CHARACTERIZATION OF DIFFERENT SITE CATEGORY METHOD ON STRONG GROUND MOTION

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ABSTRACT :

The average shear-wave velocity of the top 30 m (v_{S30}) of the earth is an important parameter used in classifying sites in US building codes. In China building code, the average shear-wave velocity of the top 20 m (v_{S20}) of the near surface and depth of the soil are both used in classifying sites. The comparison of site classification between China and US code provisions has been carried out. And the relationship between two site classifications has been found. The PEER NGA strong motion Database has been used as dataset. Site condition of each record in the dataset has been classified by China building codes. The characterization of strong motion for the China classifying dataset has been analyzed. The fuzzy of classification can make uncertainty. For one site, adoption of China or US site classification can cause different ground shaking level assessment. So the uncertainty of site category should be taken account in seismic hazard or risk analyze.

KEYWORDS: site classification, seismic code, average shear-wave velocity, uncertainty

1. INTRUCTION

Site effect on strong earthquake ground motion is an important problem for seismologists and earthquake engineers. Many strong motion data for different site condition have been recorded in Mexico, Loma Prieta, Northridge and Kobe earthquake. Simplified theory and empirical calculation show that average amplification factors calculated using spectra ratios between soil and nearby rock sites are proportional to the mean shear wave velocity of the top 30 m underground (Borcherdt, 1994). Therefore a new method has been applied in NEHRP provisions for site classifications, the method uses a quantitative index of mean shear wave velocity instead of qualitative description to soil profile. The PEER NGA strong motion Database has thousands of strong ground motion record. In this database use mean shear wave velocity of the top 30 m underground as the index to sort the site. The strong ground motion record is lack in China.

In this study two site classification methods will be compared between China and US seismic code and the relation between them will be analyzed. And then analyze the NGA strong motion Database based on China sites classification. The uncertainty of site category in assessment of ground motion will also discuss.

2.SITE CLASSIFICATION COMPARISION BETWEEN CHINA AND US SEISMIC CODE

The average shear-wave velocity of the top 30 m of the soil (v_{S30}) is used as index for classifying sites in US seismic code (Building Seismic Safety Council, 2004). On the contrast, the average velocity of top 20 m (v_{S20}) and depth of soil with average velocity large than 500 m/s are used in China provision Ministry of Construction, People's Republic of China and General Administration of Quality Supervision, Inspection and Quarantine of People's Republic of China ,2001). The rock in US code is the site which average shear-wave velocity v_{S30} is large than 760 m/s, but in China site with average shear-wave velocity V_{S20} large than 500m/s is regarded as rock site. The site category in US code have 5 classes, such as *A*, *B*, *C*, *D*, *E*. In China category only have 4 classes, such as I, II, III, IV. The average shear-wave velocity range for different site is different in US and China code. The calculation method of average shear-wave velocity is same in US and China code, but the depth is different. In this study, the same site soil profile is used to calculate average shear-wave velocity V_{S30} and V_{S20}, and then the sites are classified by China and US site category. At last comparisons of the average shear-wave velocity and the site classification are made between them.

The soil profile data used in this study come from ROSRINE (Resolution of Site Response Issues from the Northridge Earthquake) project (Bardet *et al*, 1998). In this project many free field strong ground motion station sites in California have been characterized using drilling, borehole logging, surface geophysical, and shear-wave velocity measurement. v_{S30} and v_{S20} results are shown in Figure 1. In Figure 1, *x*-axis is v_{S30}, and *y*-axis is v_{S20}. The site category in US code for each station is zoned by v_{S30}, and site category in China code is drawn by different symbols.

