SEISMIC DESIGN: FROM BUILDINGS TO CITIES

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Abstract: A human life is around 80 years. Each building will be used about 60 years. A life of the city have to be more than one thousand years. An extreme big earthquake will come to the city in every several hundred years or one thousand years. When we want to make safe city to the next big earthquake, we have to make buildings having high seismic performance structures such as seismic isolated or passive controlled structures than before.

1. Seismic design of buildings

Many studies have been carried out on a variety of earthquake resistant structures such as seismic isolated structures, passive controlled structures, strength oriented structures and ductile frame structures. Of these methods, the highest seismic performance is expected from seismic isolated structures. Structures can be designed to achieve the required performance within the limits of each of the above four structural methods, if the design earthquake ground motion can be defined.

2. Seismic design for urban city

Earthquake is a natural phenomenon. The largest problem in the seismic design of building structures is the uncertainty of future occurrence of ground motion where the building stands. When it will happen and how large it will be are totally unpredictable. The probability of occurrence of a large earthquake ground motion may be evaluated as negligible, and thus neglected in the design process on economic grounds. However, this would be a big gamble, because although the life of individual buildings may be 60 years, the life of a city may be longer than 1000 years. Individual buildings are components of a city. The seismic issues of a city cannot be solved if the seismic resistance of its individual buildings is determined only from the relationship between the life of a single building and the earthquake occurrence in this life span.

3. Level of seismic design and violation of private property rights

Nevertheless, criticism would arise from society if individual buildings were designed for the largest level of earthquake ground motion. However, if there had been no large earthquake in the period until the building was demolished after several 10s of years, the structures would have been wastefully over-designed. Actions to legally demand excessively high seismic performance are interpreted as a violation of Article 29 of the Constitution of Japan [property right]. This is a very difficult issue.

4. Leaping improvement of seismic performance that does not increase cost

New technology development needs to be advanced. It is necessary to develop new structural systems that provide a huge leap in seismic performance at the same cost as current construction methods. If the cost is not excessive, the rationale is put in place to seek no building damage against very rarely occurring large earthquake ground motions. Society could then not claim that the expenditure is wasted. As a result, safety of cities would become very high. If the life of a city were expected to be 1000 or 2000 years, it would become possible to employ that lifetime as the return period of the earthquake ground motion in design.

5. Research target

The focus of our studies is to pursue this huge leap in seismic performance. Reinforced concrete structures and steel structures introduced to Japan from Europe during the Meiji Restoration period have suffered a lot of earthquake damage in the past 100 years. In my opinion, the limit of these structures did not start to be understood until after we entered the 21st century. It is necessary to greatly improve seismic performance of cities by popularizing new technologies such as seismic isolated structures and passively controlled structures. The desired approach should be to promote building structures of higher seismic performance while maintaining generally the same cost rather than the approach of fixing the required seismic performance followed by seeking cost reduction.

