Damage capacity of the ground motions of the Dec. 1, Alaska Earthquake

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Acknowledgments and Disclaimer

The authors are grateful for the data provided by the Center for Engineering Strong Motion Data (CESMD).

This analysis is for research purpose only. The actual damage situation resulting from the earthquake event should be determined according to the site investigation.

1. Introduction to the earthquake event

At 01: 29, Dec. 1st, 2018 (Beijing Time, GMT+8), an M 7.2 earthquake occurred in Alaska, U.S.A. The epicenter is located at 61.35 N, 150.06 W with a depth of 40 km.

2. The recorded ground motions

6 ground motions of the Alaska earthquake event were recorded. The analyses of the typical ground motions are as follows:

Ground motion recorded at 8047 station

The 8047 station is located at 61.189 N and 149.802 W (Figure 1). The PGAs of horizontal and vertical components of the 8047 ground motion are 807.162 cm/s^2 and 367.243 cm/s^2, respectively. The ground motion and its response spectra in comparison with the design spectra specified in the Chinese Code for Seismic Design of Buildings are shown in Figures 2 and 3.

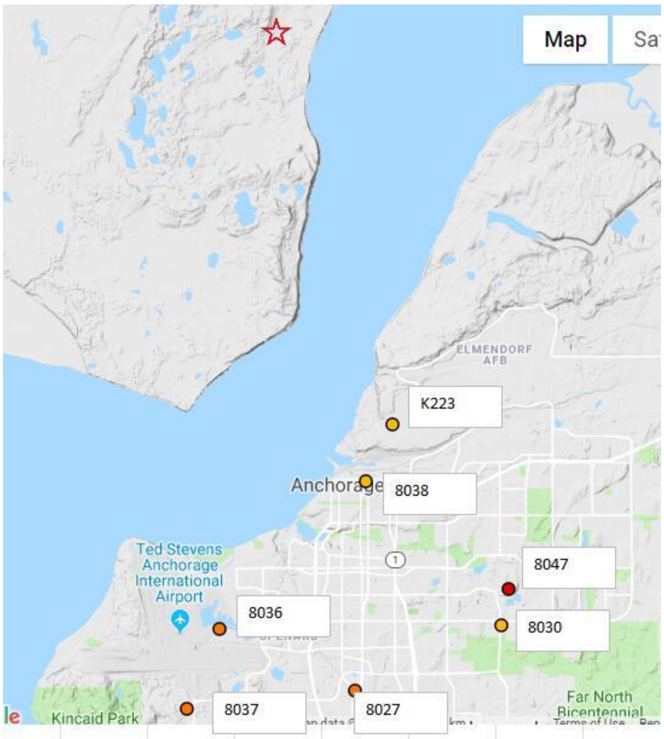
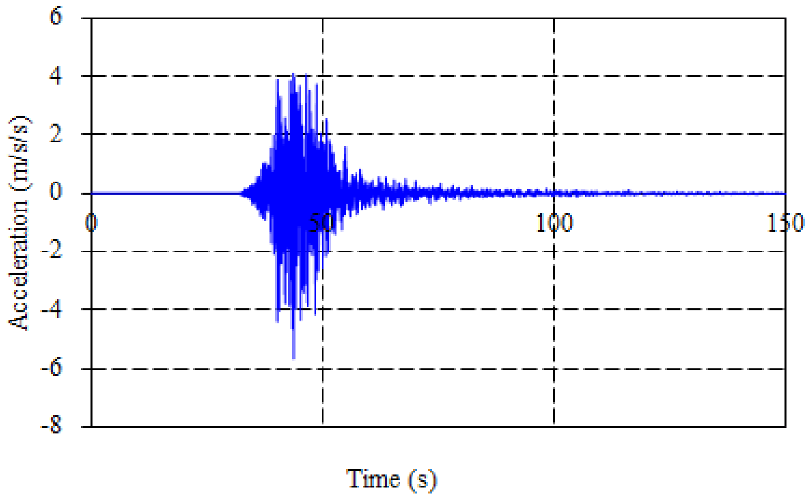
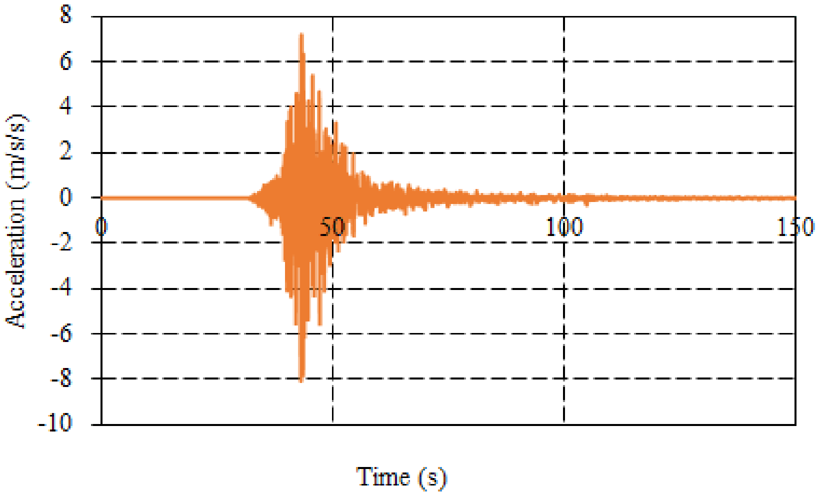


