SITE CLASSIFICATION BASED ON GEOLOGICAL GENESIS AND ITS APPLICATION

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ABSTRACT :

Site soil classification has been one of the key issues in earthquake engineering and also is the main topic for the earthquake disaster mitigation. In this paper, based on the geologic genesis and characteristics, a new method is suggested by applying the Geological Information System technology. Combined with the geological survey data, the site classification matrix is given which could be used as lookup table in GIS. Then the latest geological data of China are collected, and the site classification map is compiled by following the NEHRP methodology. At the end, the soil classification map is utilized to delineate ground motion parameter zonation map of Guangdong Province. The results show that the ground motions will be changed when considering the soil amplification.

KEYWORDS: Geologic genesis; Site classification; NEHRP; Zonation map

1. INTRODUCTION

Since the concept and method of site classification were put forward in the Code for seismic design of buildings of China in 1964, the parameters of design response spectrum have been determined by considering site classification. Before 1986, site classification method was based on the descriptions of soil characteristics, average shear wave velocity and overburden thickness of soil layer. The overburden characteristics are still used to the site classification in National Standards of P.R.C (GB50011-2001). In the other countries, one or several indexes are employed, and generally site is classified into 3 to 4 types. In most cases, two indexes, soil lithology and overburden thickness are used. In present the data of strong motion observation can not satisfy the requirements for practical application. Much too precise site classification will lead to be difficult to determine design response spectrum. Therefore, rough site classification is practical by using several indexes. Usually, soil characteristics and overburden thickness are the first choice for classifying site, because of its great effects on strong ground motion intensity and spectrum characteristics, as well as being determined easily.

With the data of regional geological survey being abundant, it was gradually adopted on site classification. The advantage of utilizing geological genesis and characteristics to classify site is that it can comprehensively involve the information of soil features, overburden thickness and so on. Based on geological characteristic, the site of San Francisco bay was classified (Borcherdt, 1994). The site effect of Japan was evaluated, combined with national land information system, considering site magnification factors of the strong motion stations of JMA (Yamasaki, 2000). Based on the geological data of 1:500000 and 1:200000 scales, the site of Taiwan was classified. The results were verified with strong ground motion data (Lee and Cheng et al., 2001).

Results of seismic damage investigation and strong motion observation show that the influence of site condition on earthquake damage is quite obvious. In this paper, applying the latest geological datum of China, the relationship between geo-genetic types and site classification is given, and site classification map is used for analyzing seismic site effect.

2. REGIONAL GEOLOGICAL DATABASE BASED ON GIS

As one of important geological achievements, geological map is the important sign of embodying the level of geological work and research of one country. In this paper, the GIS database mainly derives from China geological datum of 1:4000000, 1:2500000, 1:500000 and 1:200000 scales. The digital geographic base map is set up with 1:500000 scale. Its coordinate system is Krassovsky ellipsoid and gauss-kruger projection, and six degree as one belt (China geological survey, 1999).

With the logical topology of GIS spatial database, the stratum is divided into nine layers by following its different geological age. It includes five layers of the magmatic rock, one layer of the fault, one layer of the point element and others. The layer information contains geological age，stratigraphic unit，rock characteristic, geological boundary, fault line, genetic type of quaternary, isotopic dating method, deposit type, and so on. The block storage of digital geographic base map database could be accessed easily. The database can be queried and selected, and the user can set access right and look up modifying trace. Meanwhile, the retrieval speed can be improved greatly by building spatial index and setting searching range.

3. SITE CLASSIFICATION METHOD OF NEHRP

Because of the limited strong motion data in China, generally, earthquake response numerical analysis of the soil layer is applied to study the influential factors of site soil ground motion, and the earthquake affecting coefficient is adjusted by statistical analysis of American strong motion record. Since NEHRP code was recommend in 1994, the seismic design codes of USA used two site coefficients, the short-period Fa and the long-period Fv. However, the estimation of ground motion was based on site classification of NEHRP (Lu, 2006). In order to investigate site classification method based on geological genesis in China, in this paper, we also applied site classification method of NEHRP to complete site classification on a national scale. Table 1 is the brief description of NEHRP site classification.

