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EFFECT OF THE HOLE TYPE OF HOLLOW BRICK ON MECHANICAL BEHAVIOR

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Abstract

According to the photoelasticity models experiment's result and the stress-optic law, the mechanical behavior of several kinds of hollow brick with different perforated type were analysed. The results show that the best mechanical performance is got with circular perforations. Models' mechanical performance with small perforations or perforations arrayed staggered is better than big ones or perforations arrayed in-line. And the mechanical behavior is greatly improved with thick perforation wall.

Key Words

Hollow brick, the photoelasticity models experiment, perforated type, mechanical behavior

1 Introduction

Hollow brick is a kind of building material for saving energy, insulating heat and recycling wastes. According to the experience of manufacture and applying, hollow brick is the most suitable replacement for clay brick in many conditions. There are many kinds of hollow brick at present. Just for the shape of the perforations, there are the circular, the rectangular, the T-shaped (or the L-shaped), the lattice, etc. Furthermore, the perforations can be arrayed staggered or arrayed in-line. Different perforated types have different effects on the heat insulation, sound insulation or other function of a wall. So the problem to be solved is to consider various factors comprehensively and select the best-perforated type. The fundamental of the perforations optimization design is to greatly improve the mechanical behavior and the thermal insulation property, on the base of satisfying the requirements of production and the construction. Simultaneously, the designed perforated type should help to increase the hole ratio.

Photoelastic method is the bonding of optics and mechanics. It is an experimental method to study the stress distribution. Photoelastic effect was discovered in 1816, but it was not widely applied at that time. With the production of the optical material with high sensitivity and high transparency and the further improving of the similarity theory, photoelastic effect has been being applied more widely in the practise. In this paper,

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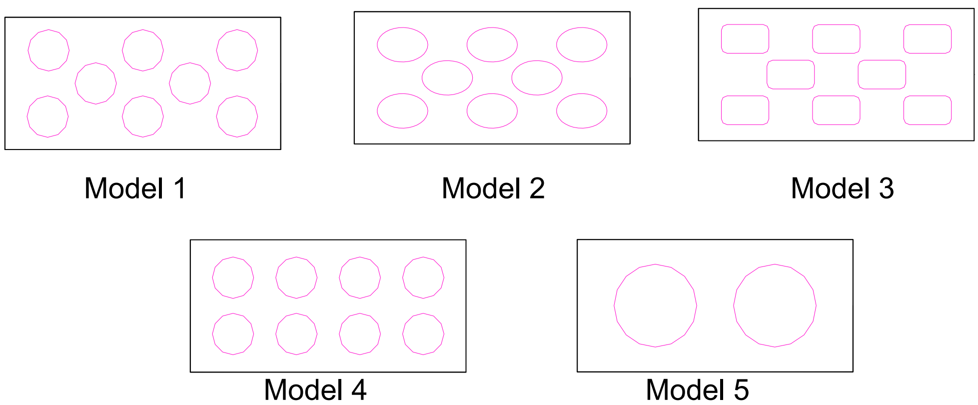
the relationship between the internal points' principal stress and the equidifferent stripe progression of hollow brick is deduced on the base of the principle of photoelastic and the knowledge related to material mechanics. The effects of various perforated type on the hollow bricks' mechanical behavior are compared, by calculating the principal tensile stress and the stress concentration indexes.

2 Experiment method

Plastic models, which are isotropic in optics and mechanics, were used in this experiment. Once the models were loaded, different birefringents were caused by the different principal stress of the internal points, thus the interferograms or stress images were designed. The principal stress value and direction of every point in these models' could be evaluated. At last, according to the similarity theory, the models' stress was converted into the stress of the structures and members, which were simulated.
The equation of stress-optic law is:

$$\sigma_1 - \sigma_2 = \frac{Nf}{h} \tag{1}$$

$\sigma_1 - \sigma_2$ is the principal stress difference;
N is the stripe progression;
f is the material fringe value, which is a constant related with the optic source and the material. It equals the ratio of wave length λ to stress-optic coefficient of the model material C. Its physical meaning is the value of the principal stress needed to create one equidifferent stripe, in a certain wave length's light, at unit thickness;
h is the model thickness.



Model 1 Circular perforations arrayed staggered;
Model 2 Oval perforations arrayed staggered;
Model 3 Rectangular perforations arrayed staggered;
Model 4 Circular perforations arrayed in-line;
Model 5 Two big circular perforations arrayed in-line.

Figure 1 Model 1-Model 5 used in the experiment

The optic material used in this experiment is epoxy. And these models were drilled to simulate hollow brick. According to the architecture module of P. R. China, the size of bricks in the experiment were designed to be 240mm × 115mm × 90mm (length × width

× thickness). And the designed hole ratio was 30%. The size ratio of the model to the hollow brick, which is simulated, is 1/3. There were six kinds of models used in the comparison experiment. Five of them were hollow models with equal hole ratio. The other one is a solid model to simulate the solid brick. There were three shapes of perforations in hollow models, the circular ones, the oval ones and the rectangular ones. They were arrayed in different ways. The models are showed in Figure 1, except the solid one.