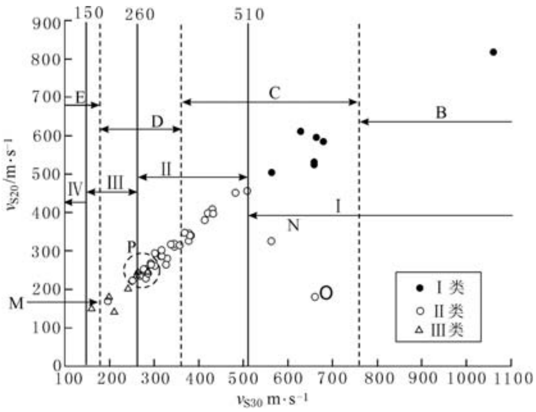

Figure 1 Comparison of site category in China and US code

Most data points in Figure 1 distribute approximately on a line, this result show clearly that the v_{S20} is somewhat corresponding to v_{S30}. There are some special points in Figure 1. Points *N* and *O* are far from the trend line. v_{S30} is strictly calculated by the top 30 m of the soil, but the depth to calculate v_{S20} is the minor value of cover soil thickness and 20 m. The cover soil thickness is defined as soil depth which average shear-wave velocity large than 500 m/s. In this case, the site in which points *N* and *O* lie are under the top 10 m of the soil and the average shear-wave velocity is large than 1 000 m/s, so the depth to calculate v_{S20} is 10 m. The v_{S20} is about 320 m/s and 180 m/s for points *N* and *O* respectively, and v_{S30} is 560 m/s and 660 m/s, separately. Points in zone *P* represent the site *D* according to US code, however in China code some represent the site II, others represent the site III, and the points distribute. This is because v_{S20} is about 250 m/s and cover soil thickness is about 50 m for these points, such v_{S20} and cover soil thickness value is close to the boundary for the Site II and III. For point *M*, v_{S20} is between 140 m/s and 250 m/s and cover soil thickness is smaller than 50 m, therefore it cannot be classified as Site III. Under such condition, two sites which have the 1 m/s difference of v_{S20} and 1 m difference of cover soil thickness may be classified as two site type. This uncertainty results from simply classifications of complicated soil site into several types. Zone *P* and point *M* exactly reflect this case.

In most case, v_{S30} and v_{S20} can be drawn as regular pattern curve as Figure 1.The v_{S30} is usually larger than $v_{S20.}$ Commonly use v_{S20} as a index to classify a site is equivalent to v_{S30} .Only in few case, when depth 20m to 30m has soft soil, the v_{S30} is smaller than $v_{S20.}$ In this case, the v_{S30} reflect the features of site more accurate. But the cost to measure v_{S30} is more expensive。

Generally, the site with v_{S30} in US code greater than 510 m/s can be corresponding to site I in China code. v_{S30} greater than 260 m/s and smaller than 510 m/s can be classified as site II, v_{S30} greater than 150 m/s and smaller than 260 m/s can be classified as site III, the other site with v_{S30} smaller than 150 m/s can be classified as site IV. Meanwhile, it can be seen that site I contains site *A*, site *B* and some site *C*; site II may belong to site *C* or site *D* and site III may belong to site *D* or site *E*. Site IV all can be classified as site *E*. If there is only site category information of US seismic code, we cannot accurately define the site type in China site category. But if we have the v_{S30} for the site, we can define site category in China seismic code for the site according to relation between v_{S20} and v_{S30}. Now many strong motion stations give v_{S30} value, then we can establish strong motion records set based on China site category to study site effect.

3.ANALYZE NGA STRONG MOTION RECORD BASE ON CHINA SITE TYPE

In this study, we will use NGA strong motion Database to analyze the characterization of soil strong ground motion based on China site category method. The PEER NGA strong motion Database has thousands of strong ground motion record. Each record in this database give the value of the v_{S30}. So we can use the relationship between v_{S30} and v_{S30} as describe as above, to sort each record's site condition again. The figure 2 give the classification result base on China site category for the NGA strong motion Database.

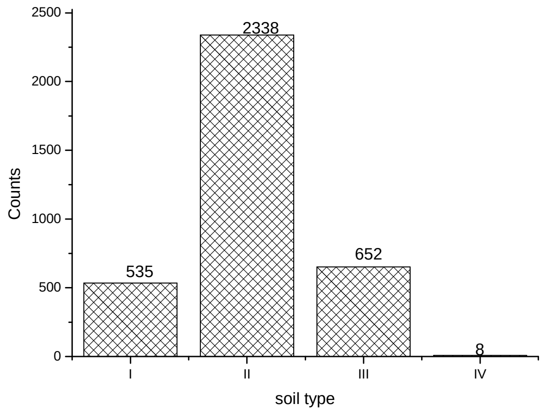

Figure 2 China soil type for NGA Strong Motion Database

In this study, we use curve shape as equation 3.1and 3.2 described to fit each strong motion record's response spectra. Amax is peak acceleration. The β_{max} and Tg have been computed for each record for type I,II and III. The records for type IV are very few, so neglect analyze these few records. The results are shown in figure3, figure4 and figure5.

$$S_a(T) = \mathrm{Amax} \cdot \beta(T) \qquad (3.1)$$

$$\beta(T) = \begin{cases} 1 & T \leqslant T_0 \\ 1 + (\beta_m - 1)\dfrac{T - T_0}{T_1 - T_0} & T_0 < T \leqslant T_1 \\ \beta_{max} & T_1 < T \leqslant T_g \\ \beta_{max}\left(\dfrac{T_g}{T}\right) & T_g < T \leqslant 3\mathrm{s} \end{cases} \qquad (3.2)$$

