# FINITE ELEMENT ANALYSIS OF THE TEMPERATURE STRESS OF CONCRETE PERFORATED MASONRY

Weijun Yang, Qunsheng Zheng, Haidian Zhang, Chunxia Yang

Changsha University of Science and Technology, Changsha Hunan 410076, China

## INTRODUCTION

People always adopt finite element analysis procedures such as SAP, ANSYS and GTSTRUDL to model the temperature cracks on the research of temperature cracks of concrete perforated brick. Mostly use of the model PLANE2, which one is only apply to the plane Stress element. And it can’t be analyzed the damage to the concrete and mortar layer.

Domestic and foreign scholars had already done a lot of work in analyzing reinforced concrete nonlinear finite element[1-3]. But it’s rarely research on the masonry materials nonlinear finite element now.In this paper, we adopted finite element program ANSYS to analyze the several important factors affecting temperature cracks by nonlinear finite element. We analyzed with different modeling methods based on the features of these factors. And it can provide scientific theory to prevent and control the temperature crack of the concrete perforated brick masonry.

## THE FINITE ELEMENT ANALYSIS OF THE OVERALL CONSTRUCTION IN COMBINED TEMPERATURE DIFFERENCE

## MODEL BUILDING

To find out the rules of deformation and temperature stress distribution,we built a finite element model of concrete perforated brick and masonry structure,which the bottom is framed structure with 19m ×10m,3m floor height and 25316 nodes in Fig 1 and Fig 2.Using Solid45 module of ANSYS to simulate and adopting mapping mesh to divide units.Block materials used MU10 block and M7.5 mortar,tensile strength is 0.41MPa[4],siza is 240*115*90mm, Double-row hole,and concrete grading used C20 concrete. The component material parameters shown in Table 1.

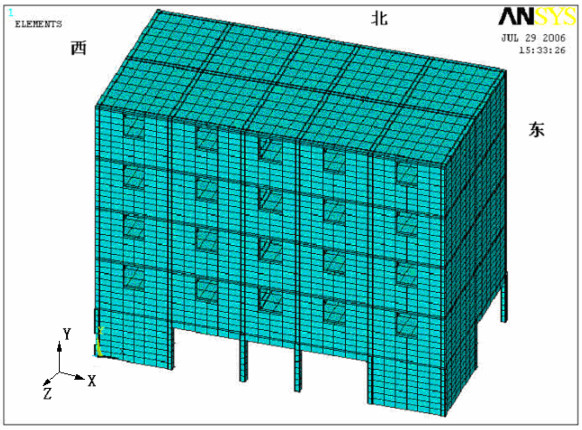



Fig 1. Perforated Brick Structure Model

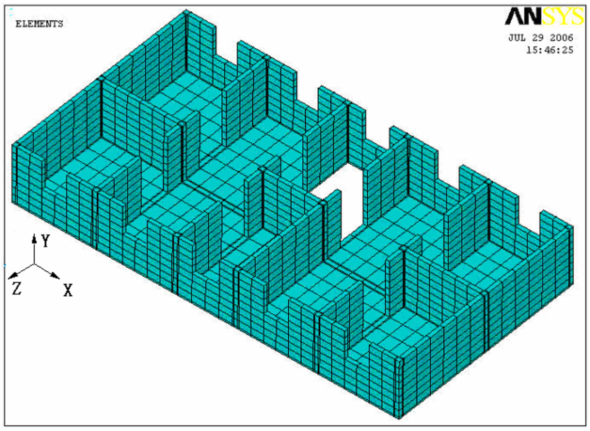



Fig2.Layout of Standard Floor

Table 1. Materials Reference[5][6]

| | Thickness (mm) | Density (kg/m$^3$) | Modulus of elasticity (MPa) | Poisson's ratio | Linear expansion Coefficient (/°C) |
|---|---|---|---|---|---|
| Wall | 240 | 1940 | $2.4\times10^3$ | 0.2 | $1.0\times10^{-5}$ |
| Rroof (floor) | 120 | 2550 | $2.55\times10^4$ | 0.167 | $1.0\times10^{-5}$ |
| Shake proof column | 300×300 | 2550 | $2.55\times10^4$ | 0.167 | $1.0\times10^{-5}$ |
| Structural column | 240×240 | 2550 | $2.55\times10^4$ | 0.167 | $1.0\times10^{-5}$ |
| Ring beam | 180×240 | 2550 | $2.55\times10^4$ | 0.167 | $1.0\times10^{-5}$ |

