Dynamic response and failure mode of series isolation system under explosion load

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Abstract. The numerical model of the series isolation structure was established by using the finite element software to simulate the dynamic behavior of the series isolation structure after explosions occurred at different positions, and study the dynamic response and failure mode of the series isolation structure under explosion load. The results show that the vertical displacement and speed of the beams on each floor show a certain regularity with the passage of time. When columns at different positions encounter explosive loads, they will cause local collapse and damage of the structure, and the damage is mainly distributed in the longitudinal and transverse ranges where the columns are located. Compared with the inner column, the structural damage caused by the explosion load on the corner column and side column is more serious.

1. Introduction
In the past two decades, more and more researchers have paid attention to the dynamic response of building structures under explosion load. Li Zhongxian et al. [1] summarized the dynamic response and collapse mechanism of steel members and steel structures under the action of explosion load. Gong Shunfeng et al. [2] studied the collapse fatality rate of building structures under the action of explosion load. Fang Qin et al. [3] analyzed the dynamic response and failure mode of a reinforced concrete structure shallowly buried in the soil under explosive load. Song Xiaosheng et al. [4] compared the effects of explosion loads and earthquakes on reinforced concrete structures. Shen Zuwu et al. [5] numerically simulated the dynamic characteristics of a two-story frame structure under explosive load. Yan Shi et al. [6] analyzed the continuous collapse process of the reinforced concrete frame structure under the external ground explosion load. Zhang Xiuhua et al. [7] analyzed the deformation characteristics and collapse failure modes of steel frame structures under the action of gas explosion. Du Yongfeng et al. Du Yongfeng et al. [8] analyzed the continuous collapse process of isolation structure under explosion load at different locations of basement.

At present, the research on the dynamic response of building structures under the action of explosion load is still in the preliminary stage. Most of the existing research focuses on the traditional structure such as reinforced concrete frame structure and steel frame structure, while the research on the isolation structure is relatively few. In view of this, this article takes the common series seismic isolation system in recent years as the research object, and conducts research on its dynamic response and failure mode under the action of explosion load.

2. Project overview and calculation model
A reinforced concrete frame series isolation structure, with 5 floors above ground and 1 floor underground, the isolation bearing is arranged at the top of the basement column. The height of the...
The first underground floor is 3.6m, and the height of each floor above ground is 3m. The column section size is 500mmx500mm, the beam section size is 300mmx600mm, and the plate thickness is 100mm. Figure 1 shows the schematic layout of the series seismic isolation structure. In the analysis of dynamic response and failure mode under explosive load, the detonation point is set in the middle of the first underground column (A1, A2, and B3) to simulate the dynamic behavior of the series isolation structure after explosion at different locations.

Figure 1 Schematic diagram of the layout of the series seismic isolation structure

Figure 2 shows the numerical calculation model of the series seismic isolation structure established by finite element software. The beams, columns, air and seismic isolation supports are all simulated by solid elements. The air and explosives use Euler grids, the structure uses Lagrange grids, and the cells use the ALE algorithm.

Figure 2 Calculation model of series seismic isolation structure

3. Dynamic response analysis

Figure 3 shows the vertical displacement time history curve of each layer of beams with each floor as a reference when the explosion occurs at different positions (A1, A2, and B3). It can be seen that with the passage of time, the vertical displacement of each layer of beams shows an increasing trend, but the development rate of the vertical displacement of the beams on each floor is different, and the development rate of the vertical displacement of the beams on the high floors is relatively high.
Figure 4 shows the vertical velocity time history curves of each layer of beams when the explosion occurs at different positions (A1, A2, and B3). It can be seen that the vertical speed of each layer of beams fluctuates around 0.0m/s before 0.2s, and the vertical speed of each layer of beams begins to increase after 0.2s, showing a certain regularity.

4. Failure mode analysis

Figure 5 shows the destruction process of the series seismic isolation structure when the explosion occurs at position A1. It can be seen that at 0.009s, the column A1 and its connected seismic isolation layer beam failed and exited the work. At 1.5s, obvious partial collapse of the structure occurred, and the component collapsed seriously, the range is limited to the vertical and horizontal span where the column A1 is located, and has little impact on the adjacent span.

Figure 6 shows the destruction process of the series seismic isolation structure when the explosion occurs at position A2. It can be seen that at 0.009s, column A2 and its connected seismic isolation layer beams are damaged, the damage of the isolated beam is more serious than that of the first and second floors above ground. At 1.5s, obvious partial collapse of the structure occurred, and the component
collapse was serious, and the scope was mainly located in the longitudinal and transverse span where the column A2 was located.

Figure 6 Structural failure process after explosion at A2 position

Figure 7 shows the destruction process of the series seismic isolation structure when the explosion occurs at position B3. It can be seen that at 0.009s, column B3 was damaged, while other components were not obviously damaged. At 1.5s, obvious local damage occurred to the structure, and the components were seriously damaged, the scope is mainly located in the longitudinal and transverse span where the column B3 is located.

Figure 7 Structural failure process after explosion at B3 position

5. Conclusion
Through the analysis of the dynamic response and failure mode of the series seismic isolation system under explosive loads at different positions, the following conclusions are drawn:

1) The vertical displacement of each layer of beams increases with the passage of time, and the vertical velocity of each layer of beams also shows a certain regularity with the passage of time.

2) When columns at different positions encounter explosive loads, the structure will collapse and damage locally, and the damage range is mainly located in the longitudinal and transverse spans where the columns are located.

3) Compared with inner columns, the structural damage of corner columns and side columns is more serious when they encounter explosive loads.

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