Session Report:

Disaster (Earthquake) I

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Lessons Learned from Chi-Chi (Taiwan) Earthquake
by Prof. Chin-Hsiung Loh
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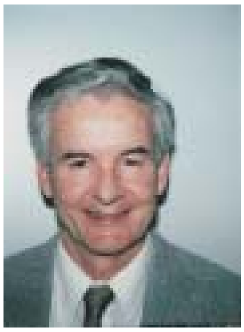
Seismic Code Development for Civil Infrastructures after the 1995 Hyogoken-nanbu(Kobe) Earthquake
by Prof. Masanori Hamada
(Waseda University, Japan)

Performance-Based Design and Seismic Rehabilitation in Preparation for the Next Earthquake
by Dr. A.Gerald Brady
(Applied Technology Council, USA)



Prof. Chin-Hsiung Loh　　Prof. Masanori Hamada　　Dr. A.Gerald Brady

1. Summary

This session included three presentations concerning the earthquake damage by recent huge earthquakes and the countermeasures for the future earthquakes. Some of the keywords in this session were lessons/experience, repair/retrofit, and performance-based design.
The first speaker, Prof. Chin-Hsiung Loh in National Taiwan University, explained the ground motions during the 1999 Chi-Chi Earthquake and the damage due to the earthquake. The second speaker, Prof. Masanori Hamada in Waseda University, described the damage of structures during the 1995 Hyogoken-nanbu (Kobe) Earthquake and the development of seismic design codes of civil infrastructures in Japan, after the earthquake. The final speaker, Dr. A. Gerald Brady in Applied Technology Council, mentioned the countermeasures for huge earthquakes in the United States including the low seismicity area.
Finally, the chairperson, Prof. Tsuneo Katayama in National Research Institute for Earth Science and Disaster Prevention, concluded this session with some encouraging statements.

2. Presentation Highlights

Prof. Loh described the outline of the ground motions and damage of various structures during the 1999 Chi-Chi Earthquake. The fault system of Taiwan has been generated by compression from south-east by the Philippine sea plate. The average velocity of the plate movement is about 6cm/year. A lot of near field ground motions with large amplitude and long period were recorded during the earthquake. These pulse-like waves are called "Killer Motions". The amplitude of the recorded motions in lower period range, from 0.2 to 0.3 second, was especially large. These motions were recorded in the east-west direction in accordance with the fault destination. The probability of the earthquake occurring was explained using a characteristic earthquake model in Taiwan.
Widespread damage of the low-rise RC buildings designed by the pre-1974 building codes was also mentioned. One of the causes for the severe damage of building structures was the pre-mentioned near-field ground velocity. Approximately 20% of the bridges in the affected area suffered minor to major damage. During the earthquake, the electric power system had severe damage. The loss in the extra-high voltage transmission system caused the worst blackout in Taiwan. After the earthquake, the structural health monitoring system was established. Also the network analysis became important for the sewage systems and other lifeline systems. Damage of bridge columns was studied using the damage index which is applicable to a mathematical model. Significant damage due to liquefaction were reported at Yuanlin.

Prof. Hamada mentioned the development and revision of seismic design codes of civil infrastructures in Japan, after the Hyogoken-nanbu (Kobe) earthquake of 17 January 1995. The earthquake was caused by an inter plate fault with 40km in length. Very strong ground motions over 800 cm/sec^2 were recorded. This kind of large amplitude motions were recorded as the first experience in Japan. The earthquake hit highly urbanized area called Hanshin area. The lessons learned from damage of civil engineering structures during the earthquake were explained. The highway concrete bridges and elevated bridges of the Shinkansen suffered shear destruction. Underground structures such as subway stations were severely damaged as the first experience. Soil liquefaction due to the strong ground motions was occurred in soft ground layers. Due to the liquefaction of a construction site of a tank, the liquid petroleum gas was leaked. The lateral spread of ground due to liquefaction occurred. The liquefaction induced ground displacement,

