Analysis of temperature stress of roof of super-long basement

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Abstract: In this paper with a practical project as an example of super-long basement, using structural analysis software MIDAS/Gen (2014) Chinese version, through the analysis of the temperature effect of indirect effect, analyze the super-long basement roof temperature stress of concrete structure, calculation of super-long structure under temperature influence of temperature stress, and according to the temperature stress calculation reinforcement, and the structure of the combination of action effects, to solve the temperature stress generated in the basement of super long concrete structure.

1. Introduction
In the general design of building structure, when the maximum applicable length of concrete structure is exceeded, the structure is usually divided into several structural units by setting seismic joints[1] . However, due to the aesthetic and functional needs of buildings, expansion joints are not set in many super-long concrete basement structures. In this way, its continuous length often greatly exceeds the limit of the "Code for Design of Concrete Structures" (GB50010-2010).

2. Project Overview
A project is an underground garage with large chassis, nine high-rise buildings are arranged around and in the center[2]. The main building adopts reinforced concrete shear wall structure, and the foundation of the main building is a prestressed pipe pile foundation. The underground garage adopts the reinforced concrete frame structure, and the surrounding concrete exterior wall is arranged. The foundation adopts the beam-slab raft foundation[3]. The basement exceeds the maximum applicable length of "Code for Design of Concrete Structures" and "Technical Specification for Crack Prevention of Underground Concrete Structures".

According to the Chinese weather website, the average monthly temperature in the area where the project is located is as follows: the lowest monthly average temperature is minus 28 degrees Celsius, and the highest monthly average temperature is 33 degrees Celsius.

3. Structural calculation model
This project is divided into two kinds of structural model calculation, the first model: calculation of basement side wall and roof temperature stress, the foundation is fixed; In the second model, the foundation stiffness is input when the temperature stress of the basement floor and the basement floor of the main building are calculated, considering the elastic supporting effect of the foundation[4].
Linear elastic analysis method is adopted. Beam and column adopt beam element, wall and plate adopt plate element, and beam and column adopt line element model[5].

Calculation assumption: the number of underground floors of the structure is 1, and the mezzanine and the first floor are built into the main building considering the partial constraints.

Unit model: the wall and the plate adopt the plate element, the unit side length is 2.0m, and the beam and column adopt the line element model.

4. Temperature stress analysis results

4.1 Stress analysis results of foundation floor

Because the foundation floor is directly connected with the foundation soil, the temperature stress of the foundation floor under the temperature load can be obtained only according to the actual input of spring stiffness of the foundation. According to Model 2, the stress of foundation floor is as follows:

Considering the elastic constraint of foundation, when the temperature difference is 20℃, the stress result of basement floor is as follows:

| Part                       | Stress value     | Full section reinforcement ratio |
|----------------------------|------------------|----------------------------------|
| The garage floor           |                  |                                  |
| Smaller stress in the edge zone | $\sigma_x=1.5, \sigma_y=1.0$ | X: 0.42%; Y: 0.28%          |
| The stress in the middle zone is larger | $\sigma_x=2.0, \sigma_y=1.7$ | X: 0.56%; Y: 0.48%          |
| The main building raft      |                  |                                  |
| Common area                | $\sigma_x=1.7, \sigma_y=1.0$ | X: 0.48%; Y: 0.28%          |
| High stress area           | $\sigma_x=2.0, \sigma_y=1.5$ | X: 0.56%; Y: 0.42%          |

4.2 Calculation results of temperature stress on basement side walls

Considering the elastic constraint of the foundation, when the temperature difference is 20℃, the stress of the basement shear wall is as follows:

| Part                       | Stress value | Reinforcement ratio |
|----------------------------|--------------|---------------------|
| Underground garage exterior wall | $\sigma_x=0.7\sim1.2$ | 0.34%                |
| Long direction: both ends   | $\sigma_x=1.5\sim1.7$ | 0.48%                |
| Long direction: middle      | $\sigma_x=0.9\sim1.2$ | 0.34%                |
| Short direction: middle     | $\sigma_x=0.8\sim1.4$ | 0.39%                |
| Main building shear wall    | $\sigma_x=0.5\sim1.4$ | 0.39%                |
| Around the garage           | $\sigma_x=0.5\sim1.5$ | 0.42%                |
| Connected to the garage     | $\sigma_x=0.7\sim1.3$ | 0.36%                |

The bottom of the foundation is fixed. When the temperature difference is 20℃, the stress of the basement shear wall is as follows:
### Underground garage exterior wall

| Part                              | Stress value | Reinforcement ratio |
|-----------------------------------|--------------|---------------------|
| Long direction: both ends         | $\sigma_x=1.0 \sim 1.8$ | $0.28\% \sim 0.50\%$ |
| Long direction: middle            | $\sigma_x=1.5 \sim 2.1$ | $0.42\% \sim 0.58\%$ |
| Short direction: both ends        | $\sigma_x=1.0 \sim 2.0$ | $0.28\% \sim 0.56\%$ |
| Short direction: middle           | $\sigma_x=1.5 \sim 2.3$ | $0.42\% \sim 0.64\%$ |

### Main building shear wall

| Part                              | Stress value | Reinforcement ratio |
|-----------------------------------|--------------|---------------------|
| Around the garage                 | $\sigma_x=0.5 \sim 1.8$ | $0.14\% \sim 0.50\%$ |
| Among the garage                  | $\sigma_x=0.3 \sim 1.5$ | $0.08\% \sim 0.42\%$ |
| Connected to the garage           | $\sigma_x=1.0 \sim 1.9$ | $0.28\% \sim 0.52\%$ |