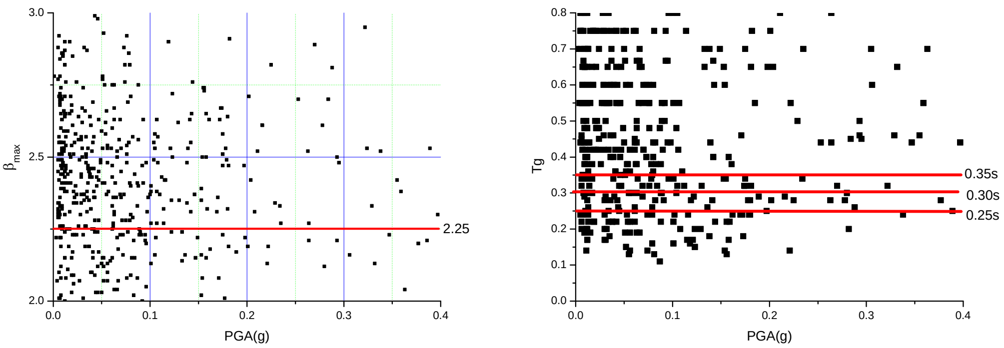

Figure 3 β_{max} and Tg for type I

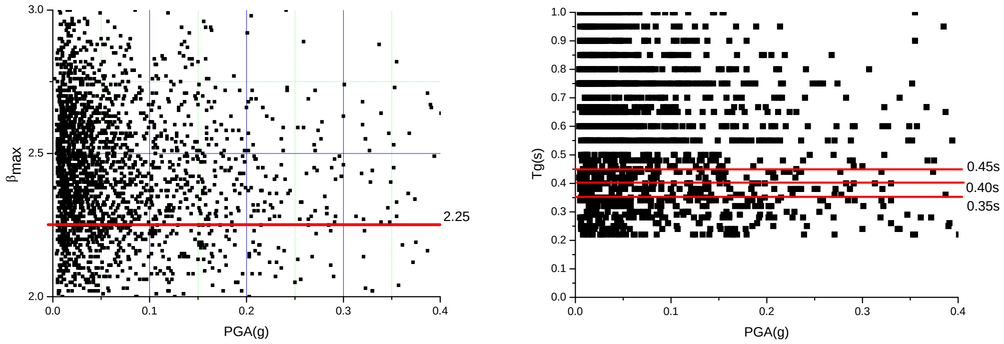

Figure 4 β $_{max}$ and Tg for type II

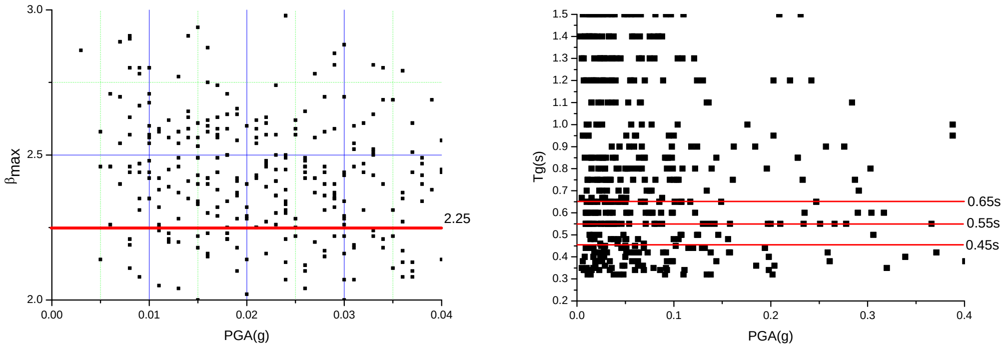

Figure 5 β $_{max}$ and Tg for type III

The defined value of β $_{max}$ and Tg in China seismic coed are also shown in figure3, figure4 and figure5.The data is scattered，but we can find that defined value of β $_{max}$ and Tg in China seismic coed are relatively lower than the real strong ground motion record. It should to raise these two values in order to improve the safety on a higher level in the future.

4.FUZZY OF CLASSIFICATION AND UNCERTAINTY IN ASSESSING GROUND MOTION INTENSITY

In terms of theory，the difference of average shear-wave velocity is 1 m/s and thickness is 1 m, the two site may be defined as two type of soil. The ground motion assessment will be different. But the accuracy for shear-wave velocity measure is lower than 10%.The measure for soil thickness can not reach such high precision. The fuzzy of classification cause this uncertainty. It should define a interval range to replace the fixed boundary value between two soil type.

Two site coefficients, F_a and F_v, corresponding to the short period and long period ranges respectively, were applied in NEHRP 1994 (Building Seismic Safety Council, 1995). The two site coefficients depend on both site category and intensity of rock motions. The NEHRP 2003 and UBC 1997 have also use these two site coefficients (Building Seismic Safety Council, 2004;Dobry et al,2000).

In present China seismic code, only long period site ground motion considers site category, but short period site ground motion is same for different site category, and do not change for different rock shaking level. In other word F_a always set to one in China seismic code. In China code, the

For a site, the v_{S20} and v_{S30} can be computed. The thickness of the soil can be measure. The soil type will be deterministic. The site can be defined as C or II by different method. If the rock input ground motion is 0.2g, the assessment intensity of this site in China code will only 70 percent of the value in US code.

In seismic hazard or risk analyze should take account of these nondeterministic factor.

5. CONCLUSIONS

Site effect is an important problem in earthquake engineering. The site classification comparison between China and US code provisions has been carried out. The relationship between two site classifications has been found.

The NGA strong motion database is analyzed base on China site category. China seismic code set the relative lower ground motion intensity level.

The nondeterministic factor such as fuzzy of soil classification and China and US code assess different ground motion intensity for same site have been discussed.

The paper is a preliminary study on the problem. If we want to analyze the problem further, it needs to collect strong motions record on different site with detail borehole logging and shear-wave velocity measurement information in the future.

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