13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 5054

STRONG MOTION PREDICTION CONSIDERING THE EFFECTS OF SURFACE GEOLOGY: INTROCUTION AND OVERVIEW

Hiroshi KAWASE [1]

SUMMARY

As an introduction of the Theme Session "Strong Motion Prediction Considering the Effects of Surface Geology", we emphasize here the importance of strong motion prediction with quantitative consideration of the effects of surface geology (ESG). We introduce a brief history of ESG studies and recent achievements on source characterization for strong motion prediction. The important issues for more quantitative prediction of strong ground motions are presented.

INTRODUCTION

In recent years our understanding of strong ground motion characteristics has increased considerably due to the tragic experience from several recent earthquakes. As a consequence of direct observations and subsequent studies, we are now closer to being able to predict strong motions quantitatively for potentially dangerous earthquakes if we can get correct boundary and initial conditions, that is, realistic modeling of source, path, and site. The effects of source and site are found to be especially important for quantifying the near-source ground motions. Although we have developed necessary basic tools for strong motion prediction such as 3-D finite difference/element codes and statistical Green's function databases, we need further studies to improve our methodologies for incorporating the effects of source complexity and surface geology into our strong motion predictions. In this introduction the author describe the background of the Theme Session in order to explain necessity and importance of the session.

EFFECTS OF SURFACE GEOLOGY

Studies on the effects of surface geology (ESG) started with a pioneering work of Japanese scientists after the 1923 Kanto earthquake. They noticed quite evident difference of damage ratios in Tokyo where soft sedimentary districts tended to have higher damage ratios of wooden houses than stiffer hilly districts. Since then we have been building up continuously piles of studies on ESG for eight decades. Until the

[1] Professor, Kyushu University, Fukuoka, Japan, Email: kawase@arch.kyushu-u.ac.jp

1985 Michoacan, Mexico earthquake, ESG had not been paid enough attention that the ESG actually deserved for. During that event we have devastating damage in Mexico City due to strong amplification in long period range created by the Mexico City basin sediments. It was really a good coincidence but in 1985 the Joint Working Group (JWG) on Effects of Surface Geology on Strong Motions under the cooperation of IASPEI and IAEE was formed. Since then international coordination for studies on ESG and strong interaction between researchers in different regions have been implemented and encouraged through various activities of this JWG. Those who want to know can refer to three volumes of proceedings of the second international symposium on EGS held at Yokohama, Japan in 1998 [1].

The importance of the effects of surface geology including the so-called basin effects could not be overemphasized. After the 1985 Michoacan, Mexico earthquake, we found that spectral ratios of observed seismograms on lake-bed sediments showed more than 40 times of amplification relative to the surrounding rock site [2]. In Japan we found recently that some of the strong motion network sites have more than 100 times of amplification at certain predominant frequencies relative to the seismological bedrock [3]. These numbers are surprisingly large, much larger than any engineers can accept for their seismic design. Thus despite of two decades of international coordination of ESG research activities we are still looking at a long way to go to implement real effects of surface geology into our seismic code and design practice.

No matter what we construct based on whatever we believe appropriate, nature behaves as he wants. The devastating damage in Kobe caused by the 1995 Hyogo-ken Nanbu earthquake of M_w6.9, which killed 6,433 people and destroyed more than 100,000 houses, told us this very simple fact. As reported already in various papers the primary cause of this devastating damage was an unfortunate combination of source and site effects. The noteworthy effect of surface geology for the building damage in Kobe was the so-called “basin-edge effect”, in which amplification in the intermediate period range around 1 second was created as a result of constructive interaction of direct S-waves with basin-induced waves along the edge of the deep sedimentary basin [4]-[7]. This is not a special feature of Kobe but a common phenomenon that we must expect to observe as long as we have a sharp basin edge, as shown in the case of Santa Monica fault, California [8]. Since the 2D/3D basin effect in various aspects is one of very important issues, we hope that this Theme Session will provide a forum on the issue.

STRONG MOTION PREDICTION

Strong ground motions are the result of seismic wave generation and propagation from a source to a receiver, and they become input motions to any man-made structures on the earth. Since they are the final products of a complex convolution process of the source, path, and site effects, we need detailed information on these three effects as quantitatively as possible. For near-fault ground motions within a short distance from a source we observe direct effects of source characteristics. After two devastating earthquakes, namely the 1994 Northridge, California and the 1995 Hyogo-ken Nanbu (Kobe), we have noticed how important it is to consider both a heterogeneous rupture pattern on a fault and rupture directivity effect in order to reproduce observed strong motions at near-fault sites. Since then we have been devoting our effort to develop a rational and physical way to generate detailed rupture scenarios for future earthquakes that have not occurred yet but are expected to happen in future. A recipe for strong motion prediction proposed by Irikura and others [9] is one of the fruits of such on-going efforts.

