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Heat Analysis of Assembled Steel-truss Concrete Hollow Floor

Hao-xue Ju[1*], Yue Zhang[2] and Xu-dong Xing[1]

[1] College of Information Technology & Art Design, Shandong Institute of Commerce & Technology, Jinan, Shandong Province, 250103, China

[2]School of Civil Engineering and Architecture, University of Jinan, Jinan, Shandong, 250022, China

[*]Corresponding author's e-mail: juhaoxue@163.com

Abstract. The numerical analysis software ABAQUS has been used to study the temperature field of an assembled steel-truss concrete hollow floor in this paper to simulate the assembled steel-truss concrete hollow floor under thermal coupling under the ISO-834 standard heating curve. The distribution principle of temperature field for different sections in the floor system has been obtained to provide a reference for the study of the mechanical properties of assembled steel-truss concrete hollow floor.

1. Introduction

The thermal and mechanical properties of building materials will vary in high temperature environment or fire. Concrete spalling may occur due to heat which inevitably leads to the softening of exposed steel bar and endangers the structure safety. Because of the large area of reinforced concrete slab, it is usually suffered to the most severe damage as structural components in the fire scenario. Therefore, researches about concrete floor system under fire are particularly important.

The British BRE and Steel Structures Association conducted a series of fire tests on a full-size steel frame structure [1]. Gordon M.E Cooke [2] carried out a fire test study on 14 simply supported reinforced concrete one-way slabs. Lim [3-4] studied a fire resistance test on three reinforced concrete simply supported two-way slabs. Foster and Burgess [5-6] experimentally and theoretically investigated the vertical large deformation of 15 small-sized reinforced concrete slabs without horizontal constraints. Bailey [7-8] tested 44 small-scale concrete slabs and proposed the theory of film forces in concrete slabs at high temperatures. José V. Aguado, A. Espinos [9] studied the effect of steel bars on the high temperature performance of four full-size reinforced concrete hollow slabs, and pointed out that the load could be calculated according to the EC2 specification. I. Venanzi, M. Breccolotti, A. [10] analyzed experimentally full-scale fire resistance of hollow core slabs. A.M. Shakya, V.K.R. Kodur [11] carried out experimental research and numerical simulation on six precast prestressed concrete hollow slabs. Aguado J V, Albero V, Espinos A [12] established a 3D finite element thermo-mechanical coupling model of concrete hollow slabs. It was found that the FE model can accurately reflect the failure mechanism of slab and cracking mode. In this work an assembled steel-truss concrete hollow floor is presented and the thermal behavior has been investigated using ABAQUS software.

2. Model

2.1 Modal

The 3D full-scale model is relatively large .Only 1/4 model is built with the consideration of symmetry

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in both directions in order to reduce the software solution time. The floor model is shown in Figure 1. ISO-834 standard curve as shown in Figure 2 has been adopted in numerical analysis.

