Study on the Influence of Different Mortar Thickness on Compressive Strength of Autoclaved Aerated Concrete Block Based on ANSYS

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Abstract. Based on Ansys APDL software, this paper conducts mechanical analysis on the autoclaved aerated concrete block walls with different thickness of masonry mortar, such as 2mm and 20mm, and explores the law of the influence of the thickness of the Mortar on the compressive bearing capacity of the autoclaved aerated concrete block walls. The test results show that the compressive bearing capacity of autoclaved aerated concrete block wall decreases continuously with the increase of the thickness of mortar joint, the compressive bearing capacity of masonry unit can be greatly improved by thin mortar joint masonry mortar, and the compressive bearing capacity of masonry with 2mm mortar joint thickness is 17.15% higher than that with 20mm mortar joint thickness. Among them, the regression curve equation of the compressive bearing capacity of the masonry unit and the thickness of the mortar is: \[ y = -0.0248x + 2.9972. \]

1. Introduction

The state is currently focusing on building energy conservation and promoting energy-saving green building materials. The autoclaved aerated concrete block masonry wall, as the only single wall that can achieve 65% building energy saving, is of great importance in its promotion and application. The thickness of traditional masonry mortar is generally 15-20 mm, and the thickness of 2-3 mm mortar is called thin layer masonry mortar. The use of thin layer masonry mortar can not only prevent the autoclaved aerated concrete blocks from discordant deformation and plaster layer falling off and other quality problems, but also effectively reduce the “micro-thermal bridge” effect on the wall, and greatly reduce the proportion of heat loss from the mortar joints so that the wall has good thermal performance. However, there are few studies on the influence of mortar thickness on the compressive strength of autoclaved aerated concrete block walls \cite{1-5}.

ANSYS software is a large general finite element analysis (FEA) software developed by ANSYS company in the United States. It can simulate various types of structures and materials, and it is currently the most popular finite element analysis software. Based on ANSYS APDL, the model of autoclaved aerated concrete block masonry sand wall is now modeled, and the research on the effect of the thickness of mortar on the compressive capacity of autoclaved aerated concrete block wall is carried out.
2. Design and test method of mechanical test specimen

2.1. Experimental materials and equipment
The B05 class autoclaving sand aerated concrete block produced by jilin penglin new building materials technology co., LTD was adopted, and the measured compressive strength was 4.5 MPa. The size is 600×300×250 (length × height × width, unit: mm). According to JGJ/T 17-2008 technical specification for application of autoclaved aerated concrete building, the elastic modulus of the block is 1900N/mm², and the poisson's ratio is 0.2. The poisson's ratio was set at 0.24 in accordance with the literature[6], and the elastic modulus was set at an integer of 8500N/mm² in accordance with the mathematical statistics regression equation $E_m = 1057f_{cm}^{0.44}$ in the literature[6]. Among them, $f_{cm}$ is the compressive strength of the mortar, calculated at 12 MPa.

2.2. Actual wall model and ANSYS analysis flow chart
Autoclaved aerated concrete blocks are usually used to build the external walls of buildings and indoor partition walls, and are connected to structural columns to function as filling walls. The model is shown in Figure 2. According to GB/T 50129-2011 Standard for Test Methods of Basic Mechanical Properties of Masonry, select the red box in Figure 2 for modeling, as shown in Figure 3. Although ANSYS Workbench is the new generation operating platform of ANSYS, ANSYS APDL (ANSYS Parametric Design Language) still has an irreplaceable role in the fields of civil engineering and structure, so APDL was selected for analysis.

2.3. Selection of ANSYS element type and failure criterion[7]
The powerful simulation function of ANSYS is inseparable from its many element types, and the choice of element type plays a vital role in the simulation results. The SOLID65 unit is a three-dimensional modeling unit developed to analyze materials that are non-uniform and non-linear, such as rock and concrete, and whose tensile capacity is much less than the compression capacity. The unit adds special cracking and crushing capabilities: it is easy to crack when tensioned, and can be broken when compressed, so it can simulate the cracking, crushing and plastic deformation of concrete in three orthogonal directions, and can be used for Concrete with reinforced or without reinforced steel. The SOLID65 element model is defined by eight nodes, each with three degrees of freedom: movable
in the x, y, and z directions of the nodes. Its node position, geometry and coordinate axis system are shown in Figure 4.

Because the properties of concrete and other materials are very complex, the strength criterion has a variety of measurement methods considering 1-5 parameters. The more parameters are considered, the more detailed the description of concrete properties will be. The adopted Willam-Warnke failure criterion is a 5-parameter model. According to its model theory, when in a state of low hydrostatic pressure, that is, when \[ |\sigma_x| \leq \sqrt{3} f_c \{\sigma_x = \frac{1}{3}(\sigma_{yy} + \sigma_{zz} + \sigma_{pp}) \} \], only enter the values of uniaxial ultimate tensile strength \( f_t \) and uniaxial ultimate compressive strength only \( f_c \). Otherwise, the system also needs to input \( f_{cb} \), biaxial compressive strength under hydrostatic pressure, \( f_{cs} \) isostatic biaxial compressive strength, and \( f_{cu} \) uniaxial compressive strength under hydrostatic pressure.

