Are buildings really safe enough to survive earthquakes of "unanticipated" scale?

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1. Introduction

Through its research in the fields of structures, fire safety, environment and equipment, the Building Department supports building technology standards based on scientific and technical findings.

The subject of this article is seismic safety of buildings, and we have been playing an essential role in setting better building technology standards. All of us may now have a keen interest in this subject, and we tend to ask ourselves whether we can just leave things as they are or we should take further action to better prepare for mega-earthquakes which are likely to occur in the future. Let me explain this subject to you.

2. The Unexpected Great East Japan Earthquake

Since the 2011 off the Pacific coast of Tohoku Earthquake (The Great East Japan Earthquake) which hit Japan in March of last year, we have often heard seismologists say the word "unexpected" referring to both the seismic scale and the tsunami's destructive power.

To non-specialists, this may have sounded like something far beyond the scope of knowledge any human could have, but to skilled people with expertise it may not have been clearly considered at the initial design stage. It is nearly unthinkable that this earthquake was beyond human knowledge. "Unexpected" may not be the type of word we should use talking to ordinary citizens who faced a disaster of that scale.

It is regrettable that we might have lost the chance to carry out a careful investigation by using the term "unexpected".

It is undeniable, however, that the earthquake and tsunami were huge. It stands to reason that people will now worry if buildings are really safe enough to survive earthquakes of "unanticipated" (I dare to use this word) scale.

3. Earthquake and Tsunami of Maximum Magnitude

The interim report submitted by "the Experts Committee to Examine Measures against Earthquakes and Tsunamis Based on Lessons Taught by the 2011 off the Pacific coast of Tohoku Earthquake" formed under the Central Disaster Prevention Council (Jun, 2011) states "To make future assumptions concerning possible earthquakes and tsunamis, we should review the way we thought in the past and must now consider each and every possibility of the largest-scale earthquakes and tsunamis based on scientific findings such as sediment examinations". They have actually put this into action by reviewing the hypocentral region and tsunami source region of the Nankai Trough. They have now taken a step forward in examining the use of a seismic source dislocation model and a tsunami dislocation model.

On the other hand, institutions such as the Japan Society of Civil Engineers or the Ministry of Land, Infrastructure, Transport and Tourism offered some guideposts (1) to the way of handling evacuation from tsunami. To prepare for the “level 1” tsunamis which take place once in several dozens of years to more than a hundred years, tangible measures are to be employed to protect human lives and properties. Evacuation will play a key role as an intangible measure in the case of “level 2” tsunami which is a level far beyond the application of tangible measures at “level 1”. They have established a policy stating that dependence on “hardware-centric policy” or constructing continuous facilities such as an embankment, is not economical, although it is theoretically possible, with an ample budget, to build independent facilities like buildings which are robust enough to withstand a “level 2” tsunami.

4. Are Buildings Really Safe Enough To Survive Earthquakes of “Unanticipated” Scale?

A consoling aspect of the Great East Japan Earthquake is that direct damage to buildings by the earthquake itself was not huge (2). However, are buildings really safe enough to survive a mega-earthquake like the Nankai Trough Earthquake which is predicted to surely come in the near future?

We have no choice but to rely on tangible facilities to deal with seismic motion which takes place right after an earthquake, even a “level 2” earthquake, as we will not have enough time for evacuation even though the intangible measures mentioned above for tsunami are supposed to basically be taken for “level 2”.

Technical standards for seismic building construction set guidelines 30 years ago stipulating an earthquake happening on rare occasions as “level 1”, and one occurring on “extremely” rare occasions as “level 2”, so the basic methodology applied here for tsunami is the same as that previously applied to earthquake classification. However, technical standards for seismic building construction, even at “level 2”, demand the use of tangible measures so that buildings will not collapse in order to save people’s lives (“hardware-centric policy”). This posture clearly contradicts the Central Disaster Prevention Council’s policy which almost abandons relying only on the use of tangible facilities as the only measures to deal with tsunami. The difference in their attitudes derives from the different ways that damages by an earthquake and by a tsunami are revealed.

