Seismic Performance Analysis of Exterior-Corridor Type and Middle-Corridor Type Architecture

Jiuyang Li1, Fangqi Li1,*, Daozheng Li1 and Fang Han1
1Changchun Institute of Technology, Jilin Province Key Laboratory for Earthquake Resistance & Hazard Mitigation of Civil Engineering, Jilin Province Research Center of Construction Technology & Engineering For Housing in Cold Regions
Changchun 130012, Changchun
*Corresponding author: li15037157044@163.com

Abstract. In this paper, SAP2000 FEM simulation software has been used to carry out modal analysis, response spectrum analysis, time-history analysis and other seismic performance researches on the structural layout scheme and optimal number of floors of certain proposed reinforced concrete frame teaching building respectively built in exterior-corridor type and middle-corridor type in order to compare the seismic performance of the structure under different working conditions. According to the analysis, the seismic performance of middle-corridor type architecture is obviously better than that of exterior-corridor type architecture along with the increase of seismic fortification intensity, while the increase of storey height within certain scope does not affect the seismic performance of these two types notably, thus providing the theoretical basis for engineering design.

Keywords: Exterior-Corridor Type, Middle-Corridor Type, Fortification Intensity, Seismic Performance, Building Height

1. Introduction
Earthquake, still a kind of unforeseeable natural disasters, is of great harmfulness [1-2]. Since most areas of China are sited in an earthquake zone, the economic loss and social influence caused by earthquake, along with the rapid growth of national economy and urbanization, have become increasingly prominent. According to previous studies and earthquake damages, the structural layout of buildings is critical to the seismic performance. Therefore, Code for Seismic of Buildings specifies that the priority of seismic design is to have rational architectural form and layout [3]. Architectural design shall focus on the influence of regularity of the plane, facade and vertical profile on the seismic performance and economic rationality, and select best regular forms with the plane layout of its lateral resisting elements being systematical. Selecting rational structural forms and systematical and regular plane layout can significantly undercut the torsion performance caused by earthquake, which is meaningful for enhancing the seismic performance of architectural structure. This paper, based on the influence of plane layout of architectural structure on seismic performance, compares the influence of the architectural design and structural layout of exterior-corridor type and middle-corridor type
buildings [4-6].

This paper applies SAP2000 FEM analysis software to carry out modal analysis, response spectrum analysis, time-history analysis and other seismic performance analysis on the structural layout of certain reinforced concrete frame teaching building respectively built in exterior-corridor type and middle-corridor type. After carrying out static elastoplastic analysis under different working conditions, it concludes the floor displacement, inter-storey displacement angle and natural vibration period of two architectures. The results of comparing the seismic performance of these two structures can serve as the basis of engineering construction and structural design [7-9].

2. Simulation Modeling

The proposed project is a reinforced concrete frame teaching building built in two structural models, namely, middle-corridor type and exterior-corridor type. The teaching building shall be a building of 4-storey, and its building height shall be 15.6m. Meanwhile, rigid connection shall be used for connection of beam columns and column bases in both schemes.

This teaching building, in linear shape, consists of 4-6 storeys, with the storey height being 3.9m and built-up area per storey being about 1,200m². There are two kinds of classrooms, which are 450mm×700mm and 350mm×700mm. The material and load parameters of the model are shown in Table 1.

According to the basic parameters of the model in Table 1, two model structures are established on the simulation platform. the models of exterior-corridor type and middle-corridor type are as shown in Figure.1.

| Table 1. Basic parameters of the model |
|----------------------------------------|
| Property type                        | Parameters                        |
| Concrete degrade                     | C30                                |
| Sectional dimension                  | Beam:200mm×500mm; column:400mm×400mm |
| Reinforcement type                   | HRB335                             |
| Earthquake magnitude                 | 6 (0.05g)                          |
| Dead load                            | 2.0kN/m²                           |
| Live load                            | 1.0kN/m²                           |
| Basic wind pressure                  | 0.35kN/m²                          |

Figure 1. Model Diagram of Architecture (a) Middle-Corridor Type (b) Exterior-Corridor Type

3. Seismic Performance Analysis

3.1. Modal Analysis

Modal analysis, also known as dynamic analysis of mode superposition method, is the most common and effective method for seismic analysis of linear structural systems. Both exterior-corridor type and
middle-corridor type architectures are featured with different dynamic characteristics and seismic performance. Since Ritz vector approach can prevent errors caused by high-order model interception, and get more accurate calculation results, Ritz vector approach has been adopted by both schemes in this paper for modes decoupling. The modal participating mass ratio and natural vibration period from 1st to 5th order concluded from modal analysis are shown in Table 2.

As we can see from Table 2, the sum of all modal participating mass ratios at X and Y direction of both two architectures is larger than 0.9, which meets the minimum requirements of cumulative mass required by model interception analysis specified in Code for Seismic of Buildings [3]. After comparing UX+Uy and Rz, it comes out that if UX+Uy is less than Rz in the 1st cycle, the first mode of both two architectures gives priority to torsion, and the torsional amplitude of middle-corridor type architecture is smaller than that of exterior-corridor type architecture. In the 2nd cycle, both structures center on translational motion along X and Y direction, and since the symmetry of middle-corridor type architecture is better than exterior, the translational motion amplitude and torsional amplitude of middle-corridor type architecture are smaller than the other. In addition, the natural vibration period of each mode of middle-corridor type architecture is larger than exterior-corridor type architecture, which is good for earthquake resistance.