The constitutive relation of beam, slab and pillar is apply to Rüsh concrete constitutive relation:

$$\sigma = \sigma_0 [2(\frac{\varepsilon}{\varepsilon_0}) - (\frac{\varepsilon}{\varepsilon_0})^2] \qquad \varepsilon \le \varepsilon_0 \qquad \text{(Rising stage)} \qquad (1)$$

$$\sigma = \sigma_0 \qquad \varepsilon_0 < \varepsilon \le \varepsilon_{cu} \qquad \text{(Decline stage)} \qquad (2)$$

The masonry wall using Chuxian Shi constitutive relation expression[5]:

$$\varepsilon = \frac{1}{\xi \sqrt{f_m}} \ln\left(1 - \frac{\sigma}{f_m}\right) \qquad (3)$$

## EFFECT OF THE TEMPERATURE PARAMETER

Because of the features of yearly temperature difference and daily temperature difference changing are quite different. We should consider the two features of both when choose the temperature parameter.

The Literature[7] put forward a method named combined difference temperature, which involves year-difference-in-temperature and day-difference-in-temperature. Though the thermal stress calculation,the results proved that the method is reasonable.

In this paper, it adopted the yearly temperature difference and daily temperature difference experimentally measured nearly one year in a concrete hollow block building, Hangzhou which refers to reference [8]. And then we got the combined temperature difference after calculated. Show as Table 2.

Table2. Temperature Difference of the Wall and Roof

| | Roof | West wall | East wall | North and south wall | Inner wall |
|---|---|---|---|---|---|
| daily | 16.8 | 5.6 | 4.9 | 4.2 | |
| yearly | 33.0 | 29.8 | 27.7 | 25.2 | 25.2 |
| combined | 44.9 | 30.9 | 28.4 | 25.6 | 25.2 |

## ANALYSIS OF STRUCTURAL DEFORMATION

Following shows the result of Table 2 under the action of combined temperature difference and construction deadweight load

