

9. DAMAGE TO BUILDINGS AND HOUSES

During the 1999 Ji-Ji earthquake, more than 14,000 buildings suffered damage in the whole area of Taiwan. In Nantou and Taichung Prefectures in the epicentral regions, more than 12,000 buildings were damaged and about the half of which totally collapsed. Most of the buildings are constructed by reinforced concrete. Piles are not usually used even in the area of soft sediments. The damage to buildings in Nantou and Taichung Prefectures is briefly introduced and some findings from the investigation are described in this chapter. The investigation carried out by Japan-HongKong Joint Reconnaissance Team (<http://is-jack.archi.kyoto-u.ac.jp/taiwan/>).

9.1 Ji-Ji

Ji-Ji locates about 3km southeast from the epicenter. Because of the short epicentral distance, many buildings in the city suffered severe damage including the total collapse of the building of Jiji station. Figure 9.1 shows the damage to 3-story RC building on Route 16. The building locates about 200m south of the station. The first story had few walls and two columns on the left-hand side collapsed. The building had been used for a bank.

Figure 9.2 shows the damage to a 2-story RC school building (Ji-Ji Junior High School). The school locates about 600 m north from the station. The building is facing to the south. Figure 9.3 shows shear cracks in a column of the first story.



Figure 9.1. Damage to 3-story RC building in Ji-Ji.



Figure 9.2. Damage to a 2-story RC school building in Ji-Ji.



Figure 9.3. Shear cracks in a column of the first story of the building in Figure 2.

9.2 Nantou

Nantou city locates about 10km northwest from the epicenter. Figure 9.4 shows damage to two 3-story RC apartment buildings with brick infill walls. The first story was used for a garage and had few walls. The collapsed columns and beams are shown in Figure 9.5.



Figure 9.4. Damage to two 3-story RC apartment buildings in Nantou.



Figure 9.5. Collapsed columns and beams of the right building in Figure 4.

9.3 Wufung

Wufung with a population of about 68,000 locates about 8 km south from Taichung City. Because the Chelongpu Fault runs in north-south direction, many ground surface ruptures were observed. Although the downtown locates on the footwall of the Chelongpu Fault, the shaking was relatively high, the reason for which may be probably due to the amplification of thick silty or clayey deposits.

Figure9.6 shows damage to a 3-story RC school building (Guangfu Elementary School). The school locates in the south of the Wufung downtown and close to a vertical fault rupture which appeared on an athletics field. Figure.9.7 shows a collapsed column of the first story of

the school building.

In Wufung, several buildings suffered severe damage due to land subsidences. Some buildings tilted due to differential settlements of foundations. Figure.9.8 shows an example of damage due to the differential settlement. The building on the right-hand side tilted but structural damage was small.



Figure 9.6. Damage to a 3-story RC school building in Wufung.



Figure 9.7. Collapsed column of the first story of the school building in Figure 9.6.

Figure.9.9 shows a 12-story RC condominium building in the center of the city. Non-structural damage was found on the outer wall, but the first story of the building was damaged as shown in Figure.9.10. Some fissures were found on the pavement around the building



Figure.9.8. Damage to RC buildings due to differential settlements in Wufung.



Figure.9.9. Non-structural damage to a 12-story RC condominium building in Wufung.



Figure9.10. Damage to the first story of the building in Figure 9.10

A numerous number of one-story houses which were constructed by sun-dried bricks completely collapsed. These houses were probably built before or just after the end of the World War II. On the contrary, wooden houses in the center of the district that had been built more than 60 years ago had relatively light damage. These wooden houses had mud walls reinforced with bamboo. Figure 11 shows an example of those non-damaged wooden houses.



Figure9.11. Wooden house with little damage in Wufung.

The reconnaissance team made a comprehensive survey in Wufung in order to investigate into the correlation of the degree of damage with various factors such as the number of stories, location, and structural type. The survey was carried out by 4 teams, each of which consisted of 2 experts and investigated the damage degree of all buildings in divided blocks. 'Damage Level Criteria from European Macroseismic Scale' was used to evaluate the damage degree. According to the temporary results, 5.8% of 812 buildings collapsed. The heavy

damage was mainly found in 2-4 story RC buildings and one-story masonry building. The details can be referred to at http://is-jack.archi.kyoto-u.ac.jp/taiwan/4_14statistics.html.

