Progress and Application of Research Activity on Strong Motion Prediction for Inland Earthquakes

Hiroshi Kawase[1]

[1] Faculty of Human-Environ. Studies, Kyushu Univ.

http://seis.arch.kyushu-u.ac.jp

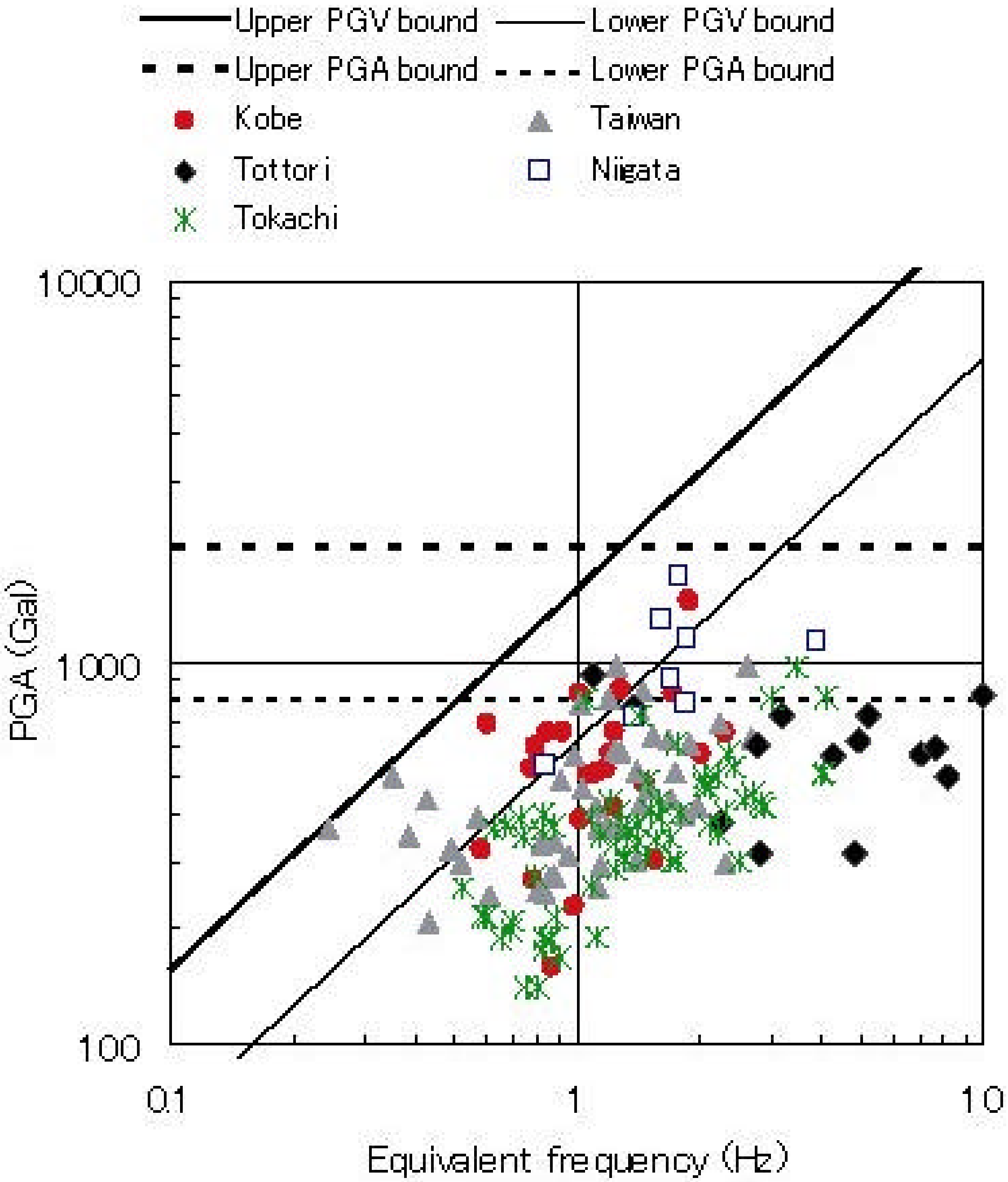
Numbers of waveforms in a source region was obtained for the first time during the Hyogo-ken Nanbu earthquake. We found that they have a common characteristic feature, namely, a distinguished pulse with a large velocity amplitude around 1 second. This large amplitude pulse is exactly the cause of the damage concentrated area, the so-called [damage belt], and therefore, the generation mechanism of this large amplitude pulse is surely needed to be solved for damage reduction for an inland earthquake. After 10 years of research we found the generation mechanism of this large amplitude pulse to be caused by combination of the spatial heterogeneity of the source, the forward rupture directivity, and the edge effect.

Although the consensus is not yet reached on how to express the source heterogeneity, it is quite sure that we need a coherent asperity in order to generate a distingushed directivity pulse. For ordinary structures, as mentioned later, the most dangerous pulse should have an intermediate period of around 1 second, which corresponds to the asperity size of 3 to 12km. If we assume a scaling law between the whole source size and the asperity size, it will be satisfied only with an earthquake of M7 class. Moreover, in order for the directivity pulse to be large in amplitude, the slip velocity inside an asperity needs to be very large on the average. We found that the slip velocity of 5 to 10 m/s is actually required in order to reproduce observed peak ground velocity, PGV (e.g., Matsushima and Kawase, 2000; Matsuo and Kawase, 2002). Since the slip velocity inside an asperity is directly linked with the ground velocity amplitude, the quantification of slip velocity remains a very important theme.

Intermediate period directivity pulse remains to be 0.5 m/s as PGV and about 400 Gals as PGA on rock, which means it is still too weak to make building severely damaged. However, by the amplification due to a basin structure, it was amplified 3 to 4 times at the position of [the damage belt], that is, 500m to 1km away from the basin edge in Kobe, which resulted the input level strong enough to cause severe structural damage. This large amplification was generated by the so-called [edge effect], in which the edge-induced waves generated at the basin edge and S-waves coming from directly below constructively interfere each other at a specific point (Kawase, 1996; Kawase et al., 1998). Our capability of calculation for a complex basin structures is improved remarkably in recent years, and we only need to consider how to construct an appropriate model of the real three-dimensional basin structure.

We still need to answer the question why the directivity pulse can make buildings so severely damaged or even collapsed whose natural period lies in the short period range of 0.1 to 0.4 seconds. Here we must consider equivalent period which is much longer for strong input because of nonlinearity. If the input has very long period, then PGA is not large enough to make a building nonlinear. Thus, to create severe damage, we need both PGV and PGA. Suppose that a ground motion fulfills these two conditions and suppose that there are maximum physical limits on both PGV and PGA, then the predominant frequency of waves that fulfill these four conditions should be around 1 Hz. We make a figure which shows relationship between the equivalent frequency, that is, PGA/(2pi*PGV) and PGA.

Although we have proved that the input waves with intermediate-period pulses are most dangerous for ordinary buildings based on nonlinear analysis for a set of building models, the current structural code does not ask to prepare for such an input. We need further effort to implement this characteristic nature of ground motion for shallow crustal earthquakes in a future design code.


Upper PGV bound
Lower PGV bound
Upper PGA bound
Lower PGA bound
Kobe
Taiwan
Tottori
Niigata
Tokachi
10000
1000
100
PGA (Gal)
0.1
1
10
Equivalent frequency (Hz)