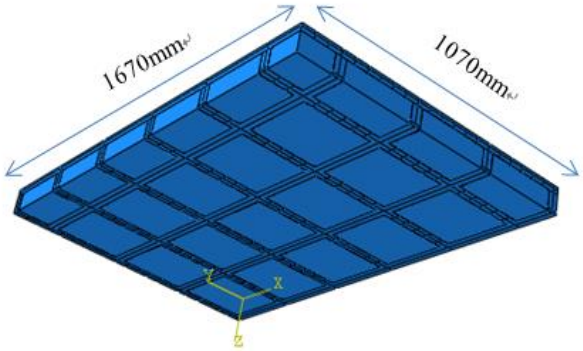


Figure 1. 1/4 model

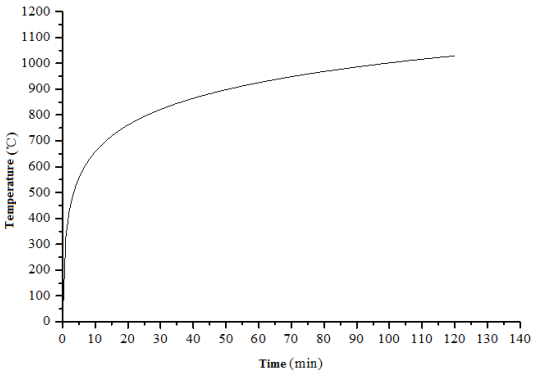


Figure 2. ISO-834 standard curve

2.2 Meshing

The element size of foamed concrete and ordinary concrete is 4 cm, and the steel mesh grid is 3 cm. After the mesh is divided by the central axis algorithm, the model meshing shape is suitable to fasten computational iteration and improve the convergence.

3. Analysis

The temperature distribution of the whole slab along both long span and short span after two-hour fire exposure has been shown in Figure 3. It can be seen that the temperatures gradient gradually reduce from the fire-exposed surface towards the unexposed surface. The maximum temperature of fire-exposed surface is about 1048℃, while the temperature of unexposed surface is about 23℃. The concrete temperatures development along the long span and short span is presented in Figure 4 and Figure 5 which indicates obvious temperature difference at the interface between foamed concrete and concrete ribs due to the heat insulation of foamed concrete.

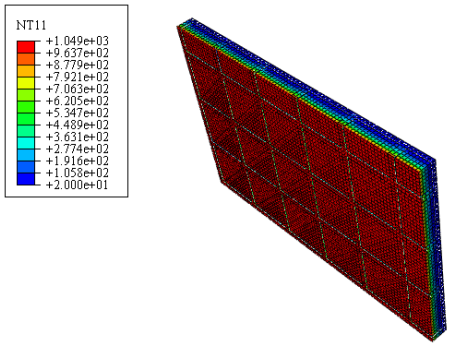
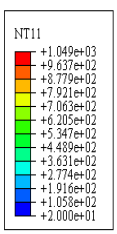


Figure 3. Temperature of the whole model



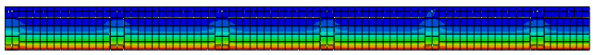
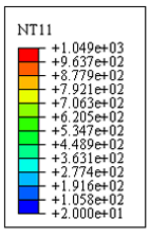


Figure 4. Temperature along long span



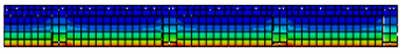


Figure 5. Temperature along short span

There are 7 measuring points along the height of concrete rib which are numbered as H1-H7 and the distance away from the fire-exposed surface is 0mm, 20mm, 60mm, 100mm, 140mm, 170mm, 190mm,respectively. There are also 7 measuring points along the thickness of foamed concrete with numbering P1-P7, and the distance away from the fire-exposed surface is 0mm, 35mm, 70mm, 105mm, 140mm, 170mm, 190mm, respectively as shown in Figure 6.