9.4 Dali

Dali is neighboring to Taichung City. Many condominium buildings had been constructed in the city and some of them seriously collapsed. Figure.9.12 shows damaged RC condominium buildings. The building in the center with L-shape plan totally collapsed in the first and second stories, and leaned on the adjacent building. Figure.9.13 shows a damaged column of a condominium building in the same site.



Figure.9.12. Damage to RC condominium buildings in Dali.



Figure.9.13. Broken column of a condominium building in Dali.

Figure.9.14 shows a RC condominium building in Dali. The location is close to the riverside of Dali River. The building had a parking spaces in the basement. Because the basement collapsed, the building leaned on a building behind it. Figure.9.15 shows another collapsed building in the same area. The building fell down with little structural damage and leaned on a neighboring building as shown in Figure.9.16.



Figure.9.14. Damage to RC condominium buildings in Dali.



Figure.9.15. Collapsed building in Dali.



Figure.9.16. Serious damage to the building behind the building in Figure 15.

9.5 Taichung

In Taichung City, more than 1000 buildings suffered damage, about the half of which totally collapsed. Figure.9.17 shows the collapse of a RC condominium building. Due to the failure of columns of the first story, the building totally collapsed. Figure.9.18 shows collapsed beams of the building. Can boxes were found in the broken beams and columns. Figure.9.19 shows a building neighboring which had a similar structure with the building shown in Figure.9.17.



Figure.9.17. Collapse of a RC condominium building in Taichung.



Figure.9.18. Collapsed beams of the building in Figure.9.17.



Figure9.19. Building directly right of the building in Figure.9.18.



Figure.9.20. Shear cracks of a 22-story RC condominium building in Fengyuan.

9.6 Fengyuan

Fengyuan locates about 15 km the north of Taichung City. Because the Chelongpu Fault runs through the city, many surface ruptures appeared in the city, some of which have vertical uplift more than 5 m. Figure 20 shows a 22-story RC condominium building in Fengyuan. The outer walls and columns of the building suffered extensive shear cracks.

Figure.9.21 shows a collapsed building on a ground surface rupture on Route 3 in Fengyuan. Many buildings collapsed along the surface fault ruptures in Fengyuan and Neiwan. On the contrary the damage to buildings apart from surface ruptures was mostly light.



Figure.9.21. Collapsed building on a surface rupture in Fengyuan.

9.7 Tungshe

Tungshe locates about 25 km the northeast of Taichung City. This area also suffered serious building damage. Figure 22 shows a collapsed 4-story RC building. Due to the failure of the columns, the building largely inclined and crashed the car at the first floor.



Figure.9.22. Collapsed 4-story RC building in Tungshe.

9.8 Concludings

In this chapter, the damage to the buildings in Nantou and Taichung Prefectures are introduced. The causes of the damage to the buildings are listed as follows;

- 1)Ground motion: Peak-ground accelerations observed in the epicentral region are higher than 0.4g. In addition, these strong ground motions were one of causes of the devastating damage in the epicentral region.
- 2)Ground deformation: Many faults ruptures appeared on the ground surface. Buildings and houses on or close to these fault ruptures were seriously damaged.

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Hitoshi Tanaka, team leader, Associate Professor, Department of Civil and Architectural engineering, Toyohashi University of Technology

Minehiro Nishiyama, Associate Professor, Department of Architecture and Architectural Systems, Kyoto University

Akira Sumi, Chief Engineer, Division of Structure Design, Takenaka Corporation

Pam Hoat Joen, Associate Professor, Department of Civil Engineering, The University of Hong Kong

Keiichiro Suita, Assistant Professor, Department of Architecture and Environmental Design,
Kyoto University

Hisataka Sato, Engineer, Research Institute of Asanuma Gumi Corporation

Takumi Toshinawa, Associate Professor, Department of Civil Engineering, Tokyo University
of Technology

Susumu Kono, Assistant Professor, Department of Architecture, Kyoto University

Hiroshi Tagawa, Assistant Professor, Department of Architecture and Architectural Systems,
Kyoto University

Fumio Watanabe, Professor, Department of Architecture and Architectural Systems, Kyoto
University

Hitoshi Shiohara, Associate Professor, Department of Architecture, Tokyo University

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