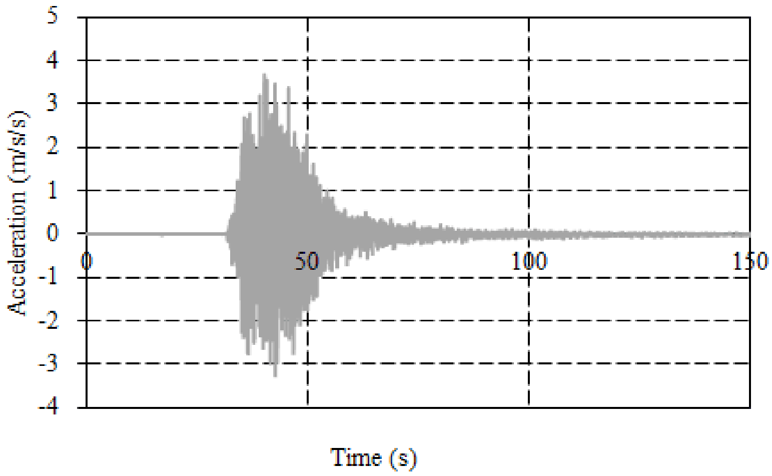
Figure 1 Location of the 8047 ground motion station



(a) EW



(b) NS



(c) UD

Figure 2 Ground motion recorded by the 8047 station

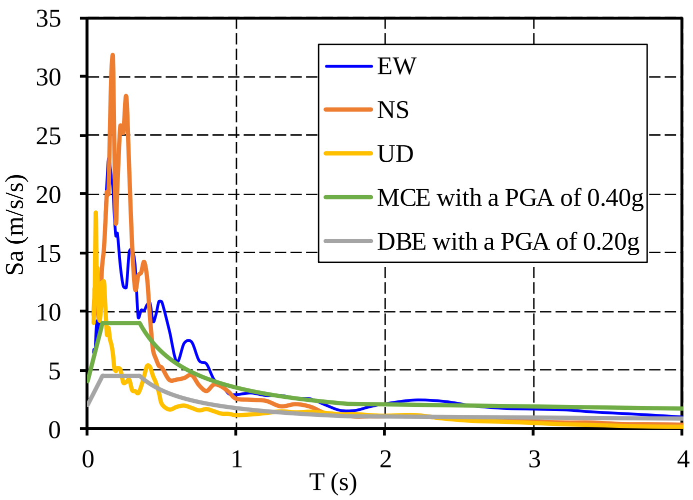
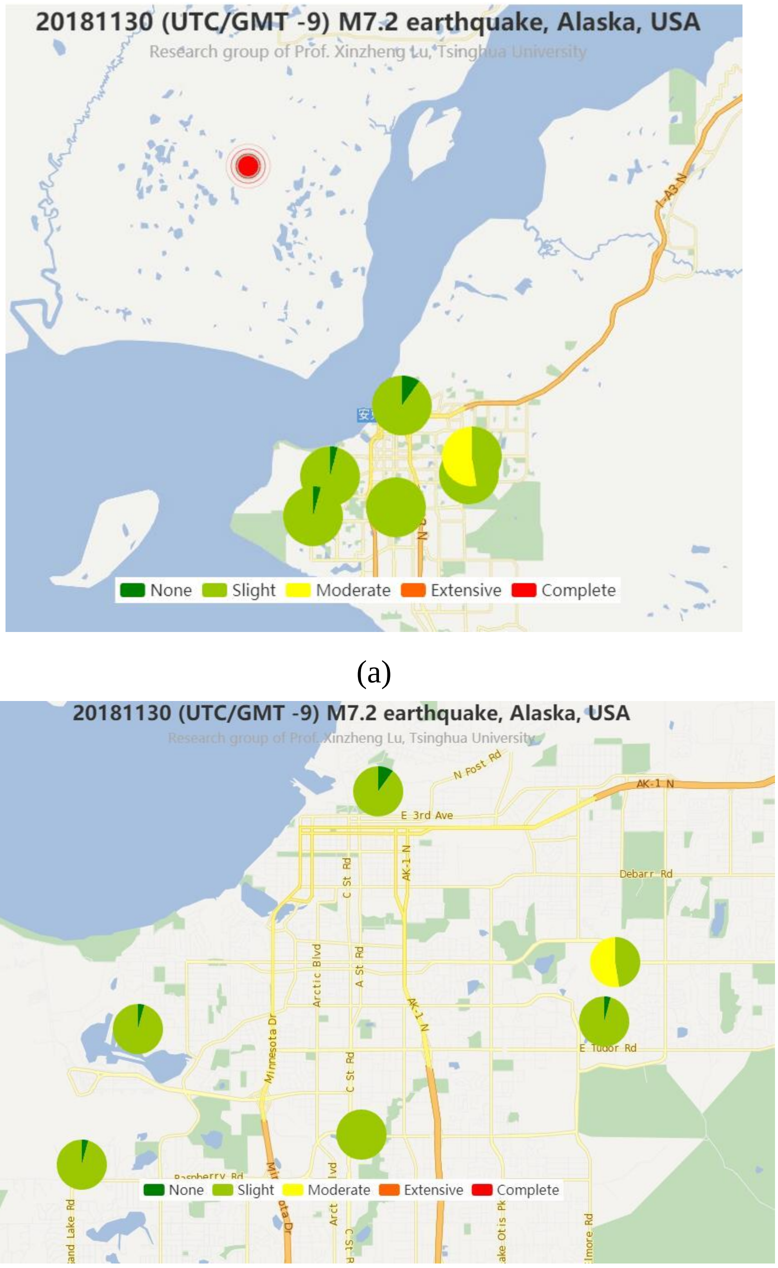