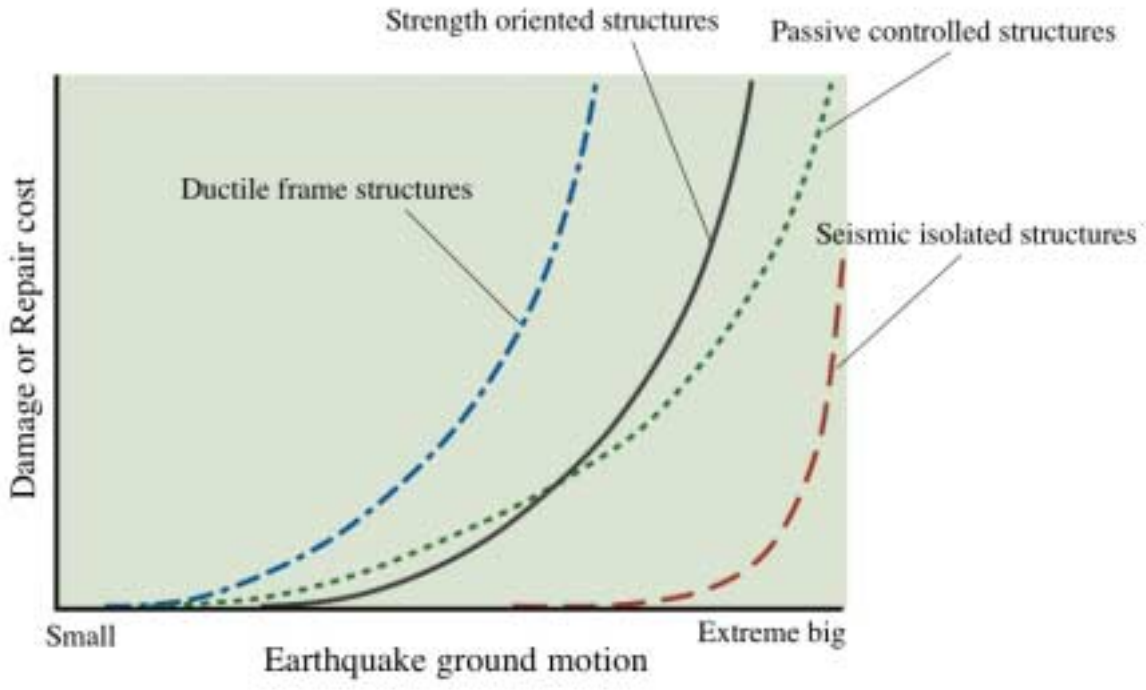

Fig. 1 Earthquake ground motion vs. Damage or Repair cost

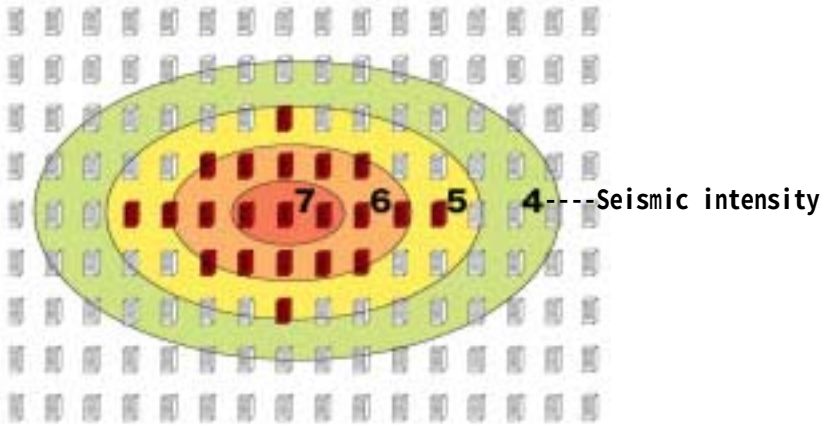

Fig. 2 Damages of buildings in the city after big earthquake, in the case that all buildings were designed as ductile frame structure.

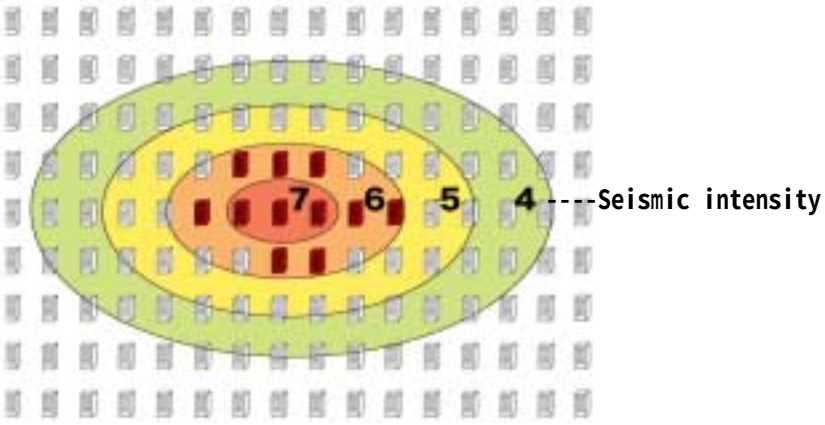

Fig. 3 Damages of buildings in the city after big earthquake, in the case that all buildings were designed as strength oriented structure.

