To incorporate the latest findings in seismology and earthquake engineering in the practice of seismic design

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1. Introduction

Recently, it has become quite common to see 3-dimensional reconstructions of massive earthquakes occurring along the Nankai Trough. Here, the processes whereby an earthquake occurs and radial earthquake waves spread from the epicenter to the Japanese archipelago are realistically reproduced. We see how high-rise buildings in the center of the capital region sway from side to side, and how major fires are started. When I first saw Sakyo Komatsu's film "Nihon Chinbotsu" (Japan Sinks), it all felt very artificial, but these new visuals are a world apart from those old attempts. And it's not just the video technology that has progressed; we have accumulated so much more scientific knowledge on earthquakes since then.

When the Great Hanshin-Awaji Earthquake struck in 1995, it led to the establishment of the Headquarters for Earthquake Research Promotion (Earthquake HQ)[1), a body for unified promotion of research on earthquakes. Every year, it updates its website with announcements of new research findings. In July last year, it uploaded a compilation of these in the form of "National Seismic Hazard Maps", followed by "Long-period Seismic Hazard Maps: 2009 Prototype" in September.

For a hypothetical earthquake, seismic motion is predicted by following a "recipe" (so called because the same results will be produced, whoever uses it), setting models for the epicenter and underground structure, etc. As a specific example, the shaking of the Aichi Prefectural Government Buildings during an earthquake in the Tonankai area is shown in the form of waves. Given sufficient time, however, it is even possible to calculate seismic motion in the grounds of individual building structures during the hypothetical earthquake.

We now need to make studies aimed at using these seismic motion predictions, proposed from the latest research, for practical seismic design work.

2. Matters to consider when using seismic motion prediction for practical seismic design work

Seismic motion predictions for various types of earthquake are also made by the Central Disaster Management Council and others, besides the Earthquake HQ mentioned above. Studies are also being made, from different aspects, by the Architectural Institute of Japan and the Japan Society of Civil Engineers, among others. In some cases, these have proudly announced completely different seismic motion predictions for the same location during the same earthquake, leading seismologists to wonder which of them is actually to be believed.

Quite aside from analytical techniques, seismic motion prediction depends on the intricacy of epicenter models describing how the destruction advances from the epicenter, underground structure models showing the course of propagation from the epicenter to the location where seismic motion is to be predicted, and so on. In the proposals by Earthquake HQ, seismic motion is predicted with these models as givens; there is not necessarily enough explanation as to how the predicted seismic motion is influenced by error inherent in the employed modeling itself. As a result, we must first ascertain the impact of this error when applying these predictions to practical seismic design work.

While the predicted seismic motion is generally assessed at ground level, the seismic motion used in seismic design is the input seismic motion observed directly below the building. Essentially, therefore, these are two different things; it is really not appropriate to apply the proposed seismic motion prediction to practical seismic design work, as if it were input seismic motion, without first studying the relationship between the two.

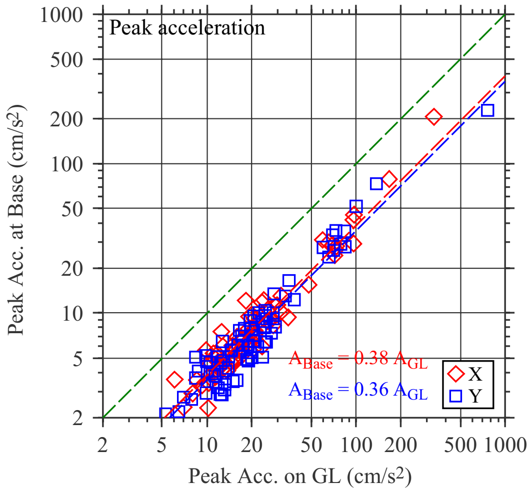


Fig. 1 Strong motion observation inside and outside Hachinohe City Hall (Source: Building Research Institute)

Fig. 1 compares the results of strong motion observation directly beneath Hachinohe City Hall and at ground level adjacent to the building (including observed data from the Iwate-Ken Engan-Hokubu earthquake of July 24th, 2008). The vertical axis shows observation results directly beneath the buildings. Compared to the observation results at ground level, as shown in the horizontal axis, this shows an acceleration of around 40% less. If the relationship between the two is formally converted to the difference in JMA (Japan Meteorological Agency) instrumental seismic intensity, input seismic motion will be around 0.75 smaller than the seismic motion at ground level. Although input loss is known to result from dynamic interaction and other factors, this makes it perfectly clear that seismic motion prediction at ground level must be treated separately from input seismic motion as the force that actually impacts on buildings.