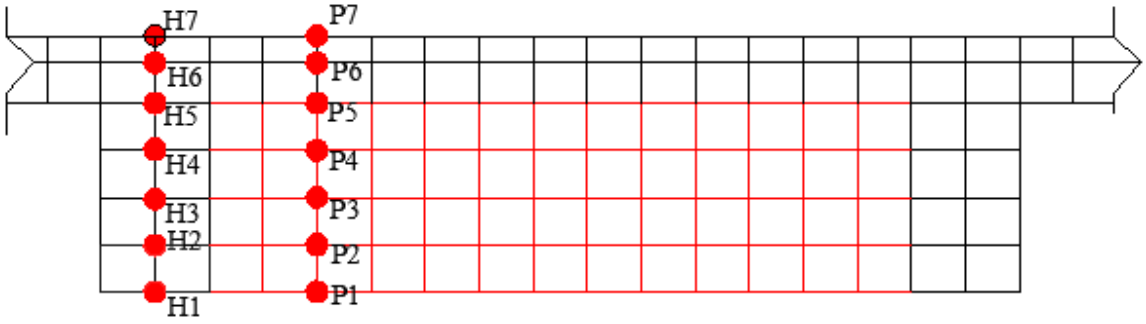


Figure 6. Measuring point arrangement

The temperature-time curves of measuring point H1-H7 are presented in Figure 7. It can be seen that the temperature development for each point is not completely same. The temperatures of H1, H2 and H3 have a faster growth in the first 30min, while the temperatures of H4-H7 develop slowly. With the increase of time, the temperatures of each measuring point show a nonlinear development. It indicates that the farther away from the fire-exposed surface, the smaller the temperature gradient is, which has agreement with the actual fire condition. The temperature development of measuring points P1-P7 is compared in Figure 8. It can be seen that foamed concrete and the rib concrete have the same trend of temperature development. However, for the same height level the temperatures of foamed concrete is lower than that of rib concrete. According to the analysis, the thermal characteristics of foamed concrete are superior to the ordinary concrete, which results in less temperature transfer towards the top part of floor system and ensures a good thermal insulation performance.

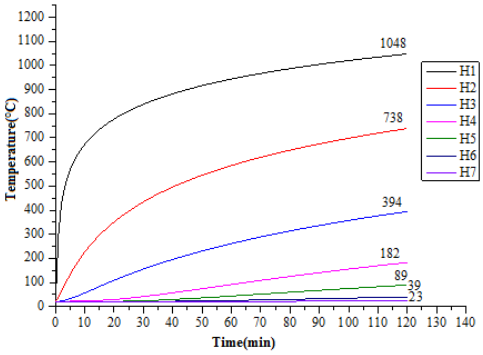


Figure 7. Temperature curves for rib

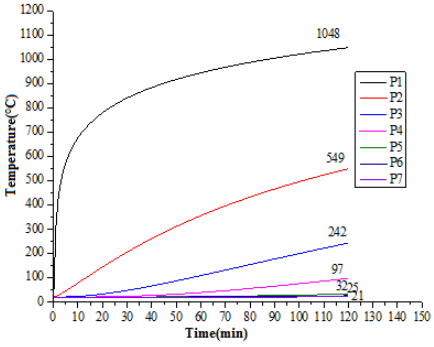


Figure 8. Temperature curves for foamed concrete

Figure 9 shows temperature distribution of steel trusses. The maximum temperature of steel truss system appears at the bottom. The minimum temperature occurs at the farthest position away from the fire-exposed surface. The conclusions can be drawn that temperature increase in the steel truss will result in a sharp decrease of strength and elastic modulus. According to the results of temperature field distribution aforementioned, the temperatures of steel wire mesh locating in the concrete top layer are close to room temperature.

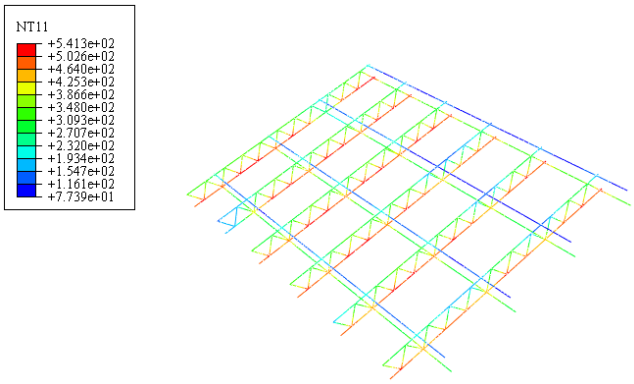


Figure 9. Temperature distribution of steel trusses

4. Conclusion

In this paper, the numerical software ABAQUS has been used to simulate the assembled steel-truss concrete hollow floor under the action of ISO834 standard curve. The temperature field distribution of different floor parts is obtained.

- The temperature field of floor is depending on the fire-exposed section, but the temperatures gradually reduce in a nonlinear manner from the fire-exposed surface to the unexposed surface.
- Foamed concrete can provide effective fire protection with heat insulation property, and the size of section has no effect on the temperature of the steel-truss at the same thickness of the protective layer.

Acknowledgement

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