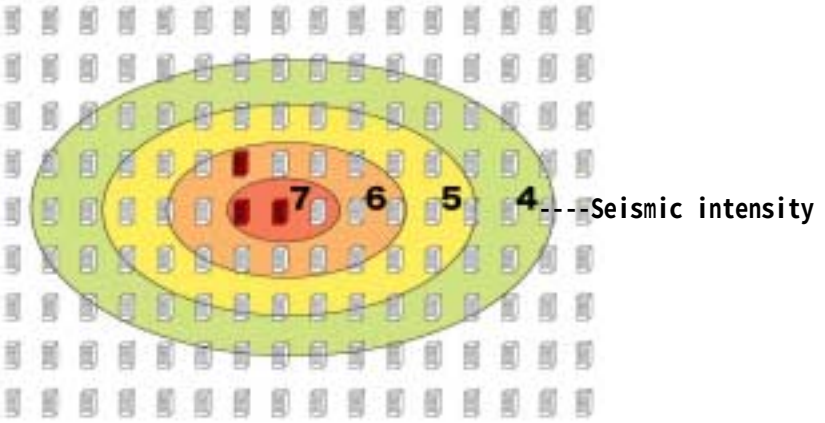

Fig. 4 Damages of buildings in the city after big earthquake, in the case that all buildings were designed as passive controlled structures.

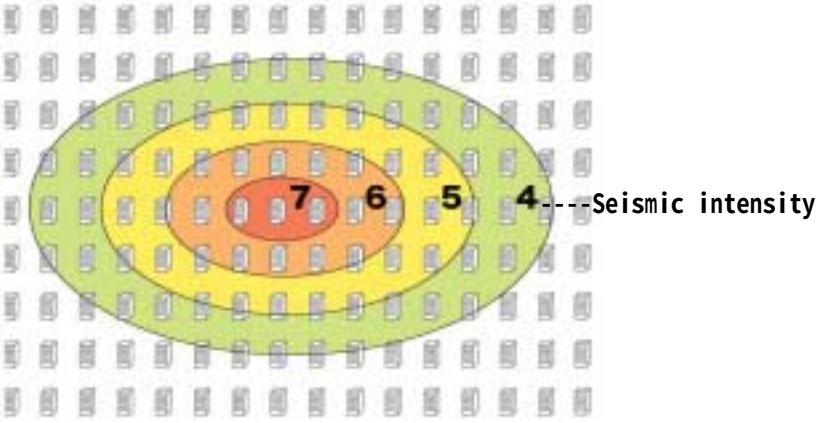

Fig. 5 Almost no Damage of building in the city after big earthquake, in the case that all buildings were designed as seismic isolated structures.