### 4.3 Calculation results of temperature stress of basement roof

When the foundation is fully embedded, when the temperature difference is 20°C, the main stress values and temperature bars are summarized as follows:

| Part                              | Stress value | Full section reinforcement ratio |
|-----------------------------------|--------------|---------------------------------|
| The garage roof                   |              |                                 |
| Smaller stress in the edge zone   | $\sigma_x=1.5, \sigma_y=1.2$ | X: $0.42\%$; Y: $0.34\%$ |
| The stress in the middle zone is larger | $\sigma_x=2.0, \sigma_y=1.6$ | X: $0.54\%$; Y: $0.44\%$ |
| Large stress at the opening       | $\sigma_x=2.2, \sigma_y=2.0$ | X: $0.62\%$; Y: $0.56\%$ |
| Stress around the main building is high | $\sigma_x=2.2, \sigma_y=2.0$ | X: $0.62\%$; Y: $0.56\%$ |
| Common area                       | $\sigma_x=1.2, \sigma_y=0.8$ | X: $0.34\%$; Y: $0.22\%$ |
| High stress area                  | $\sigma_x=1.5, \sigma_y=1.0$ | X: $0.42\%$; Y: $0.28\%$ |

Considering the elastic constraint of the foundation, when the temperature difference is 20°C, the stress of the basement roof is as follows:

| Part                              | Stress value | Full section reinforcement ratio |
|-----------------------------------|--------------|---------------------------------|
| The garage roof                   |              |                                 |
| Smaller stress in the edge zone   | $\sigma_x=0.9, \sigma_y=0.6$ | X: $0.25\%$; Y: $0.17\%$ |
| The stress in the middle zone is larger | $\sigma_x=1.3, \sigma_y=0.9$ | X: $0.36\%$; Y: $0.25\%$ |
| Surrounding places with large stress at the entrance of the cave | $\sigma_x=1.6, \sigma_y=1.5$ | X: $0.45\%$; Y: $0.42\%$ |
| Stress around the main building is high | $\sigma_x=1.6, \sigma_y=1.5$ | X: $0.45\%$; Y: $0.42\%$ |
| Common area                       | $\sigma_x=1.0, \sigma_y=0.6$ | X: $0.28\%$; Y: $0.17\%$ |
| High stress area                  | $\sigma_x=1.3, \sigma_y=1.0$ | X: $0.36\%$; Y: $0.28\%$ |
4.4 Calculation results of temperature stress of basement roof beam
Considering the elastic constraint of foundation, when the temperature difference is 20°C, the stress of beam element is as follows:

| Part                          | Stress value | Reinforcement ratio |
|-------------------------------|--------------|---------------------|
| The underground garage        |              |                     |
| Long direction: both ends      | \( \sigma x = 0.5 \sim 0.8 \) | 0.22\%             |
| Long direction: middle         | \( \sigma x = 0.8 \sim 1.2 \) | 0.34\%             |
| Short direction: both ends     | \( \sigma x = 0.3 \sim 0.5 \) | 0.14\%             |
| Short direction: middle        | \( \sigma x = 0.5 \sim 0.7 \) | 0.20\%             |
| The hole is located in the span and adjacent span | \( \sigma x = 1.0 \sim 1.5 \) | 0.42\%             |
| The stress connected with the shear wall is larger | \( \sigma x = 1.0 \sim 1.5 \) | 0.42\%             |
| 0.0 the main beam              |              |                     |
| All round                     | \( \sigma x = 1.0 \) | 0.28\%             |
| In the middle                  | \( \sigma x = 0.6 \) | 0.17\%             |

When the bottom of the foundation is fully embedded and the temperature difference is 20°C, the stress results of the basement roof are as follows:

| Part                          | Stress value | Reinforcement ratio |
|-------------------------------|--------------|---------------------|
| The underground garage        |              |                     |
| Long direction: both ends      | \( \sigma x = 0.5 \sim 1.0 \) | 0.28\%             |
| Long direction: middle         | \( \sigma x = 1.0 \sim 1.7 \) | 0.48\%             |
| Short direction: both ends     | \( \sigma x = 0.5 \sim 1.0 \) | 0.28\%             |
| Short direction: middle        | \( \sigma x = 1.0 \sim 1.3 \) | 0.36\%             |
| The hole is located in the span and adjacent span | \( \sigma x = 1.5 \sim 2.0 \) | 0.56\%             |
| The stress connected with the shear wall is larger | \( \sigma x = 1.5 \sim 2.0 \) | 0.56\%             |
| 0.0 the main beam              |              |                     |
| All round                     | \( \sigma x = 1.5 \) | 0.66\%             |
| In the middle                  | \( \sigma x = 1.0 \) | 0.28\%             |

5. Conclusion
Through the above analysis, the following conclusions are drawn:

1. Since the constraint effect of foundation soil on the superstructure is not completely embedded, considering the elastic constraint of foundation soil can reduce the adverse effect of temperature action and effectively reduce the project cost when conducting temperature stress analysis.

2. Super long concrete structure should be selected according to the actual progress of the project appropriate temperature action conditions, to meet the construction stage and the use of the stage of the stress requirements. Excess length of concrete structures requires close cooperation between the
design, construction and construction units to ensure that the adverse effects of temperature action are minimized.

(3) Expected length of concrete structure without seam will increase the project cost to some extent, but through the selection of reasonable calculation parameters and working conditions, the project cost can be reduced to the minimum on the basis of satisfying the structural safety.

References
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