Table 1 The brief description of NEHRP site classification

Site classification	Description	Index
A	Very hard rocks	V_{se} > 1500m/s
B	Rocks	1500m/s > V_{se} >760m/s
C	Hard or very hard soils, gravels, soft rocks	760m/s > V_{se} > 360m/s or N> 50, S_u.> 100Kpa
D	Hard soils (sands, clays and gravels)	360m/s > V_{se} > 180m/s or 50 > N > 15, 100 > S_u > 50Kpa
E	Soft clays of thickness about H in site profiles	V_{se} <180m/s or H>3m (PI > 20, w > 40%, S_u < 25Kpa)
F	Easy Subsidence or failure highly sensitive clays; poor cohesiveness soil; mudstone or organic matter clays; high plasticity clays	H >3m; H >8m, and PI >75 H >36m

When soil layer is classified on a national scale, a look-up table is set up, as table 2 shown. Therefore, the soil classification and GIS manipulation become portable. Applying the datum of China geological and topographic map of different scales, the database is sorted based on the age of rock and soil layers, then the processes are grouped into 3 steps with NEHRP standard and division of geological age scale.

(1) Age before the Permian (P) of Paleozoic (Pz)
The rock and soil layers before the Permian (P) of Paleozoic (Pz) (including P) are assigned type-A, except for highly weathering rock layers which assign type-BC and terribly weathering rock layers assign type-C. Consequently, the rock and soil layers whose ages are before Permian (P) are assigned type-A. In GIS, highly and terribly weathering rock layers are assigned type-BC and type-C after searching them.

(2) Age from Triassic(T) of Mesozoic (Mz) to upper Pleistocene (Q3) of Quaternary(Q)
In this stage, geological age in sequence are Triassic (T), Jurassic (J), cretaceous (K), Paleocene(E1), Eocene(E2), Oligocene(E3), Miocene(N1), Pliocene(N2), lower Pleistocene(Q1), middle Pleistocene(Q2) and upper Pleistocene(Q3). Each of them is classified and assigned following the standard of NEHRP.

(3) Age after Holocene (Q4 or Qh) of Quaternary (Q)
After Holocene (Q4 or Qh) of Quaternary (Q), the basic data of soil layers is not detailed enough for the classification. Must be considered the characteristics and genesis of soil or rock layers, as well as its surrounding environment when soil or rock layers are assigned. Meanwhile, some books such as China geological dictionary are looked up. So the workload of this step is rather heavy.

Following the same method and processes, for other scale geological data, the site soil or rock layers are assigned completely. Check and adjust all values roughly. Consequently, a matrix of site classification based on geological genesis and characteristic is set up, as table 3 shown partially. Using GIS technology, the results are embodied on geological layers, then checked detailedly and adjusted finally. Figure 1 shows the whole work flow and figure2 shows the results of site classification in China.

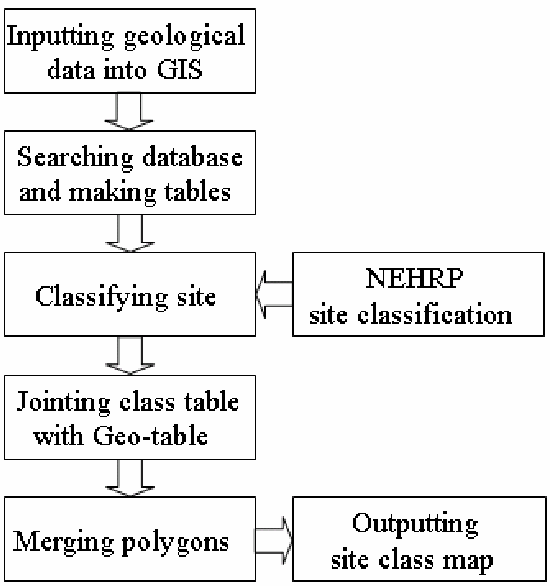

Figure 1 Work flow of site classification

Table 2 Site classification index of GIS table

NEHRP classification	Index
A	0
B	1
BC	1.5
C	2
CD	2.5
D	3
DE	3.5
E、F	4
rivers and lakes	5

Table 3 Matrix of site classification based on geological age and genesis (partially)

Description of geology and age	Holocene Series	Upper Pleistocene	Middle Pleistocene	Lower Pleistocene	(Age)…
Silt, bay mud	4	3.5	3.5	3.5	…
latchstring deposit	4	3.5	3.5	3	…
lower alluvial	3.5	3	3	3	…
Mixed alluvial	3.5	3	3	3	…
Elian sand	3.5	3.5	3	3	…
(Genesis) …	…	…	…	…	…