which was almost 1m to 2m toward sea. Due to this displacement, caissons and piers moved laterally.
Then, the concept of the new recommendation in earthquake resistant design philosophy developed by Japan Society of Civil Engineers was described. In this, it is recommended that the resistance of civil engineering structures against earthquakes should be examined for such strong earthquake ground motions as observed during the Kobe earthquake. The list of large earthquakes with magnitude of 6.5 and over, in Japan during twenty century was illustrated. Eight inter plate earthquakes occurred during twenty century. Especially, the 1896 Sanriku earthquake with "Tsunami" disaster and the 1923 Kanto earthquake with fire disaster had huge impact on Japan. The return period of the strong motion in the recommendations is 100 to 1,000 years. The probability of occurrence of such kind of motion is vary rare. So design earthquake is divided into two levels. Level 1 motion is the rational design motion used by Japanese specifications which occurs several times during a structural lifetime. And level 2 motion is new conceptual motion which rarely occurs during a structural lifetime, such as Kobe motions. Level 2 motion is determined using fault parameters. Seismic performance of the civil engineering structures is divided into three categories, before yielding, before ultimate strength, and after ultimate strength. Not only developing the urgent technical retrofitting method but also considering the fault movement are important.
However, a large number of needs for future research and development still remain, because the revision and the development of design codes had to be completed in few years after the earthquake for the practical needs and the study on the lessons from the earthquake are still not enough.

Dr. Brady mentioned the countermeasures for huge earthquakes in the United States. The level of shaking was defined. USGS already made the contour maps showing peak ground acceleration and structural response acceleration for design with following probability; 1)10% chance of being exceeded in 50 years, recurring in ~ 500years. 2)2% chance of being exceeded in 50 years, recurring in ~ 2500years. The building performance level were defined as following four levels; 1)Operational level, 2)Immediate occupancy level, 3)Life safety level, 4)Collapsed prevention level. Fundamentally, these levels were classified using the force displacement curve depend on the ductility of the buildings.
The rehabilitation strategy of the existing buildings in the FEMA-273 was also explained. The FEMA-273 classifies the design level into following two levels; 1)collapse prevention against the 2% chance of being exceeded in 50 years ground motion. 2)life safety against the 10% chance of being exceeded in 50 years ground motion.
The fundamental policy of design motion in low seismicity area was also pointed out. The selection of the performance level, collapse prevention and life safety, are obvious selections. The hazard levels are selectable by society. “Prevent collapse for the ground acceleration that would repeat every 2500 years” might become “---every 500 years”, a less expensive selection. There’s a 10% chance of its being exceeded in 50 years, rather than a 2% chance.
Finally, the engineering input for seismic societal decision-making was provided to society. In design, or in rehabilitation, aiming for a lower-level building performance is less costly. Designing for a lower-level earthquake must be less costly.

3. Conclusion

The chairpersons, Prof. Katayama, summarized the session as follows. The chairperson's summary is more of a list of keywords than a well considered summary. There were several common words in the three presentations in the session "Disaster I". Some of the keywords in the session, in my opinion, were lessons/experience, repair/retrofit, and performance-based design.

All three presentations more or less contains what has been learned from past damaging earthquake. I could not stop realizing that experience is the name so many people give to their mistakes(Oscar Wilde). This seems to be presentations, we heard a number of statistics, but they seemed to be a group of numbers looking for an argument.

Evaluation appeared in two different meanings, evaluation immediately after an earthquake and that during the ordinary days. Evaluation is needed for partially damaged buildings after an earthquake, and evaluation is important for existing buildings especially in large built-up areas.

Repair has always been one of the major issues after recent earthquakes. In the cases of the Kobe earthquake and the Turkey earthquake, what to do with damage but not-collapsed buildings became a difficult problem. In many of mega-cities in the world, earthquake resistance of existing buildings needs to be evaluated for possible retrofit before the next earthquake to come. However, evaluation methodologies and repair/retrofit technologies have rarely been established in the form of building codes of developing countries as of today.

Performance-based design was another keyword of the session. In Japan, after the Kobe earthquake in particular, it has become engineers' consensus that it is at least impractical for all structures to be intact against such strong ground motions as experienced in the hardest-hit areas during the Kobe earthquake. This implies the need for the concept of multi-level performance criteria. Buildings should be designed, constructed and retrofitted for various performance levels by considering the importance of each building. For this purpose, design must be based on probability and structure's life. This kind of design concept has not always been familiar to practicing engineers. Especially, the "economic" life of building is difficult to understand.

How much has earthquake disaster science explained? Some say that we see light at the end of the tunnel, while others may argue that it is the light of an oncoming train. I cannot tell whether or not we should be optimistic.

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