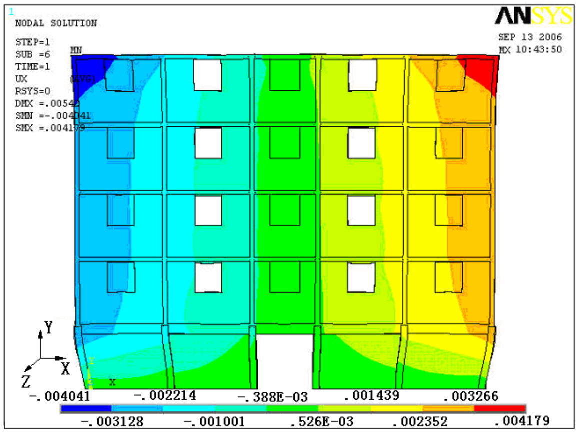



Fig3. The Displacement Nephogram of the South Wall

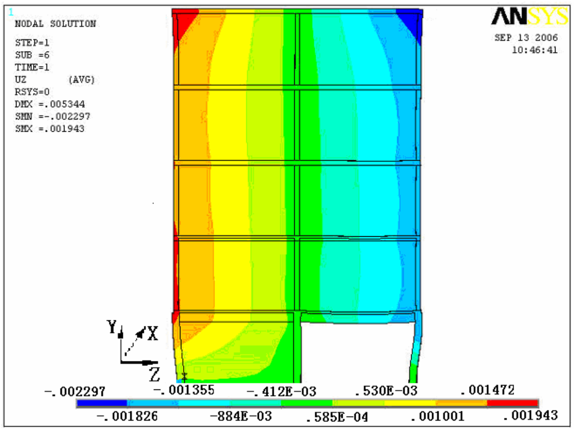



Fig4. The Displacement Nephogram of the West Wall

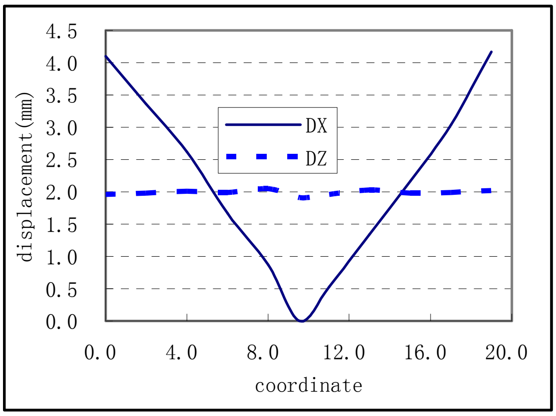



Fig5.The horizontal displacement nephogram of south outer top wall

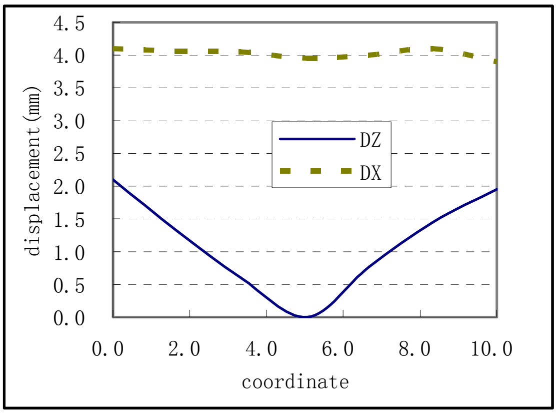
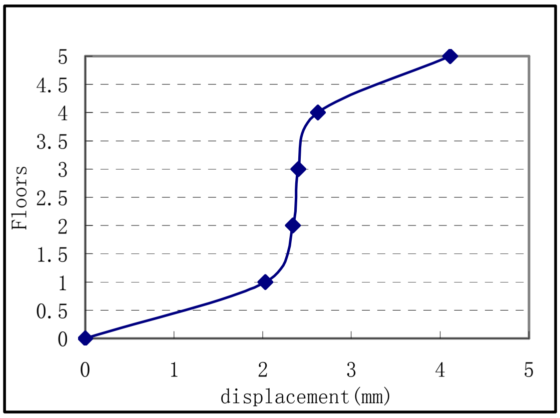



Fig6. The horizontal displacement nephogram of west outer top wall



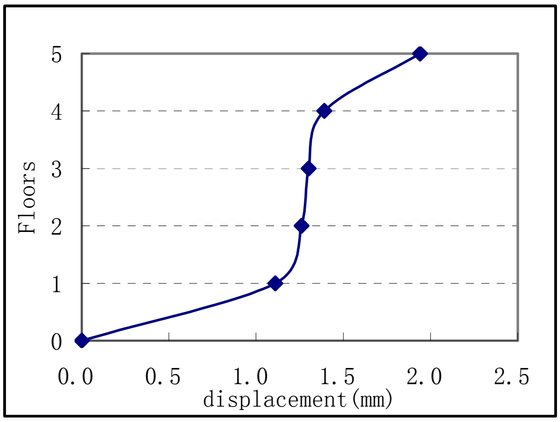



Fig7. Maximum longitudinal horizontal displacement $U_{xmax}$

Fig8. Maximum lateral horizontal displacement $U_{zmax}$

It comes to the conclusion from the figures:

The maximum horizontal displacement and maximum vertical displacement of different layers decreased downward. And the deformation effect of temperature difference decreased upward, especially with a greater affect to the upper two floors.

The deformation of the top floor is much obviously than that of the wall. So, it will be first appear temperature cracks on the wall of the top floor.

## ANALYSIS OF TEMPERATURE STRESS

The principal tensile stress of south wall and western wall is shown as Fig 9、Fig 10.