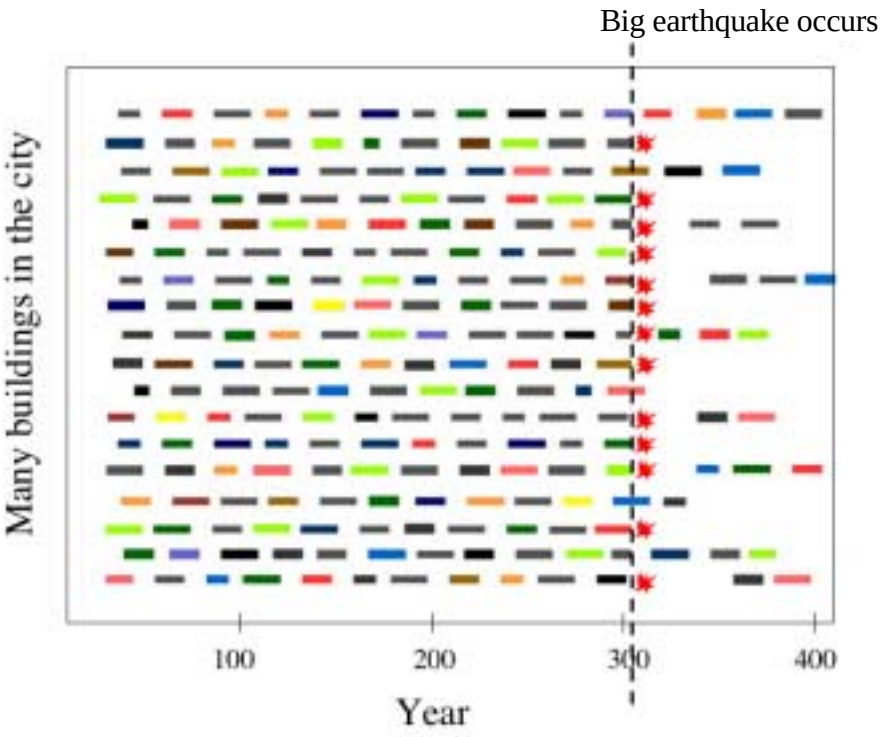

Fig. 6 Many buildings will suffer severe damages by the next big earthquake when the buildings are designed in considering with performance of the structures in 60 years and permitting of large plastic deformation of the structures.

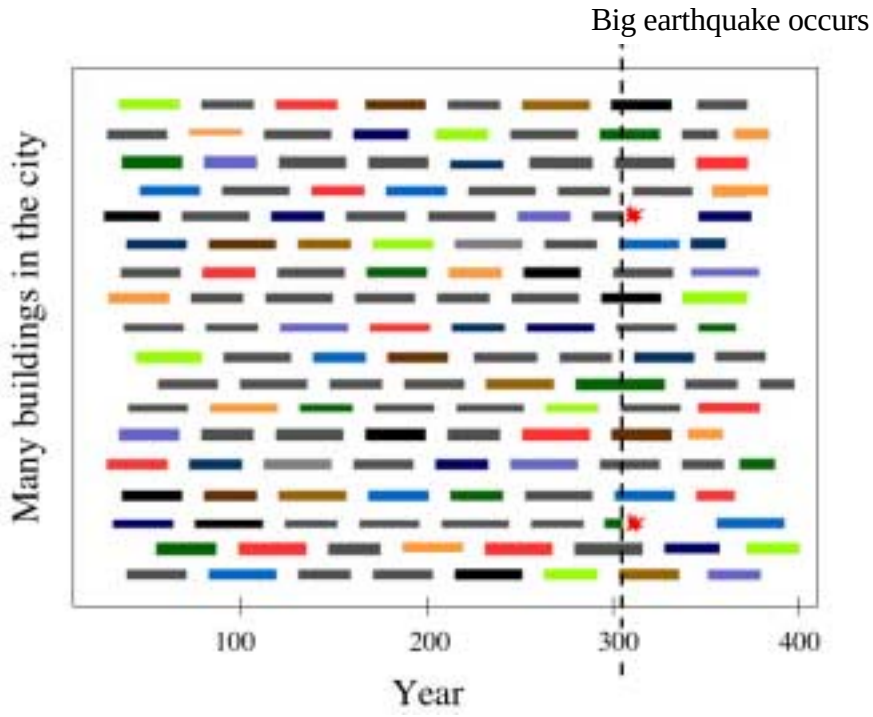

Fig. 7 Few buildings will suffer severe damages by the next big earthquake when the buildings are designed in considering with performance of the city in 1000 years and using seismic isolated or passive controlled structural system or new technologies.