Here the author would like to emphasize the importance of predicting intermediate period component of strong motions around 1 second because heavy damage to ordinary buildings such as reinforced concrete buildings and wooden houses strongly depend on the strength of the intermediate period component. The reason why damage of ordinary buildings correlates with the intermediate ~1 second period component, not the natural periods of these buildings ~0.2 second, is that buildings should undergo nonlinearity for a strong input so they will respond to longer period component than their elastic period. Another way to explain this importance is that we need high peak accelerations to make building nonlinear and at the same time we need high velocities to make large deformation (since we need energy to do so). Waveforms with both high PGA and PGV inevitably have predominant period around 1 second.

If we need to predict 1 second pulse of strong motion in the near-fault area, what do we need to prescribe source heterogeneity? We need to predict spatial characteristics of source on the order of several kilometers. Most importantly we need to quantify the size and peak slip velocity of a strong rupture patch or patches with that size on the fault. This is a formidable task for strong motion prediction since we have not resolved yet the source complexity on the order of one kilometer. Compared to this intermediate period band, long period range longer than 2 second or short period range shorter than 0.5 second is much easier to predict since we have piles of inverted source models with the resolution of a few kilometers for the former and we can use stochastic parameters and randomization for the latter. Thus we are looking for one way or another to represent a detailed rupture process of an earthquake that can quantitatively predict intermediate period component in the near-fault region. We hope that we can discuss this issue to some detail in this Theme Session.

SCOPE OF THE SESSION

In this Theme Session paper, we have proposed to discuss important issues such as 1) effects of one-dimensional and two- or three-dimensional modeling of a basin, 2) delineation of a basin structure via various techniques, 3) comparison with observation and inversion of geological structures, 4) nonlinear effects of near-surface soils, 5) deterministic versus stochastic approaches, 6) dynamic modeling of the source and strong motion generation mechanisms, 7) directivity effects, 8) the source scaling with active fault and/or historical earthquake information, and 9) applications for future scenario earthquakes and relevance to code provisions. We also want to draw lessons learned from recent large earthquakes worldwide that will contribute very much towards a more realistic prediction of strong ground motion. We would like to encourage researchers of these related subjects to have a lively discussion that will help delineate future directions of studies in this very important field of earthquake engineering and seismology.

ACKNOWLEDGEMENT

The authors sincerely appreciates great help provided by J. Bielak of Carnegie Melon University, P.G. Somerville, R.W. Graves, and A. Pitarka of URS Corp., J. Steidl of University of California Santa Barbara, and T. Satoh of Shimizu Corporation.

REFERENCES

1. K. Irikura et al. (Eds.), “The Effect of Surface Geology on Seismic Motion”, Balkema, Rotterdam, Vol.1-3, 1998.
2. Kawase, H. and K. Aki, “A study on the response of a soft basin for incident S, P, and Rayleigh waves with special reference to the long duration observed in Mexico City”, Bulletin of the Seismological Society of America, 79, 1361-1382, 1989.
3. Kawase, H. and H. Matsuo, “Amplification characteristics of K-NET, KiK-net, and JMA Shindokei network sites based on the spectral inversion technique, Proc. of 13th World Conf. on Earthq. Eng., Vancouver, 2004.
4. Kawase, H., “The cause of the damage belt in Kobe: ‘The basin-edge effect’, constructive interference of the direct S-wave with the basin-induced diffracted/Rayleigh waves, Seismological Research Letters, 67, 25-34, 1996.

5. Pitarka, A., K. Irikura, T. Iwata, and T. Kagawa, “Basin structure effects in the Kobe area inferred from the modeling of ground motions from two aftershocks of the January 17, 1995, Hyogoken-nanbu earthquake”, J. Phys. Earth, 44, 563-576, 1996.
6. Motosaka, M. and M.Nagano, “Analysis amplification characteristics of ground motions in Kobe City taking account of deep irregular underground structure - interpretation of heavily damaged belt zone – “, Journal of Phys. Earth, 44, 577-590, 1996.
7. Matsushima, S. and H. Kawase (2000) Multiple asperity source model of the Hyogo-ken Nanbu earthquake, *J. Struct. Constr. Eng*., AIJ, 534, 33-40.
8. Graves, Robert W.; Pitarka, Arben; Somerville, Paul G., “Ground Motion Amplification in the Santa Monica Area: Effects of Shallow Basin Edge Structure”, 88, 1224 – 1242, 1998.
9. Irikura, K., “Amplification characteristics of K-NET, KiK-net, and JMA Shindokei network sites based on the spectral inversion technique, Proc. of 13th World Conf. on Earthq. Eng., Vancouver, 2004.