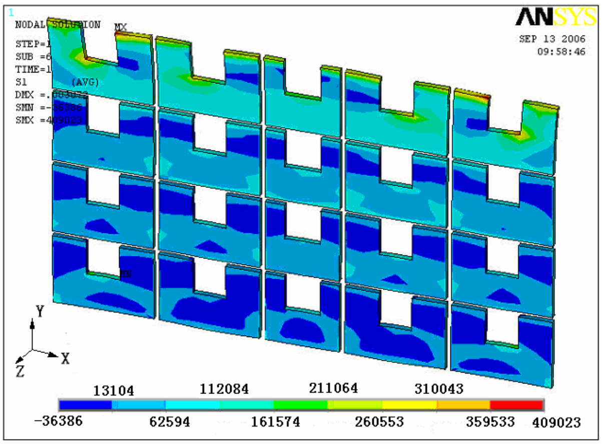



Fig9 South wall principal tensile

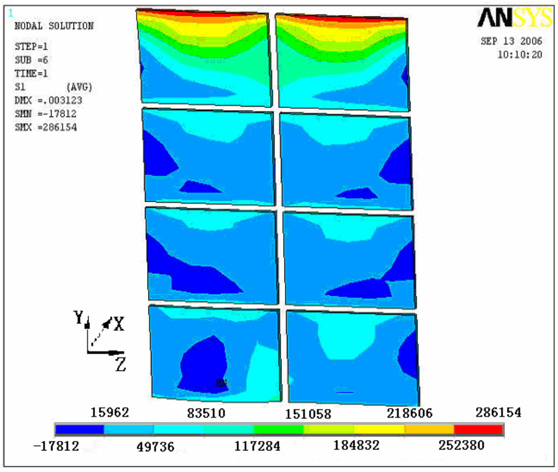



Fig10Western wall principal tensile

The largest first principal stress of outer walls appears at the top floor and decreased downward (Fig 9, Fig 10).It’s further explained the reason for temperature cracks often appears on the top floor.The principal tensile stress of top western wall is greater than that of the below walls,and it increases from the centre to the bottom.

## THE EFFECT OF THE TEMPERATURE DIFFERENCE BETWEEN ROOF

**AND WALL TO THE MASONRY**

The deformation in Fig 1 to Fig 8 is caused by the combined temperature difference, the temperature difference between roof and wall is the most important factor to cause the temperature cracks of top floor. We used the following two analysis methods to make clear the relationship between temperature difference and temperature stress of roof and wall.

**THE FIRST METHOD:**

Make the building situation under the following temperature conditions.And the results are shown in Table 3.

Situation 1: roof 8°C， others 0°C; Situation 2: roof and others 8°C
Situation 3: roof 16°C，others 8°C; Situation 4: roof and others 16°C
Situation 5: roof 24°C，others 16°C; Situation 6: roof and others 24°C
Situation 7: roof 32°C，others 24°C; Situation 8: roof and others 32°C

Table 3 the whole displacement of the top floor and the relative displacement of each floor under the different situations:

| | Situation 1 | Situation 2 | Situation 3 | Situation 4 | Situation 5 | Situation 6 | Situation 7 | Situation 8 |
|---|---|---|---|---|---|---|---|---|
| Longitudinal Ux | 0.73 | 0.98 | 1.62 | 1.91 | 2.56 | 2.91 | 3.58 | 3.86 |
| Lateral Uz | 0.21 | 0.29 | 0.50 | 0.58 | 0.78 | 0.87 | 1.07 | 1.16 |
| δx | 0.62 | 0.11 | 0.74 | 0.20 | 0.96 | 0.38 | 1.34 | 0.13 |
| δz | 0.20 | 0.02 | 0.23 | 0.04 | 0.26 | 0.07 | 0.29 | 0.09 |

The table 3 shows:

(a)While the roof and wall under the same temperature difference, the holistic

displacement is basically proportional to the holistic temperature difference, shown as Situation 2, 4, 6, 8.