During the experiment, the stress concentration indexes were calculated firstly. Then the best-perforated type for mechanical behavior could be selected by comparing the indexes evaluated. The mechanic model of this experiment is showed in Figure 2.

Stress concentration around the hole edges would not happen, because of the vertical compression is along the direction of perforations in the model. Thus the model's mechanic state could be looked as shearing single. The distributed compression caused by W is added to the result at last. And the epoxy bond of the top and the bottom simulated the motar bond. The mechanic device of this experiment is showed in Figure 3.

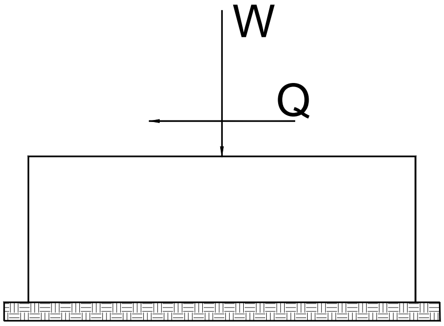


Figure 2 Mechanical equipment

According to the principle stress equation:

$$\begin{matrix}\sigma_1 \\ \sigma_2\end{matrix} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy}^2} \tag{2}$$

The maximum shear stress τ_{xy} can be obtained:

$$\tau_{xy} = \frac{Nf}{2h} \tag{3}$$

The principal tensile stress σ_1 can be evaluated after τ_{xy}, equation (3), was dropped into the equation (4):

$$\sigma_1 = \frac{\sigma_x}{2} + \sqrt{(\frac{\sigma_x}{2})^2 + \tau_{xy}^2} \tag{4}$$

Thus the mechanical behavior of different perforated types can be compared and analysed, according to the value of the principal tensile value.

3 Results

The experiment's results of the hollow brick pohotoelasticity models are showed below:

Table 1 Slice thickness d and the stripe progression N

Model type	d (cm)	N (progression)
Model 1	0.30	0.55
Model 2	0.28	0.60
Model 3	0.29	0.69
Model 4	0.31	0.98
Model 5	0.30	0.78
Solid model	0.25	0.28

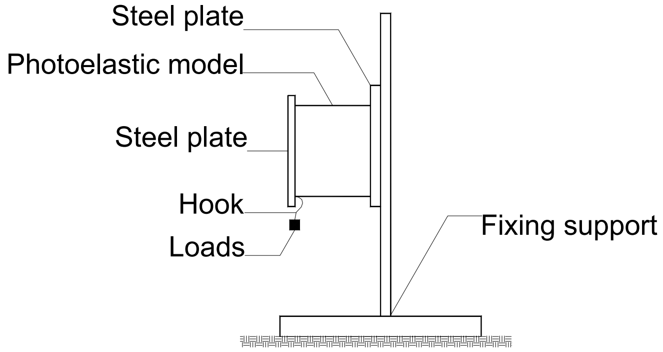


Figure 3 Mechanical device

The τ_{xy} of the six models can be obtained, after the values of Table 1 were dropped into equation (3). (f =0.351kg/cm each progression =351N/m each progression)

Table 2 Maximum shearing stress τ_{xy}

Model type	Maximum shearing stress τ_{xy} (MPa)
Model 1	0.319
Model 2	0.374
Model 3	0.416
Model 4	0.557
Model 5	0.458
Solid model	0.191

The stress concentration indexes used in the comparison and the principal tensile stress can be evaluated, when the values of Table 2 were dropped into the equation (4).

Table 3 Principal tensile stress and stress concentration indexes

Model type	Principal tensile stress (MPa)	Stress concentration indexes
Model 1	0.081	2.7
Model 2	0.109	3.6
Model 3	0.132	4.4
Model 4	0.221	7.4
Model 5	0.157	5.2
Solid Model	0.030	1.0

4 Conclusions

According to the results of the hollow brick's photoelasticity models experiment, the conclusions can be drawn:

(1) By comparing the data of Model 1, 2, 3, the circular perforations mechanical behavior is the best, and the oval ones is the better, and the rectangular ones is the worst.

(2) By comparing the data of Model 1, 4, the perforations arrayed staggered have better effects on the hollow brick's mechanical behavior than the ones arrayed in-line.

(3) By comparing the data of Model 1, 5, small perforations have better influences of the mechanical behavior than the big ones.

(4) By comparing the data of Model 4, 5, the thicker perforation wall can greatly improves the hollow brick's mechanical behavior.

References

Fan Ding, Shuguang Zhang, Wei Li, 1999. 09, The use of optics elasticity method in the internal force analysis of structure, Journal of Jilin Architectural and Civil Engineering Institute 3,40-46.

Ruyi Zhang, Yaozhen Lu, 1981, Experimental Stress Analysis, Beijing: China Machinery Press, 217-228.