Figure 3 Response spectra of the ground motion recorded by the 8047 station

3. Seismic damage analyses for Anchorage region subjected to the recorded ground motions

Using the real-time ground motions obtained from the strong motion networks and the **cityscape nonlinear time-history analysis**, the damage ratios of buildings located in different places can be obtained, which can provide a reference for post-earthquake rescue work. The damage ratio distribution of the buildings near to different stations is shown in Figure 4.



(a)

(b)

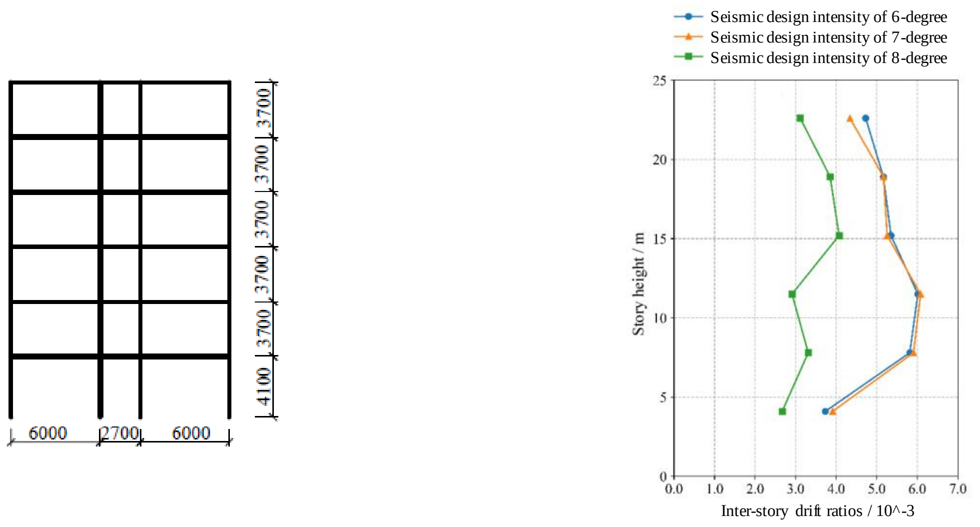
Figure 4 Damage ratio distribution of the buildings near to different stations

4. Seismic damage analyses for typical buildings subjected to the recorded ground motion

(1) Multi-story reinforced concrete frames

Model 1: 6-story reinforced concrete frame

The 8047 records are input into three typical 6-story reinforced concrete (RC) frames, with seismic design intensities of 6-, 7-, and 8-degrees, respectively. The envelope of the inter-story drift ratios obtained from the nonlinear time-history analyses are shown in Figure 5(b).

