Study Trip Report on

TOHOKU UNIVERSITY: INSPECTION OF DAMAGED BUILDING

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Tohoku University is located at Sendai city, at the north region of Honshu island. After the March 11th 2011 Earthquake, some facilities of the university were damaged. This report summarizes the most important damages presented in the buildings of Aobayama campus of the university.

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(Google)

The most damaged buildings where we visited are shown in the figure. The inspected buildings are:

A) Department of Information and Intelligent Systems
B) Research Building of Department of Civil Engineering and Architecture

Department of Information and Intelligent Systems was qualified as unsafe, and damages were presented in structural and not structural elements.
Figure 1 shows some damages presented on the building, such as the separation of the window panel from the main RC walls. Sliding was presented in 7th and 8th floors.

Figure 1. Elevation view of department of information and Intelligent systems.

Figure 2 shows the most critical damage on the same building. The building had a discontinuity in elevation for levels higher than the 8th where the worst damages were presented.
As can be seen, shear failure was presented in RC wall's main sections and also the concrete was collapsed and completely shattered in the small sections close to openings. In the figures it can be seen that only the main vertical reinforcement uses deformed bars, but the horizontal reinforcement bars are smooth, due to the fact that reduces the anchorage significantly.

Figure 2. Damage at the top floor of the Department of Information and intelligent systems building

Figure 3. Collapse of walls around openings

Figure 3 shows the collapse of the walls around openings. The concrete in those walls was also shattered but some steel reinforcing bars were not buckled. This failure seems like the walls behaved as short columns, this is evidenced because the walls without opening didn't show concrete collapse.
The amount of horizontal reinforcement bars in the collapsed sections was poor to carry the shear force by the walls in the concrete sections.

Damages were also presented in the columns of the first floor. Figure 4 shows the collapse of the columns of the first floor. Main observed damage was due to the shear cracks. The distribution of the steel reinforcement can be seen in the figure showing a long separation of the stirrups that allow the formation of shear cracks along columns and the consequent failure.

Figure 4. Damage in columns at the first floor

Figure 5. Research Building of Department of Civil Engineering and Architecture

The research building of Department of civil engineering and architecture was classified as unsafe. This is a 9-story building (non-full web Steel Encased Reinforced Concrete Building according to Professor Motosaka). It was damaged in the past by the 1978 Miyagi-ken Oki earthquake. This building was discontinuous in the third floor with a smaller cross section in plane from the 3rd to the 9th level. The main damage occurred in the base columns of the 3rd level because of the collapse generated by the axial force due to the overturning moment as is shown in Figure 6. Horizontal cracks were also developed at the base of the wall showing sliding, however this sliding damage was slight according to the commentary of Professor Motosaka .

Figure 6. Damage on the walls of 3rd floor

The structural health was observed and analyzed with the help of BRI Tsukuba using strong motion records taken from the first, the fifth and the ninth floors. According to the record, the acceleration at the 9th floor was 908cm/s^2 and at the 1st floor 333 cm/s^2. Important changes in the 1st natural frequency were found according to the analysis of the structural health. Comparing the microtremor and the earthquake frequencies, considerable difference was found after the March 11th 2011 main shock.

Seismic retrofitting had been performed on the building before the earthquake due to past damages. It consisted of the replacement of side walls, installation of steel braces, reinforcement of beams and reinforcement of the slab.

After the 2011 earthquake, a provisional retrofitting has been performed as shown in Figure 7. This retrofitting consists of the installation of new pretensed columns, with steel bolts able to resist the

axial load at the bottom corners of the wall, and prestressed concrete to support large compression forces.
The permanent retrofit of the building or reconstruction has not been performed because the information about the damages and structural health is still being analyzed.

Figure 7. provisional retrofit of the base of walls of 3rd floor.

Conclusion and final comments

The observation of damaged buildings in Tohoku University was performed. The main damages were caused in old buildings constructed without the use of the newest design provisions for seismic structural safety such as the reinforcement detail and the dimensions. The building irregularity was one important factor of the damages in the inspected structures. On the other hand, the change of natural period of the affected buildings due to the main shock of the 2011 earthquake has been evidenced on the Research Building of Department of Civil Engineering and Architecture, and it remarks the importance of the structural health observation in order to expect the damages of buildings and to take countermeasures to guarantee the structural safety.