### Table 2. Natural Vibration Period and Modal Participating Mass Ratio of two types

| Mode sequence | Cycle (s) | UX+Uy | Rz | Cycle (s) | UX+Uy | Rz |
|---------------|-----------|-------|----|-----------|-------|----|
| 1             | 0.98144   | 0.00696 | 0.35753 | 0.84941 | 0.10769 | 0.41661 |
| 2             | 0.86861   | 0.94425 | 0.26049 | 0.78427 | 0.93363 | 0.51583 |
| 3             | 0.86516   | 0.92225 | 0.32643 | 0.73902 | 0.86626 | 0.02248 |
| 4             | 0.41677   | 0.03644 | 0.01290 | 0.25487 | 0.00215 | 0.00070 |
| 5             | 0.27296   | 0.00217 | 0.00910 | 0.23883 | 0.02188 | 0.00009 |

3.2. Response Spectrum Analysis

Response spectrum analysis is simulated dynamics analysis. First, apply dynamic analysis method to calculate seismic response at particles, then apply the statistical method to establish the response spectrum curve, and finally carry out the structural analysis through static analysis method. In general, floor horizontal movement and inter-storey displacement angle are used to measure the deformation extent. The horizontal movement and inter-storey displacement angle concluded through response spectrum analysis on the condition that seismic fortification intensity is 6-degree (0.05g) are shown in Figure 2.

**Figure 2.** Comparison of simulation results of two structures (a) floor displacement (b) storey drift

The comparison of analysis results between two architectures shows that the top displacement of both structures are 10.79mm and 9.01mm respectively, with the top displacement of middle-corridor type architecture being 19.76% shorter than exterior-corridor type architecture; when comparing the
inter-storey displacement angle of both structures, the maximum inter-storey displacement angle of exterior-corridor type architecture and middle-corridor type architecture is 0.00062 rad and 0.00047 rad respectively, both smaller than 0.0018 rad - the limit of inter-storey displacement angle specified in the code. However, the inter-storey displacement angle of exterior-corridor type architecture is 24% less than that of exterior-corridor type architecture, which means that the middle-corridor type design can remarkably enhance the anti-deformation capacity and decrease the seismic damage.

In order to analyze the deformation of both two architectures under different seismic fortification intensities, compare and analyze the displacement of both structures when seismic fortification intensity is 6-degree (0.05 g) and seismic fortification intensity is 8-degree (0.2 g), with results shown in Figure 3.

The comparison results when seismic fortification intensity is 8-degree show that the middle-corridor type architecture is better than the other no matter from floor displacement or inter-storey displacement angle, and all inter-storey displacement angles of middle-corridor type architecture are less than 1/550, which means that it can maintain the elastoplastic phase [10]. On the contrary, when it comes to elastoplastic phase, the exterior-corridor type architecture will suffer from structural damage. On the other hand, the floor displacement of both structures will increase along with the increase of seismic fortification intensity, but the difference will get larger and larger.

**Figure 3** Comparison of two structures when Seismic Fortification Intensity is 8-Degree (a) floor displacement (b) storey drift

By analyzing Figure 2 (a) and Figure 3 (a), it can be concluded that with the increase of seismic intensity, the floor displacement of the two structures becomes larger. But the distance between the two curves becomes larger, which shows that the seismic performance of the inner gallery building is higher.

**Table 3** Displacement of 6-Storey Architecture

| Floor | Horizontal displacement of veranda (mm) | Horizontal displacement of inner Gallery (mm) | Displacement ratio |
|-------|----------------------------------------|----------------------------------------------|-------------------|
| 1     | 8.62                                   | 8.29                                         | 0.964             |
| 2     | 12.43                                  | 11.94                                        | 0.961             |
| 3     | 15.27                                  | 14.67                                        | 0.961             |
| 4     | 17.48                                  | 16.78                                        | 0.960             |
| 5     | 19.00                                  | 18.23                                        | 0.960             |
| 6     | 19.82                                  | 19.00                                        | 0.959             |

In order to study the seismic performance of these two structures along with the increase of floor height, this paper also analyzes the model of 6-storey building when seismic fortification intensity is 8-degree (0.2 g), as shown in Table 3.

It’s obvious that the deformation of both structures under the same seismic fortification intensity increases along with the increase of the overall building height, but the displacement ratio of both
remains almost the same. This means that the middle-corridor type architecture is more advantageous than the other, but influence of such advantage is not obvious.

4. Conclusion
This paper analyzes the seismic performances of exterior-corridor type and middle-corridor type architectures under different seismic fortification intensities and different building heights. According to the above-mentioned comparison, the floor horizontal displacement and displacement angle of middle-corridor architecture are smaller than the other and along with the increase of seismic fortification intensity, the performance of middle-corridor type gets better than exterior. However, the increase of building height within a certain scope cannot affect the performance of middle-corridor architectures obviously.

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