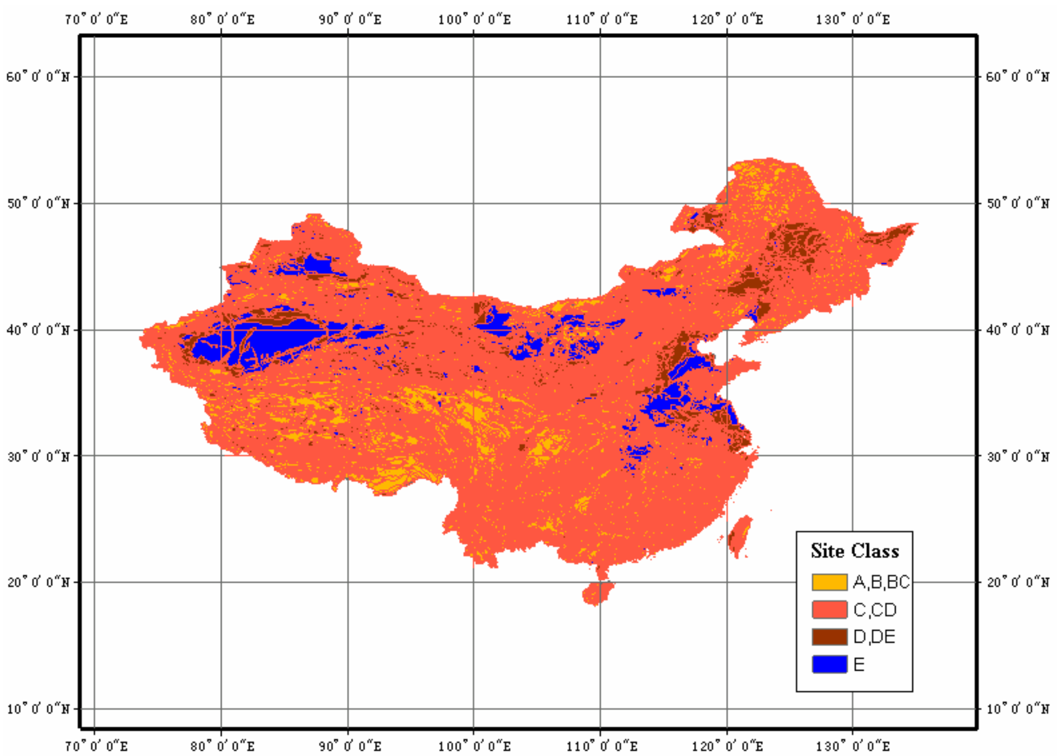

Figure 2 Site classification map based on geological genesis and characteristics

4. Application of China site classification for Seismic zoning map

In this paper, the soil classification map is applied in the seismic zoning map of Guangdong Province. Figure 3 shows the results of site classification in. There are 11905 calculating grids whose size is 0.05°×0.05°. Figure 4 shows potential seismic sources around Guangdong Province. Utilizing GIS technology, the seismic activity parameters of interest areas are obtained. The appropriate ground motion attenuation relationship and model of seismic hazard analysis of Guangdong Province are selected. Then peak ground acceleration (PGA) of each grid on bedrock is calculated, with10% exceeding probability in 50 years. Figure 5 shows the calculating results in Guangdong Province. Following the site amplification coefficient of ground motion of NEHRP, considering type-A, type-B, and type-BC as bedrock, a table of ground motion conversion factor is deployed, as table 4 shown. Multiplied PGA of bedrock by these ground motion conversion factors, Ground motion parameter zonation map of Guangdong Province with site amplification is delineated, as figure 6 shown.

Table 4 Ground motion conversion factors

PGA(g)	A, B, BC	C	CD	D	DE	E
<=0.05	1	1.38	1.47	1.77	2.08	2.38
0.05	1	1.32	1.41	1.67	1.93	2.18
0.1	1	1.26	1.35	1.57	1.78	1.98
0.15	1	1.22	1.29	1.47	1.64	1.8
0.2	1	1.18	1.24	1.38	1.51	1.63
0.3	1	1.07	1.09	1.14	1.18	1.21
>=0.4	1	1	1	1	1	1