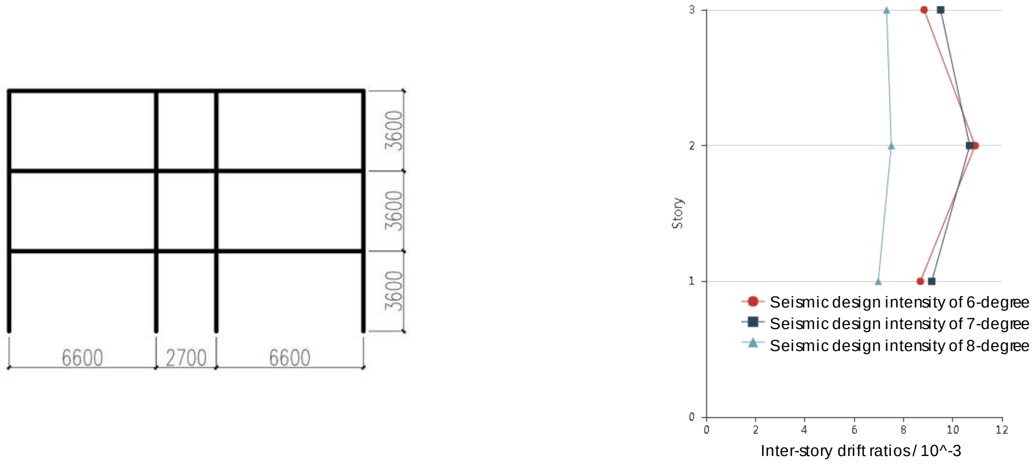


(a) Elevation view (unit: mm) (b) Envelope of the inter-story drift ratios

Figure 5 Three typical 6-story RC frames

Model 2: 3-story reinforced concrete frame (Thanks Prof. Wang Qi from China Architecture Design & Research Group for providing the model)

The 8047 records are input into three typical 3-story reinforced concrete (RC) frames, with seismic design intensities of 6-, 7-, and 8-degrees, respectively. The envelope of the inter-story drift ratios obtained from the nonlinear time-history analyses are shown in Figure 6(b).



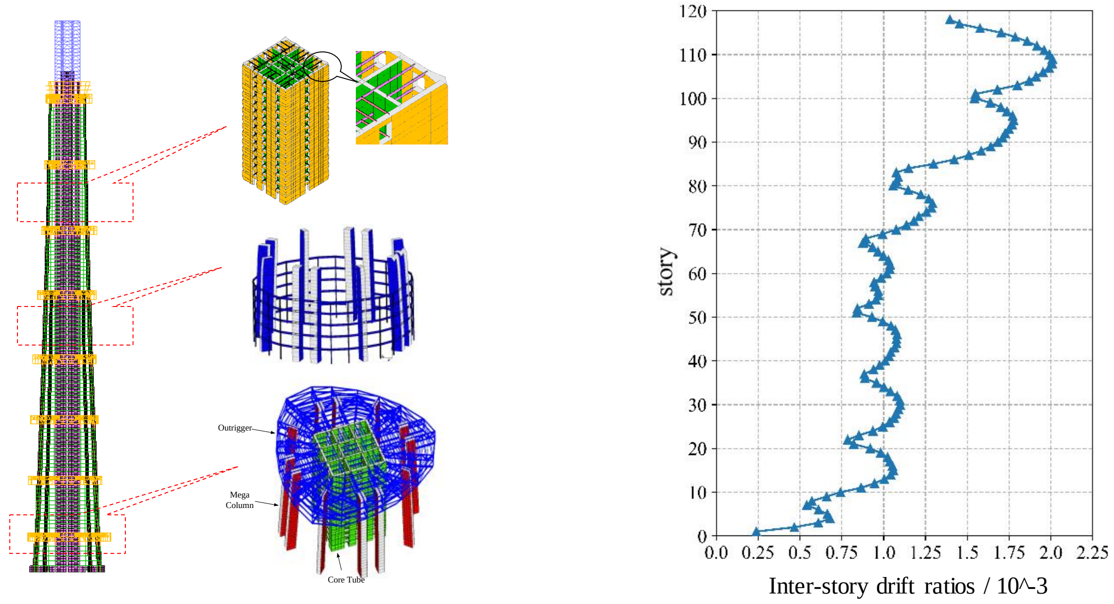
(a) Elevation view (unit: mm) (b) Envelope of the inter-story drift ratios

Figure 6 Three typical 3-story RC frames

(2) Super-tall buildings

Model 1

By performing the seismic damage analysis for the typical super-tall building 1 (Figure 7(a)) using the ground motion recorded by the 8047 station, the envelope of the inter-story drift ratios is obtained, as shown in Figure 7(b).