It is irrelevant to make a simple comparison between the largest scale earthquakes defined by the Expert Examination Committee of the Central Disaster Prevention Council and the extremely rare earthquakes defined by the technical standards for seismic building construction, because the former assumes specific earthquakes and the latter does not necessarily do so. The latter is also more focused on seismic ground motions than on the earthquake itself.

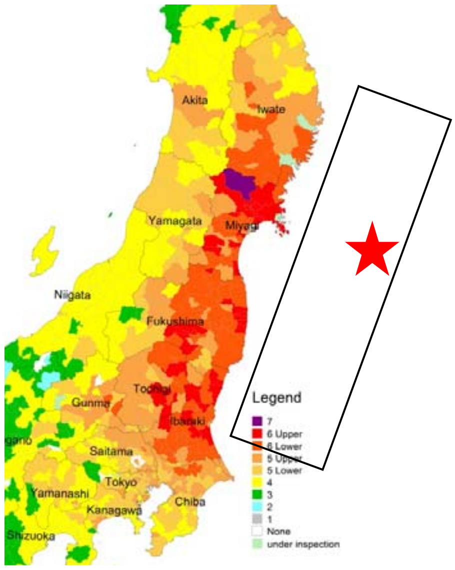

Figure 1. Seismic Intensity of Each Region from the Great East Japan Earthquake

On the other hand, what they have in common is the fact that final judgments are always made by experts based on scientific and empirical information such as the past earthquake damage and observation records.

There is a methodological process of extrapolation, whereby largest scale earthquakes and their subsequent “level 2” ground motions are determined in terms of xx year recurrence intervals using past observation records as statistical data. But simply applying numerical formula is, needless to say, an impractical way to predict earthquakes and ground motions of maximum magnitude which are thought to be barely predictable. So it is appropriate to make an expert judgment at the present stage to make comprehensive decisions based on a combination of various findings and information.

Figure 1 shows the seismic intensity caused in each region by the Great East Japan Earthquake. Most assessments now available concern the impacts of seismic ground motion on buildings judging from each of the seismic intensities, but the geographical distribution is decided by the shortest distance from the hypocentral region rather than the distance from the epicenter （★） as shown on the chart.

In that sense, the bigger an earthquake, the larger the area of the hypocentral region and of the damaged area. Inversely, tangible measures against ground motions may effectively deal with overly large earthquakes on the condition that the seismic resistances of buildings are verified to cope with past earthquakes which were close to the fault (inland earthquakes, e.g. earthquakes like the 1995 Great Hanshin-Awaji Earthquake which caused tremendous damage). It is a common understanding among experts that the current technical standards for seismic building construction revealed good performance during the 1995 Great Hanshin-Awaji Earthquake, which means less need to modify the current technical standards.

However, the larger an earthquake, the larger the slippage in the hypocentral region. Also, if the area of the hypocentral region is large, duration of the earthquake is prolonged. So we have to watch for reciprocal response of ground motions accelerated by phenomena such as sympathetic vibrations.

5. Conclusion

Although most buildings satisfying the current technical standards for seismic building construction may provide sufficient earthquake resistance against larger than expected earthquakes, we still need to be cautious about potential hazards including sympathetic vibration of super high-rise buildings caused by long-period ground motions or liquefaction which is susceptible to the duration of ground motion. On these issues, we are working for measures.

Meanwhile, what we must not forget is that there are still many buildings not satisfying the current technical standards for seismic building construction, so called existing unqualified buildings in cities.

[References]

(1) For example, Examination Committee for Tsunami Protection Measures for Seashores: The basic rehabilitation plan for facilities such as sea embankments damaged by the 2011 off the Pacific coast of Tohoku Earthquake. November 16, 2011

(2) National Institute for Land and Infrastructure Management, and Building Research Institute Quick Report of the Field Survey and Research on "The 2011 off the Pacific coast of Tohoku Earthquake" (the Great East Japan Earthquake). May, 2011