(b)Compared with the Situation 1, 3, 5, 7, the relative floor displacement caused by relative temperature difference is much greater than that by holistic temperature difference.

**THE SECOND METHOD:**

From Fig.7 and Fig.8, we can see the floor horizontal displacement between 3rd and 4th is obviously less than that between 4th and 5th. And the floor horizontal displacement for other floors is much indistinct. So, it can be considered that the 3rd floor has no horizontally restraint to the bottom of the 4th floor. Therefore, we can simplify the multilayered structure into double-deck simplified model M1 when we analyze the masonry top crack. Meantime, we use Solid65 module to simulate and Willam-Warnke[9] failure criterion to analyze the nonlinear finite element of M1,and others do not changed.Releasing the bottom horizontal displacement and just constraining the bottom vertical displacement, using load-step loading and keeping 0 ° C for the parts of below roof, the roof temperature will rise 4 ° C in every step, the result as follow:

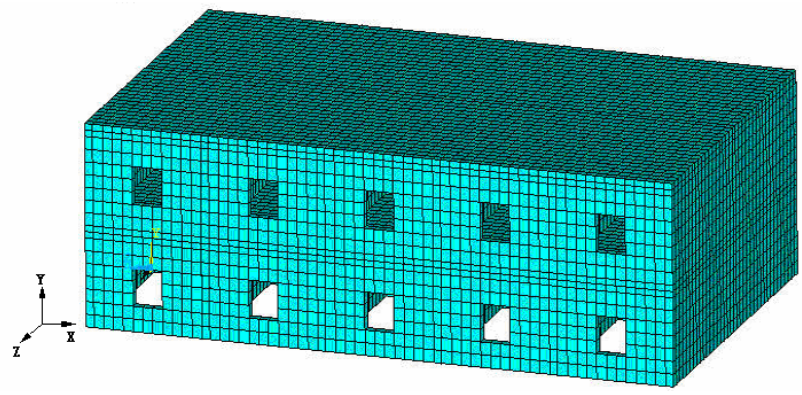



Fig11.  M1 Finite Element Analysis

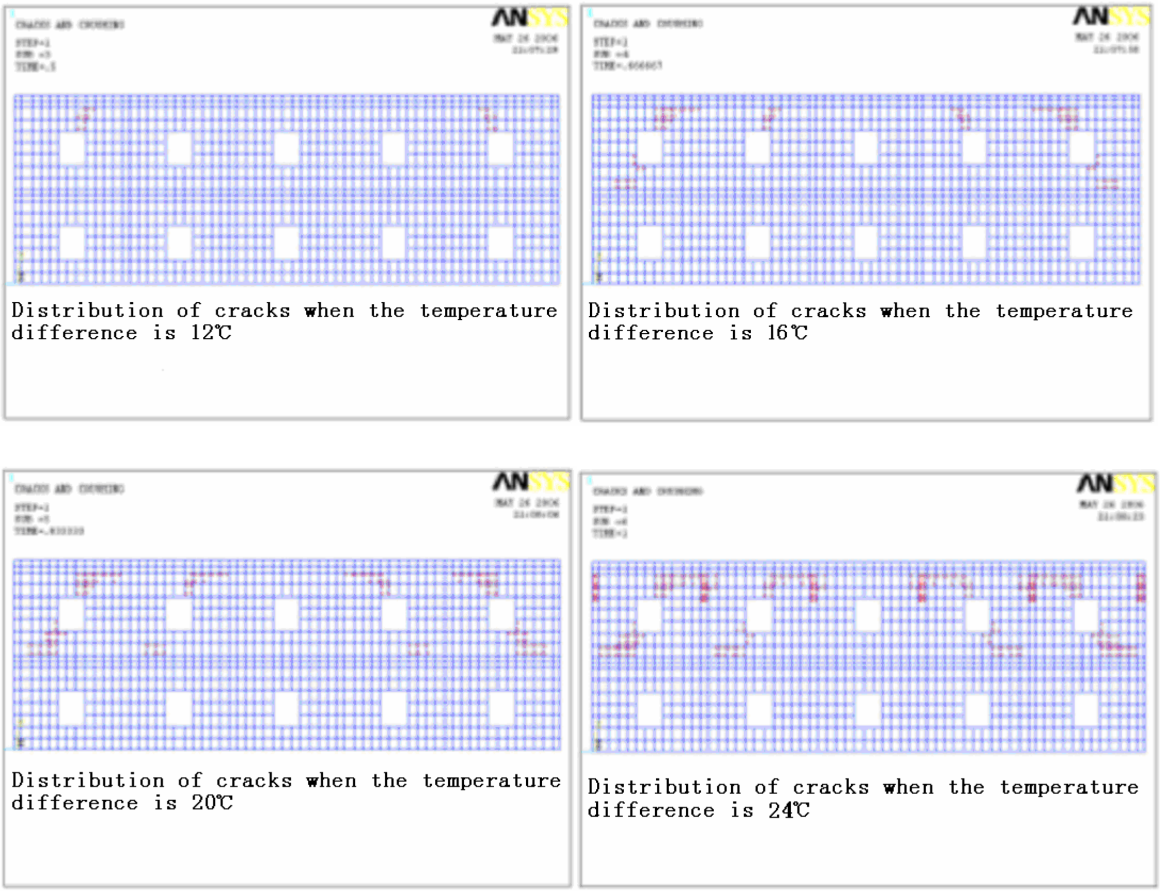



Fig 12 The crack processing with step-load

Table 4 The Temperature Domino Effect Value in Different Temperature Difference

| Temperature difference | Maximum horizontal displacement | Maximum principal tensile stress |
|---|---|---|
| 4°C | 0.35 | 0.243 |
| 8°C | 0.69 | 0.486 |
| 12°C | 1.08 | 0.858 |
| 16°C | 1.45 | 1.123 |
| 20°C | 1.86 | 0.591 |
| 24°C | 2.35 | 0.673 |

Wall cracks began to appear in the third load-step, that is, when the temperature reached 12 ° C at the top end bay window angle cracks began to appear (Figure 12). Then, with increasing the load-step, cracks continued to expand and became more

frequently. Throughout the period, the maximum horizontal displacement is roughly proportional to the temperature difference. And the principal tensile stress of wall reached maximum when the temperature reached 16 ° C. When the temperature of roof still rose, the masonry which close to cracks has quit its action and the wall redistributed its stress. Hence, it’s appeared