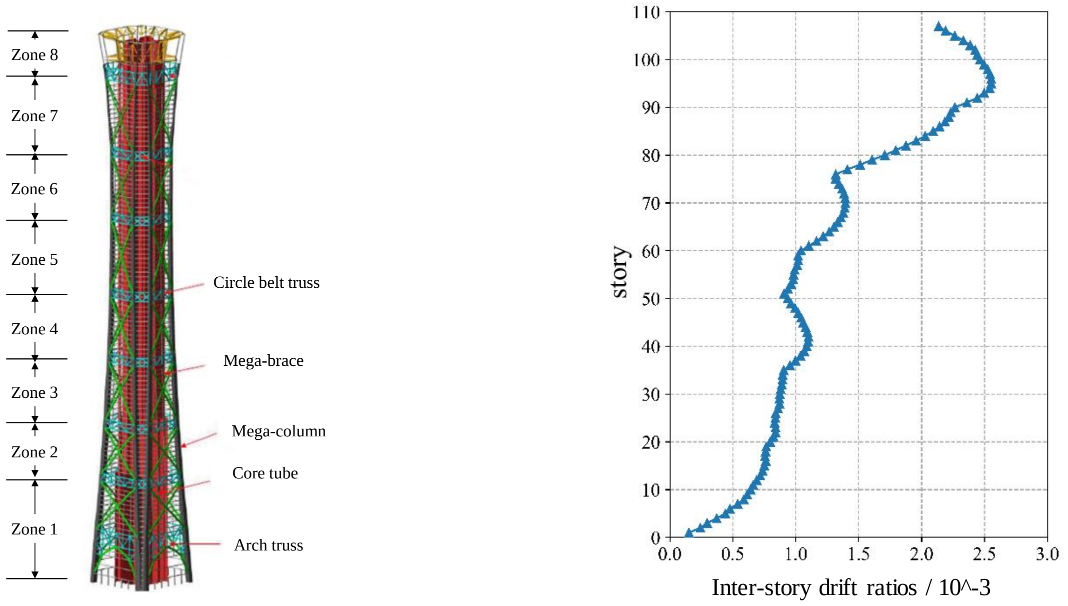


(a) Typical super-tall building 1 (b) Envelope of the inter-story drift ratios

Figure 7 Typical super-tall building 1

Model 2

By performing the seismic damage analysis for the typical super-tall building 2 (Figure 8(a)) using the ground motion recorded by the 8047 station, the envelope of the inter-story drift ratio is obtained, as shown in Figure 8(b).



(a) Typical super-tall building 2　　　　(b) Envelope of the inter-story drift ratios