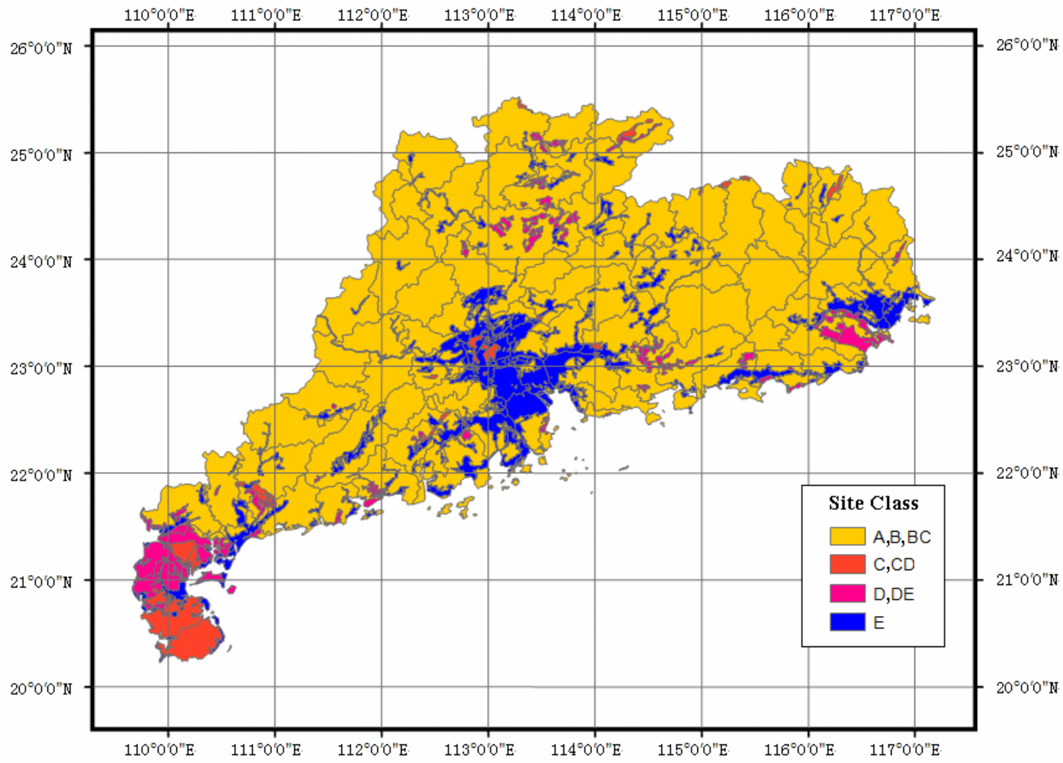

Figure 3 Site classification of Guangdong Province based on geological genesis

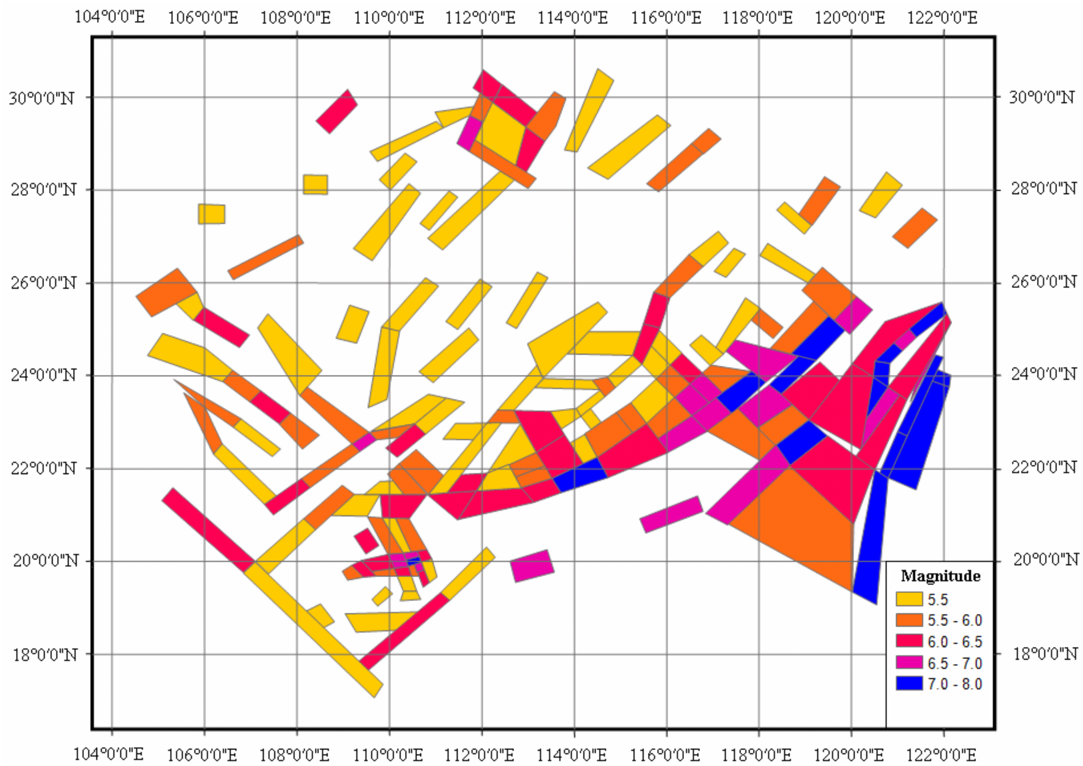

Figure 4 Map of potential seismic