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Monitoring and maintenance of long isolated building and regularization of isolation detailing

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ABSTRACT

This paper presents a long-term monitoring of long, complicated isolated buildings and carried out quantitative study on the effect of inaccuracy in isolation detailing on the performance of isolated buildings. An isolated building with irregular plan was taken as example, the change of temperature, the change of thermal displacement in the isolators has been monitored and the response result has been compared with those simulated using FEM software of MSC.MARC and SAP2000. The variation of structural stiffness in the construction process has been calculated through FEM simulation, and compared with those obtained from dynamic diagnosis method. Another subject of this paper is to study the negative effect of the inaccuracy of isolation detailing on the anti-overturning property of the isolated structures, and the stiffness of inaccurate isolation detailing is analyzed using FEM model and static experiment, the negative effect is shown through both time domain analysis and random response.

1. INTRODUCTION

Base isolation technique has found wide application in the last few decades, and a lot of isolated buildings have been built worldwide. More and more isolated buildings have experienced recent strong earthquakes and exhibited good performance, promoting further popularization of isolation technique. With the progress of base isolation technique, many long buildings have been designed as base isolated buildings. However, large lateral deformation in rubber bearings which occurs during the construction phase have become a perplexing problem for engineers, in that such kind of lateral deformation may cause negative effect in the stability of rubber bearings. The investigation made by the author’s team shows that excessive displacement in the isolators caused by temperature differential and shrinkage of concrete in long isolated buildings in some region with high temperature fluctuation, partly because the isolated

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buildings have lower horizontal stiffness and higher flexibility in the isolation layer (Du, *et al*, 2014; Li, *et al*, 2013). Moreover, some isolation detailing inaccuracy widely exists in isolated buildings, which may decrease the performance of isolated buildings(Du and Li, 2012).

In this paper, the long isolated building with irregular plan was taken as example, the change of temperature, the change of thermal displacement in the construction process was studied, and the shrinkage of concrete impact on the deformation of the isolator together with the temperature fluctuation, and the effect of different schemes of post-pouring strips on the deformation of the isolator in a long isolated building are compared using finite element software. The quantitative study of the effect of inaccuracy in isolation detailing on the dynamic response of the isolated structures is carried out at the end.

2. ANALYSIS OF THE COMPREHENSIVE TEMPERATURE DIFFERENTIAL

The comprehensive temperature differential of structure includes two aspects, one is seasonal temperature differential, the other is shrinkage equivalent temperature differential of concrete. The two different temperature differentials are explained in the following part of this section.

2.1 Seasonal temperature differential

Seasonal temperature differential often refers to the temperature's difference of the structure between the construction phase and the use phase, due to the material properties of concrete, seasonal temperature differential is calculated as follows:

$$\Delta T = \begin{cases} T_{\max} - T_0 \\ T_0 - T_{\min} \end{cases} \tag{1}$$

Where, ΔT is seasonal temperature differential; T_0 is the temperature for hardening concrete (construction phase); $T_{\max}$、$T_{\min}$ are the average temperature in the warmest month and the coldest month.

2.2 Shrinkage equivalent temperature differential of concrete

To facilitate research, the concrete shrinkage usually represents by temperature loads which makes structure produce the same deformation. This temperature differential is called "shrinkage equivalent temperature differential". Shrinkage of the concrete at any time can be calculated as follows:

$$\varepsilon_y(t) = \varepsilon_y^0 M_1 M_2 \cdots M_n (1 - e^{-bt}) \tag{2}$$

Where, $\varepsilon_y(t)$ Shrinkage when the concrete age is t days; ε_y^0 is the limit shrinkage of concrete under standard conditions, $\varepsilon_y^0 = 3.24 \times 10^{-4}$; b is the empirical coefficient, generally take 0.01or 0.03 that Maintenance is poor; $M_1, M_2 \cdots M_n$ is the correction coefficient considered various non-standard conditions; t is the time.

According to the shrinkage and deformation of concrete, one can obtain the shrinkage equivalent temperature differential as follows:

$$\Delta T^{'} = -\varepsilon_y(t)/\alpha \tag{3}$$

Where, α is the thermal expansion coefficient of concrete, based on “Design of concrete structures”, $\alpha = 1\times 10^{-5}$ / ℃。

2.3 Comprehensive temperature differential

The comprehensive temperature differential of concrete structures is calculated as follows:

$$T = \Delta T + \Delta T^{'} \tag{4}$$

3. EXAMPLE ANALYSIS

3.1 Structure and parameters

A long isolation structure with irregular plan, the super structure is RC frame, the floor is beam-slab system. There are three towers, namely 1 #、2 # and 3 #. with deformation between them. The finite element model was created by SAP2000 as shown in Fig. 1. Rubber isolator’s mechanical properties and parameters are as shown in Table 1.