Figure 8 Typical super-tall building 2

(8) Multi-story reinforced masonry structures

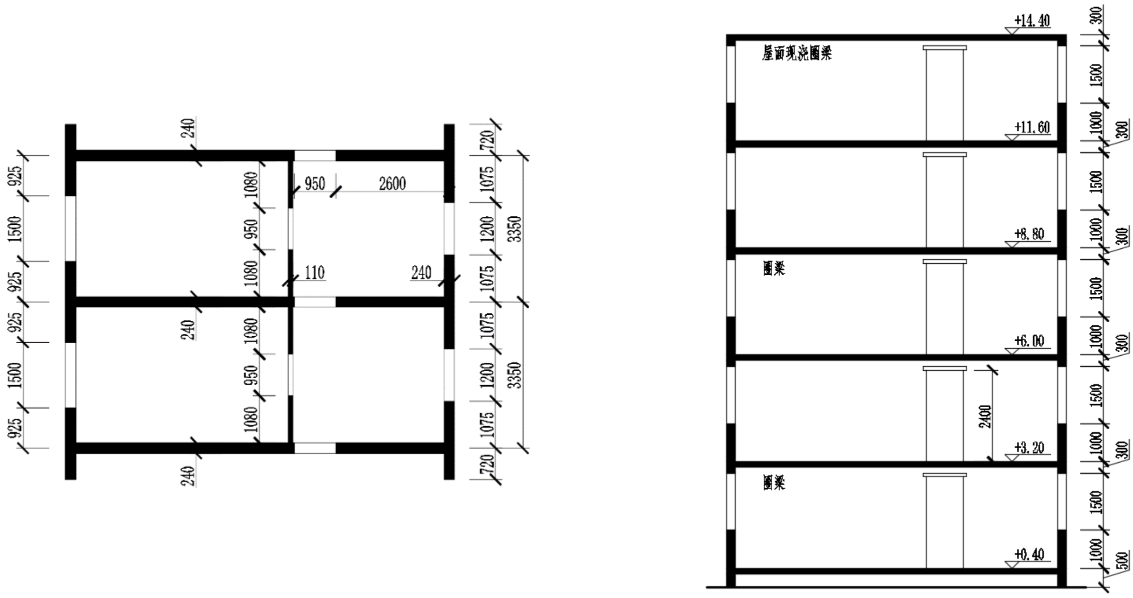
Model 1: 1-story unreinforced masonry

The 8047 records are input into a single story unreinforced masonry in Figure 9. The damage state of the structure is **complete damage**. (Ji X D, et al. Shaking table test of unretrofitted and retrofitted brick-wood structures representative of existing rural buildings in Beijing. 2012, 11, 53-61.)

Figure 9 The shaking table test of a 1-story unreinforced brick-wood residential structure with three rooms

Model 2: 5-story simple masonry

The 8047 records are input into a 5-story simple masonry in Figure 10. The damage state of the structure is **moderate damage**. (Zhu B L, et al. Seismic resistance capacity analysis of a five-story masonry test building in Shanghai)

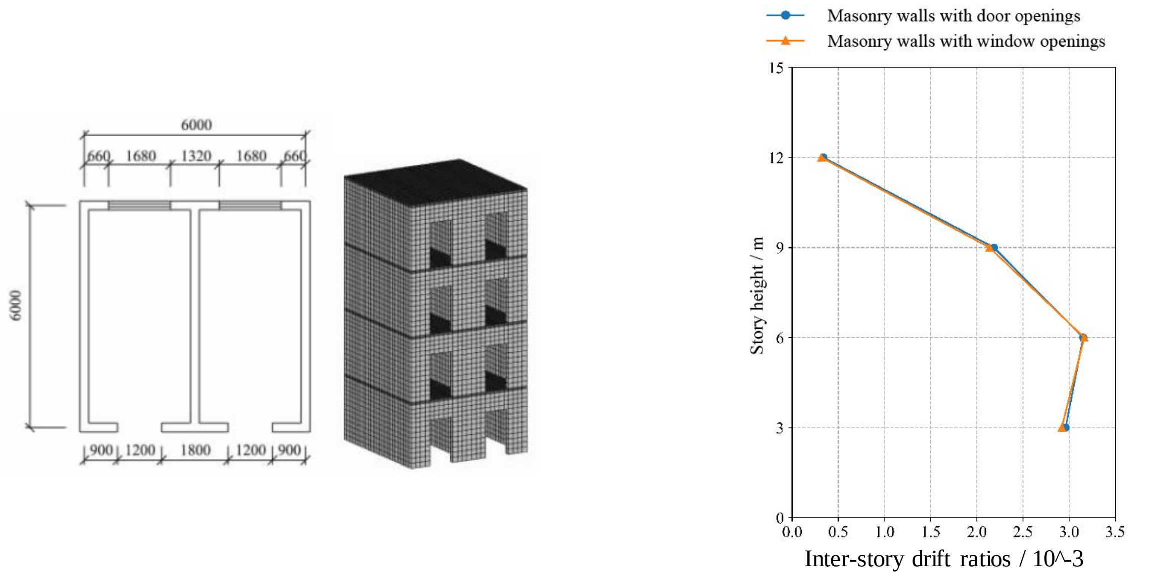


(a) Plan view (b) Section view

Figure 10 A 5-story simple masonry

Model 3: 4-story reinforced masonry

The 8047 records are input into a 4-story reinforced masonry in Figure 11(a), the envelope of the inter-story drift ratios is obtained, as shown in Figure 11(b).



(a) Plan view and 3D model (b) Envelope of the inter-story drift ratios

Figure 11 A typical 4-story reinforced masonry structure

(4) Typical bridges

Model 1: Highway bridge built in 1980s (Thanks Prof. Gu Yin from Fuzhou University)

8047 records are input into a highway bridge built in 1980s in Figure 12. The damage state of the bridge is **moderate damage**.