3. "Notification waves" in the Building Standards Law

An Enforcement Order was used to provide performance standards in 2000 following the 1998 amendment to the Building Standards Law. The Order specified the acceleration response spectrum (5% damping) at engineering foundations, converted from the earthquake force that had been used in seismic regulations until then (the 1981 amendment to the Building Standards Law, or the New Seismic Design Method). This is known as the notification spectrum, and the “notification wave” that fits this spectrum is used as the input seismic motion in time-history response analysis for buildings approval.

While it has already been pointed out that input seismic motion should be distinguished from seismic motion at ground level, instrumental seismic intensity is sometimes calculated formally from the notification wave created as a unidirectional wave. In Soil Type 2, instrumental seismic intensity has been known to reach around 5.9. Since the instrumental seismic intensity during an actual earthquake is calculated from a 3-directional component earthquake wave, if we similarly consider the notification wave with a 3-directional component, the instrumental seismic intensity will become about 6.05. From this numerical fact alone, some have expressed concern that buildings designed under existing seismic design standards will invariably collapse if the earthquake magnitude is larger than the instrumental seismic intensity of 6.05 (i.e. 6+ or 7). In fact, however, it is not so simple.

This is because an Interim Report[2] from the Building Earthquake Damage Survey Committee stated that buildings designed in line with the New Seismic Design Method generally manifested good seismic performance, following damage surveys in Kobe City and surrounding areas that suffered human judged seismic intensity 7 during the Great Hanshin-Awaji Earthquake.

Why was there so little terminal damage even in an area subjected to human judged seismic intensity 7, when the instrumental seismic intensity formally calculated from the notification wave was about 6.05? It is conceivable that even in areas with human judged seismic intensity 7, the input seismic motion may in reality have been small, for the reasons shown in Fig. 1. Another reason may well be the point that, since the minimum specified value is used as the strength of materials used in practical seismic design work, there is already a margin in there; an increase in resistance could also be anticipated due to redistribution of stress after plasticization of the buildings; and so on.

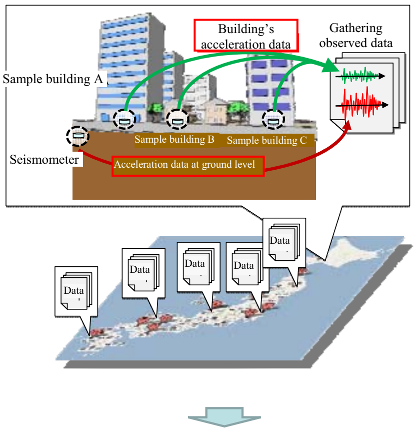
4. Comprehensive Project on Sophistication of Seismic Design – Developing technology for evaluating the seismic performance of building structures in response to the advance of seismic motion information –

To study whether seismic motion prediction based on the latest findings in seismology and earthquake engineering can be applied as they are to building seismic design, and to ascertain what kind of study is needed in order to use it, etc., we will start a Comprehensive Project on Sophistication of Seismic Design[3] in fiscal 2010.

The core of research in this project will lie in surveying the relationship between seismic motion at ground level and input seismic motion by studying the soil-structure interaction model, using existing observed data of strong motion inside and outside buildings. Another important component will be to enumerate the relationship between input seismic motion and seismic motion at ground level for each ground condition, building scale, and frequency. This will be done by accumulating observed data of strong motion inside and outside buildings for ground conditions, structural types and scales of building structure not handled by existing strong motion observation.

Specifically, by conducting the study shown in Fig. 2, we will develop 1) techniques for assessing earthquake force taking into account the properties of both the building and the ground, 2) methods of continuously improving seismic design technology based on strong motion observation results, and 3) efficient seismic restoration technology, including ground foundations, based on strong motion observation results.

To conduct this research, it will also be vital to have the cooperation of the private sector, universities and other related institutions, and to gather and analyze earthquake observation records from as many building structures as possible. As such, we look forward to significant cooperation from related institutions and individuals.



Clarify the relationship between seismic motion at ground level and input seismic motion working directly beneath buildings

Fig. 2 Image of research in the Comprehensive Project on Sophistication of Seismic Design

5. Conclusion

Methods of seismic design for building structures have learnt many lessons from past earthquakes, leading to their present format.

To boldly incorporate cutting-edge findings from seismology and earthquake engineering, as presented by Earthquake HQ and others, in practical seismic design, we will need to achieve a good balance between research on aspects of seismic motion and research on aspects of building structures. We will also need to aim for an even higher level of regulation on performance than heretofore.

In the Building Department, as one aspect of this kind of research, we plan to embark on the Comprehensive Project on Sophistication of Seismic Design from fiscal 2010.

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