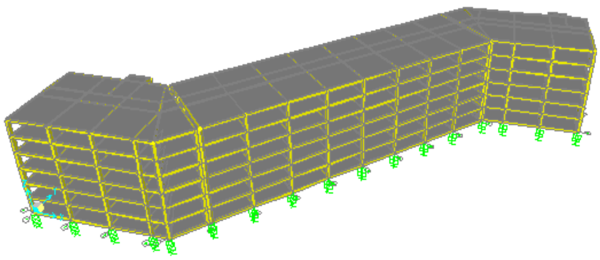

Fig.1 Finite element model of the structure

Table 1 Mechanical properties of rubber isolators

Model	Horizontal stiffness (kN/mm)		Equivalent damping ratio	
	γ=50%	γ=250%	γ=50%	γ=250%
GZY500	2050	1140	0.2	0.15
GZY600	2350	1800	0.2	0.15
GZY700	3000	2380	0.2	0.15
GZY800	3500	2720	0.2	0.15
GZP800	1860	1730	0.05	0.04

3.2 Comparison between FEM simulation and measured values

Temperature effect on the isolators’ displacement

With temperature reduced, there will form a larger tensile stress in the floor of long structure, so in this paper the main consideration is the temperature reduced influence.

The Comprehensive temperature differential is applied to the model as a negative temperature differential, thus get vertical and horizontal bearing displacement of three measuring points. Specific results shown in Figure 2 and 3. One can be seen from figures:

(1) The vertical deformation value is larger, and the lateral deformation values is smaller. The maximum monitoring longitudinal value reaches 27mm, simulated value reaches 29.16mm; maximum monitoring lateral value reaches 5.5mm, the simulated value reaches 5.7mm.

(2) The deformation of the measuring points 1 and 3 toward the middle of the structure (fixed point near), but their deformation trend is same.

(3)The bearing deformation changes fast in the beginning, and slow at the late. And with the temperature change in the construction process , isolator’s deformation has been restored, but the deformation caused by shrinkage is unrecoverable. When the comprehensive temperature differential is 39.2 ℃ , the measuring point 1 longitudinal shrinkage deformation reaches 8.5mm, 31% of the total deformation.

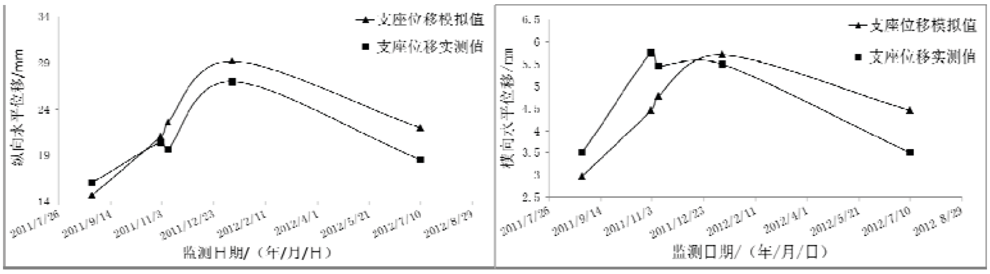

Fig. 2 Comparison of bearing displacement of the measuring point 1 between simulated values and monitoring values

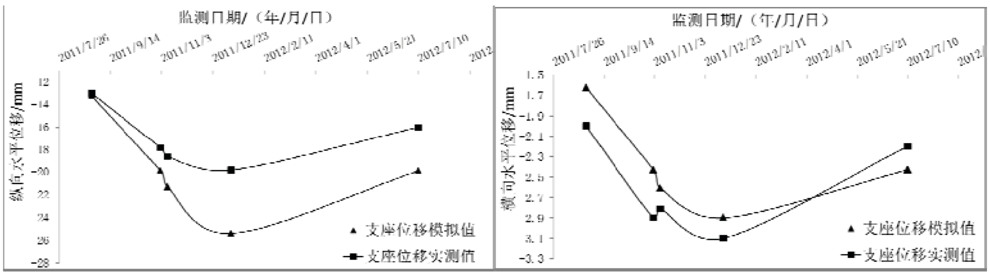

Fig. 3 Comparison of bearing displacement of the measuring point 3 between simulated values and monitoring values

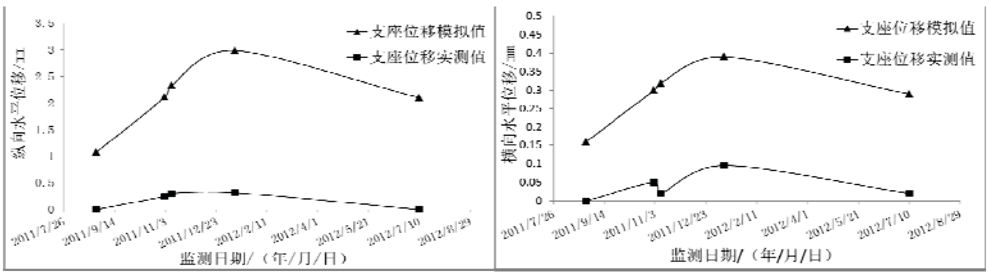

Fig. 4 Comparison of bearing displacement of the measuring point 2 between simulated values and monitoring values

The deformation of measuring point 3 is small, the maximum monitoring longitudinal value reaches 0.31mm, and the simulated value reaches 2.98mm; the maximum monitoring lateral value reaches 0.39mm, the simulated value reaches 0.095mm. The characteristics and trends of deformation is similar with the measuring points 1and 3, bearing deformation displacement is shown in Figure 4.