3. Simulation results and analysis

3.1. The failure process of masonry units with different thickness of mortar joints

The following prerequisites are determined before the test simulation:

1. Mortar and masonry shall be regarded as continuous isotropic materials;
2. The mortar and masonry are completely bonded before destruction without relative movement. The bond between the two ensures that they work together until they break. It is proved that the shear stress between mortar joint and block under vertical load is much less than the frictional resistance caused by vertical load.

According to APDL, the failure process of masonry units with different mortar joint thicknesses is basically similar, and the failure process is summarized as the following three steps:

1. As the vertical pressure began to increase, sporadic cracking and failure began near the junction of the horizontal and vertical joints of the mortar, as shown in Figure 5 (A).
2. When the vertical pressure continues to increase, the two horizontal joints of the wall unit will develop tensile failures along the horizontal joint from the middle to both sides, as shown in Figure 5 (B).
3. Tensile cracks damage both sides of the vertical joint covered with mortar. Finally, the block is destroyed and the wall unit loses its bearing capacity, as shown in Figure 5 (C).
3.2. Comparison of compressive capacity and stress analysis of masonry units with different mortar thickness

Under the premise of ensuring that the size of the block and various material parameters remain unchanged, the compressive model experiment of the autoclaved aerated concrete block wall with different thicknesses of 2mm, 8mm, 14mm and 20mm. According to the calculation, the compressive strength of the wall unit with a thickness of 20 mm mortar is 2.508 MPa, and the compressive strength of a wall unit with a thickness of 2 mm mortar is 2.939 MPa. In comparison, the compressive bearing capacity has increased by 17.15%. Figure 6 is a graph of the relationship between the unit compressive strength of the wall unit and the thickness of the mortar. It can be seen that the compressive strength value of the masonry unit continues to decrease as the mortar thickens. According to formula (1)\(^6\), the compressive load-bearing value of the masonry unit is 2.975MPa, and the experimental simulation results are very close to the theoretical calculation values.

\[
f_m = k_1 f_1^\alpha (1 + 0.07 f_2) k_2
\]

\(f_m\)----Average axial compressive strength of masonry
\(k_1\)----For the parameters related to the type of masonry, the autoclaved aerated concrete block is 0.78
\(f_1\)----Average compressive strength of blocks
\(\alpha\)----For parameters related to masonry type, the autoclaved aerated concrete block is 0.5
\(f_2\)----Average compressive strength of mortar
\(k_2\)----Mortar strength affects correction coefficient. When \(f_2 > 10\)MPa, take \(1.1 - 0.01 f_2\).

![FIG. 5 Failure process of masonry modeling unit](image)

![FIG. 6 The relationship between the compressive strength of masonry unit and the thickness of mortar](image)

The equation of the regression curve is:

\[
y = -0.0248x + 2.9972
\]

\(x\) is the thickness of the mortar, unit: mm; \(y\) is the pressure resistance value of masonry unit, unit: MPa)

It can be seen from the simulation process that the main failure mode of the wall unit is tensile cracking. The reason is that the lateral deformation value of the masonry unit mortar is greater than the value of autoclaved aerated concrete blocks. Due to the uncoordinated deformation of the two when
stressed, the mortar with a larger deformation trend will give the autoclaved aerated concrete block tension. The thicker mortar, the greater the tensile stress on the block, and the more severe the tensile damage. Therefore, the thicker the mortar, the lower the strength of the masonry. On the premise of ensuring that the uneven parts on the surface of the block can be filled, theoretically the thickness of the mortar can be reduced as much as possible. However, in the actual production process, if there are small stones in the sand, it will act as a rigid point in the mortar, which will lead to increased bending and shear stress at this point, reducing the overall mechanics of the wall unit. It can be seen from Figure 1 that the cutting surface of the high-performance autoclaved aerated concrete block is very smooth and flat, and the 70-90 mesh quartz sand is used for the thin-layer masonry mortar, which can completely avoid the adverse factors in the above actual construction operations.

3.3. Analysis and judgment of other factors affecting the compressive strength of masonry units
(1) The strength of blocks and mortar is an important factor affecting the compressive strength of masonry. The higher the strength of the two, the higher the compressive strength of the masonry. From formula (1), it can be deduced that for improving the overall compressive strength of the masonry, the effect of increasing the compressive strength of the block is more obvious than that of the mortar.

(2) The tensile stress of the block unit increases as the mortar becomes thicker, it is inferred that when the block height and thickness are fixed, the longer the block size, the greater the tensile stress of the block unit. That is, the size of the block will definitely have an effect on the overall compressive bearing capacity of the wall, and the bearing capacity of the wall unit decreases as the length of the block increases.

4. Conclusion
The main failure mode of the wall unit is tensile cracking. The thickness of masonry mortar has a significant effect on the compressive strength of autoclaved aerated concrete block masonry walls: the compressive strength of the wall continues to decrease as the thickness of the mortar increases. Therefore, thin-layer masonry mortar can greatly improve the compressive strength of masonry. The masonry of 2mm thick mortar masonry is 17.15% higher than the traditional 20mm mortar thick masonry. The regression curve equation between the compressive strength of the masonry and the thickness of the mortar is: \( y = -0.0248x + 2.9972 \).

Acknowledgments
This work was financially supported by China's 13th five-year national key research and development plan (No. 2018YFD1101001) and the Key project of science and technology development plan of jilin province, China (No. 20180312018ZX).

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