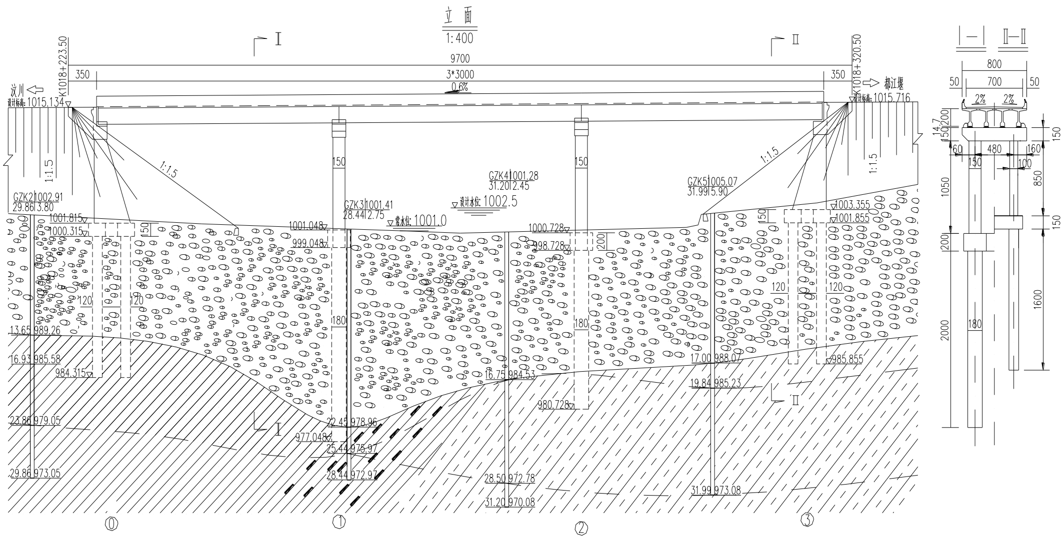


Figure 12 A highway bridge built in 1980s

Model 2: Approach bridge of a super large bridge (Thanks Prof. Gu Yin from Fuzhou University)

The 8047 records are input into the approach bridge of a super large bridge in Figure 13. The damage state of the bridge is **moderate damage**.

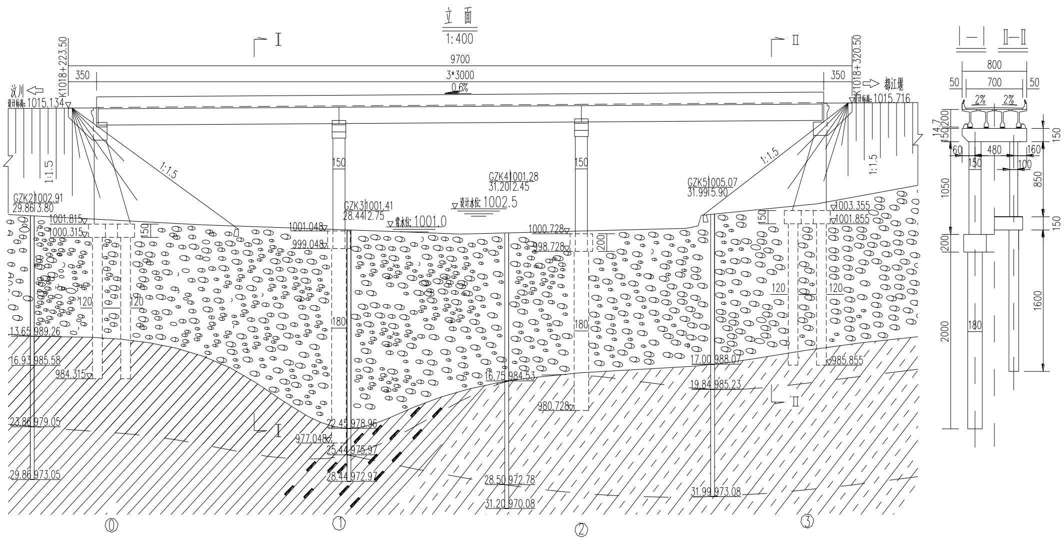
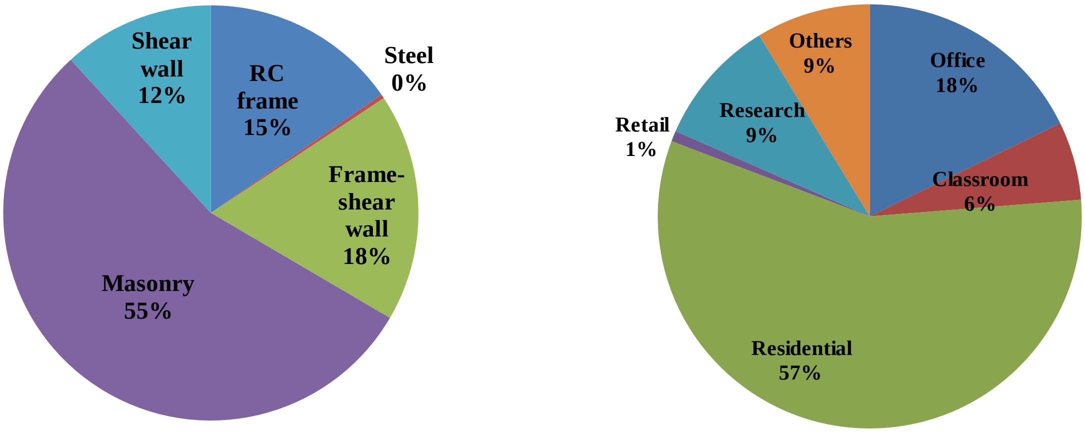


