrossRef]
- 8. Amran, M.; Ali, A.A.; Rashid, R.S.; Hejazi, F.; Safiee, N.A. Structural behavior of laterally Loaded precast foamed concrete sandwich panel. *Constr. Build. Mater.* **2016**, *107*, 307–320. [CrossRef]
- 9. Pan, G.; Wang, J.; Jia, L.; Wang, W.; Pang, S. Experimental and numerical analysis of flexural behavior of cold-formed thin-walled steel composite walls infilled with light polymer material. *J. Hefei Univ. Technol.* **2020**, *43*, 823–829.
- 10. Rozylo, P. Failure analysis of thin-walled composite structures using independent advanced damage models. *Compos. Struct.* **2021**, *262*, 113598. [CrossRef]
- 11. Rozylo, P.; Falkowicz, K. Stability and failure analysis of compressed thin-walled composite structures with central cut-out, using three advanced independent damage models. *Compos. Struct.* **2021**, 273, 114298. [CrossRef]
- 12. Zang, M.; Hu, Y.F.; Zhang, J.; Yang, M.; Ye, W.; Mao, G. Experimental and numerical studies on free vibration of CFRP laminate with cutout. *Compos. Struct.* **2021**, 269, 114014. [CrossRef]
- 13. Ministry of Housing and Urban-Rural Development. *RISN-TG 028-2017: Technical Guideline for External Thermal Insulation Engineering Based on Insulated Decorative Panel;* China Architecture & Building Press: Beijing, China, 2017.
- 14. Ministry of Construction PRC. *GB* 50009-2012: Load Code for the Design of Building Structures; China Architecture Building Press: Beijing, China, 2012.
- 15. ABAQUS/Standard, Version 6.20; ABAQUS Inc.: Pawtucket, RI, USA, 2020.
- 16. National Technical Committee on Cement Products of Standardization Administration. *GB/T* 15762-2020: *Autoclaved Aerated Concrete Slabs;* China Quality Inspection Press: Beijing, China, 2020.
- 17. Chen, B.S. *Experimental Research and Numerical Simulation on Mechanical Behavior of Autoclaved Aerated Concrete Panel;* Beijing University of Civil Engineering and Architecture: Beijing, China, 2016.
- 18. Ministry of Housing and Urban-Rural Development of the People's Republic of China. *GB* 50010-2010: Code for Design of Concrete Structures; China Architecture & Building Press: Beijing, China, 2010.
- 19. Ministry of Housing and Urban-Rural Development of the People's Republic of China. *JGJ/T* 17-2008: *Technical Specification for Application of Autoclaved Aerated Concrete;* China Architecture & Building Press: Beijing, China, 2008.
- 20. Wittman, F.H. Autoclaved Aerated Concrete-Properties Testing and Design (RILEM Recommended Practice); Spon Press: London, UK, 1993.