the situation of the maximum principal stress constantly fluctuated. From this, we can see that the wall temperature effect on the roof and wall temperature is much sensitive. So, keep its insulation for roofing and wall as to reducing the temperature difference of roof can effectively reduce the temperature stress and temperature sidesway for the wall. It’s also indirectly explained that the phenomenon of temperature cracks in masonry buildings rarely appeared when good job to roofing insulation.

## CONCLUSIONS

The wall along the direction of the axis deviation gradually increasing from the middle to both ends. And the excursion increased along the height direction of wall. In actual structure of the building should be considered in the two ends taken to strengthen.

The principal tensile stress of the vertical outside wall’s top end is greater than that of the middle parts; also the tensile stress of the walls below the ring beam is much greater. And the stress center on the hole of doors or windows, thus it’s well explained the phenomenon of eight-shape cracks on the vertical outside walls. Therefore, we should consider carrying out measures to strengthen both ends of the construction in the course of building.

The relative displacement of concrete brick masonry construction includes two sections: one is the layer relative displacement caused by the holistic temperature difference, the other is the layer relative displacement caused by the relative temperature difference between roof and wall, while the latter is much greater than the former.

Under the condition of combined temperature difference for the whole model, the main tensile stress and displacement of the second, third and fourth walls are similar. So when we analyze the temperature stress to the multi-storey masonry, we could use the simplified two-tier model.

The temperature difference of the roof and walls is the main factor for wall cracks, which shows the importance of installing heat insulation to roof. Therefore, it’s an effective way to reduce temperature stress by strengthening the heat insulation of the roof.

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