<u>Inaccuracy detailing effect on the isolator's displacement</u>

The isolated structure's central tower equipped with two elevators, due to the construction workers was once mistakenly elevator shaft contact with the ground directly, making the elevator shaft at the inaccuracy detailing, the author has also simulated the corresponding model, so that the model is fixed at the two elevator shaft. Analyzing the Figure 5 thick solid line marked isolator displacement. Comparison displacement value the elevator shaft grounding and ungrounded cases shown in Figure 5.

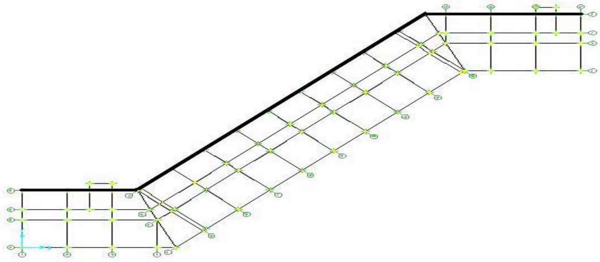

Fig. 5 Selected isolation layer

As can be seen from Figure 6, the elevator shaft position shifted to the left of the structure, so the displacement of the left bearing has a large degree of decrease, and the right is the same. The inaccuracy detailing in the elevator shaft will have an adverse impact on isolation performance of the structure, but the inaccuracy detailing will reduce the bearing displacement in construction phase.

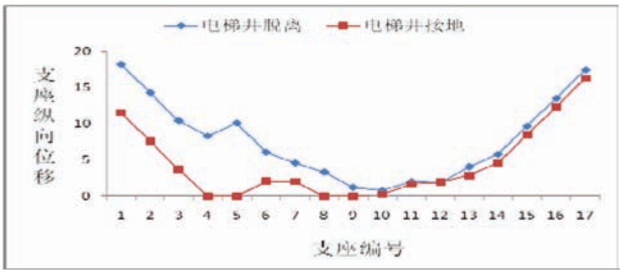

Fig. 6 Bear displacement contrast in two different situations

After the construction side corrects the inaccuracy detailing, the comparison of measured and simulated values, as shown in Figure 7. As can be seen from the figure, the maximum vertical displacement of the bearing is 22.45 mm, the maximum lateral displacement of the bearing is 23.05 mm. The maximum longitudinal displacement is in the ends of the structure, and the maximum lateral displacement is in the two corners of the structure. With the monitoring carried out, the author found that the bearing displacement has a certain degree decreases as temperatures rise.

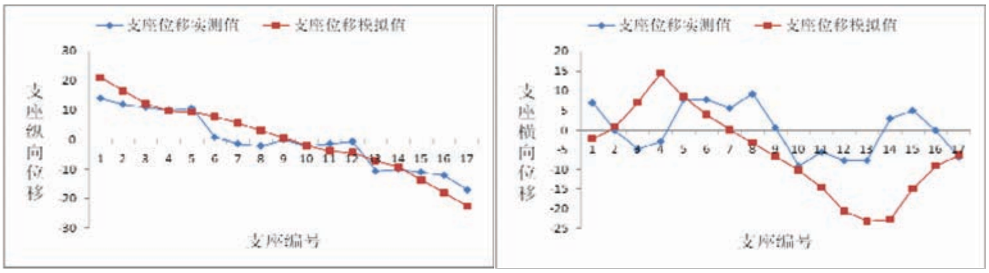

Fig. 7 Comparison of measured and displacement simulated values of rubber bearing

4. CONCLUSIONS

In this paper, using the finite element simulate temperature effect of a plain irregular long isolation structure in the construction, and monitoring the bearing deformation, after analyzing simulating and monitoring data, one can get the following conclusions:

(1) In the construction phase, isolation layer is in open-air environments, and there will have a large temperature differential, coupled with concrete shrinkage deformation which occurred in the early completion of the pouring, so the bearing deformation of non-load mainly occurs in the construction process. Bearing deformation caused by temperature differential is changing with the environment temperature difference, but the deformation caused by concrete shrinkage has unrecoverable. For the monitoring of actual project in this paper, the longitudinal deformation in the ends caused by concrete shrinkage can be more than 30% of non-load deformation, so the concrete shrinkage deformation in the long isolated structure is important part of the non-load deformation.

(2) In the long isolation structure, the bearing deformation will large under concrete shrinkage and seasonal temperature differential and other factors together affected, which the deformation generated by temperature changing with the seasons change. When the structure is in the construction season, the most deformation can recover, but deformation caused by shrinkage will unrecoverable.

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