source around Guangdong Province

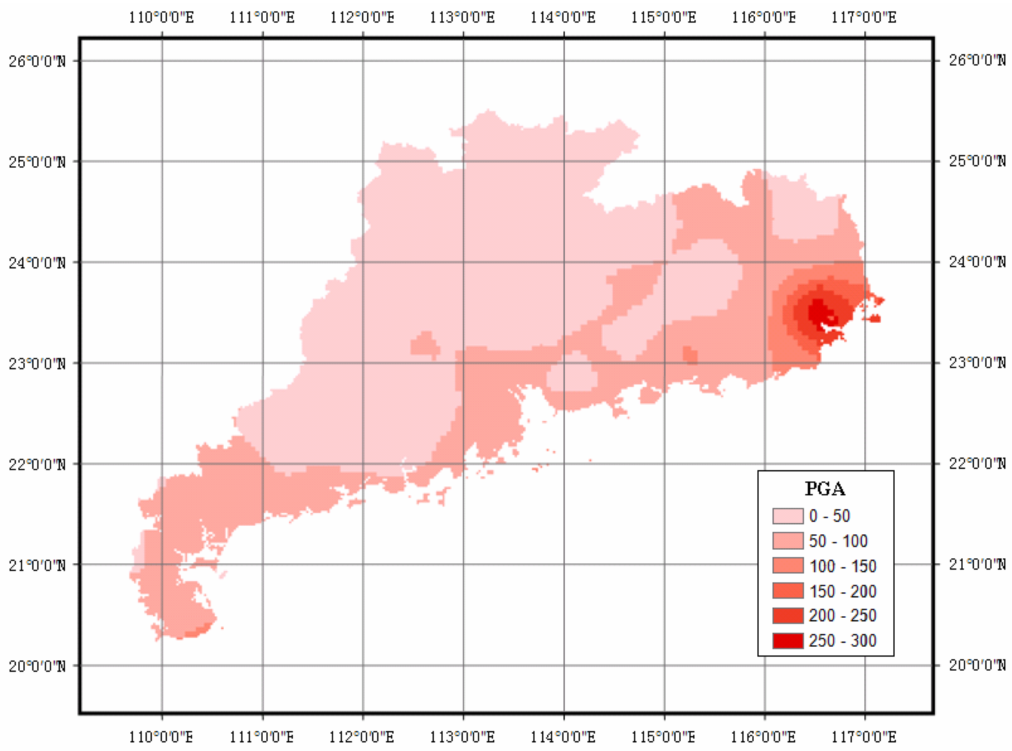

Figure 5 Distribution of peak ground accelerations on bedrock in Guangdong Province (with10% exceeding probability in 50 years)