Figure 13 The approach bridge of a super large bridge

5. Seismic damage analyses for Tsinghua campus subjected to the recorded ground motion

In order to compare the damage states of different ground motions to an urban area, the campus of Tsinghua University is also selected as a typical region. 619 buildings in the campus are considered. The percentages of different structural types and occupancies are shown in Figure 14. The ground motion recorded by the 8047 station is inputted to the buildings. The damage states are obtained from the **cityscape nonlinear time-history analysis** considering the uncertainty of the structural seismic resistance, as shown in Figures 15. The predicted damage states of typical buildings in the campus are shown in Table 1. Note that there are three columns for each type of building, representing the median - σ, median and median + σ results, where σ is the standard deviation of the building seismic resistance.



(a) Percentages of different structural types (b) Percentages of different building occupancies

Figure 14 The buildings in the campus of Tsinghua University

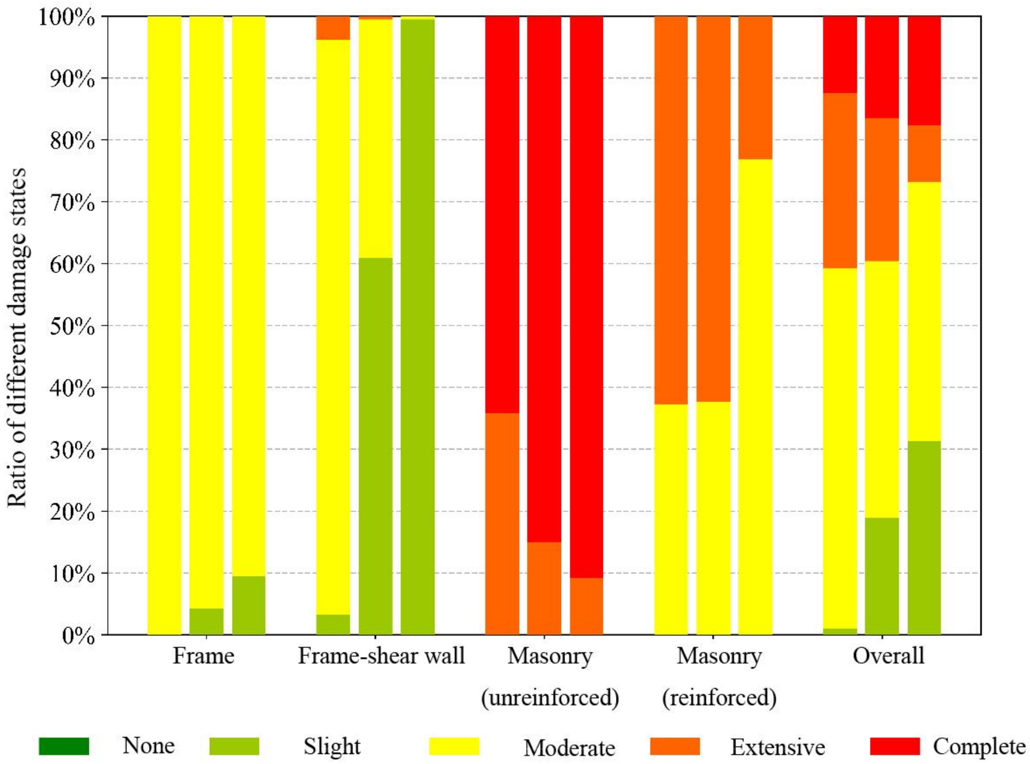


Figure 15 Damage states of Tsinghua University campus subjected to the ground motion recorded by 8047 station

Table 1 The predicted damage states of typical buildings in the campus of Tsinghua University

Name	# stories	Occupancy	Median - σ	Median	Median + σ
Department of Civil Engineering	4	Office	2	1	1
Main Building	10	Office	3	1	1
Teaching Building #4	4	Classroom	2	2	2
Teaching Building #6（Area B）	9	Classroom	2	1	1
Building #1	4	Dormitory	4	4	4
Campus Hospital South Building	2	Hospital	2	2	2
Campus Hospital North Building	4	Hospital	3	3	3

Note: 0 - none, 1 - slight, 2 - moderate, 3 - extensive, 4 - complete