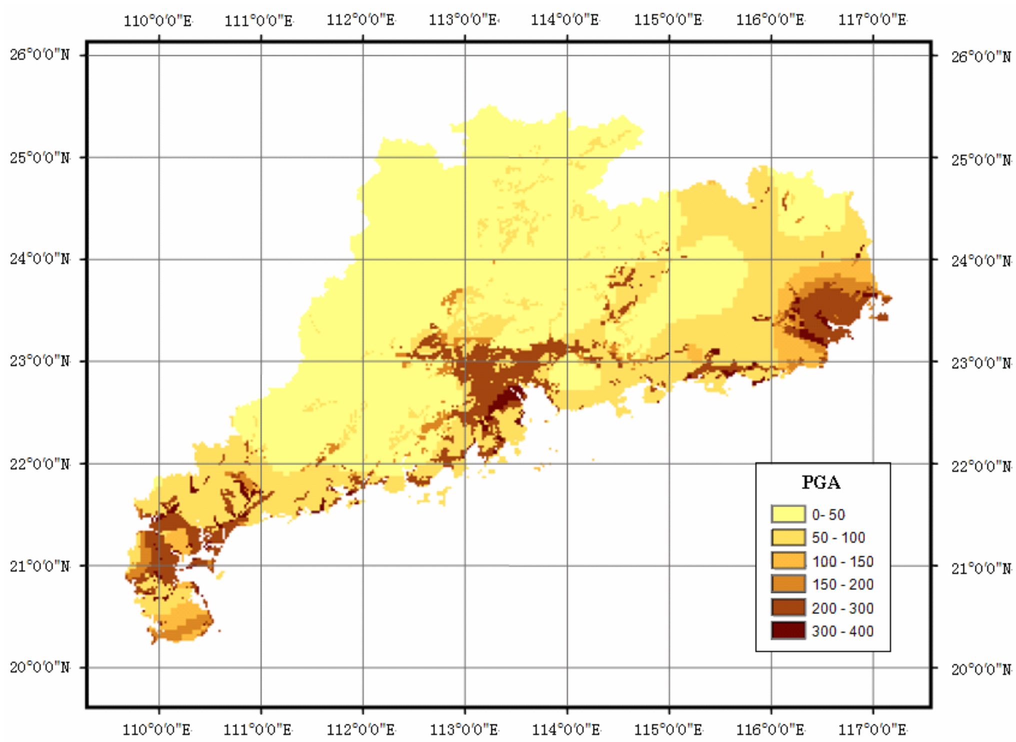

Figure 6 Ground motion parameter zonation map of Guangdong Province with site amplification (with10% exceeding probability in 50 years)

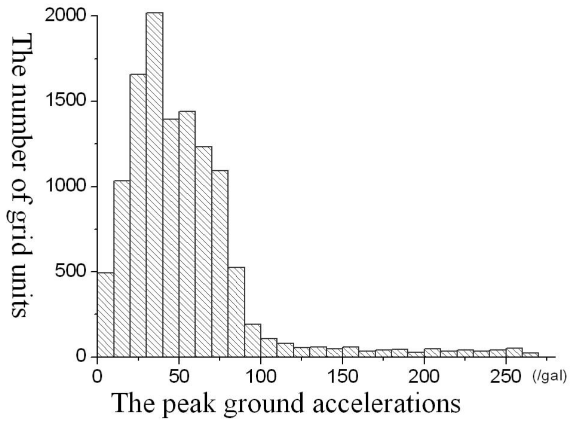

Figure 7 Graded statistical graph without soil amplification

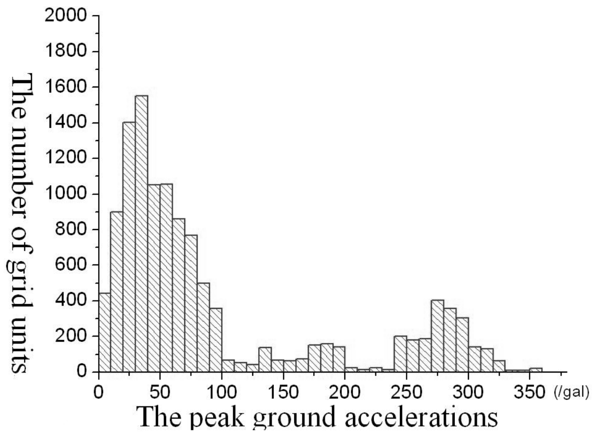

Figure 8 Graded statistical graph with soil amplification

The numbers of grid units of different PGA are surveyed. Figure 7 and figure 8 shows graded statistical without and with soil amplification separately. Obviously when PGA is higher, the grid numbers with soil amplification is more than ones without soil amplification. And when PGA is lower, the grid numbers with soil amplification is less than ones without soil amplification. It is caused that the PGA of bedrock is amplified by soil layer.

5. CONCLUSIONS

With the rapid development of China economy, the demand of soil classification is not only in a particular city or region, but also in all the country. Based on the latest geological data and GIS technology, the relationship between geological genesis and site classification is established appropriately, and nationwide site classification is preliminarily completed. Finally the soil classification map is utilized to delineate ground motion parameter zonation map of Guangdong Province. It is concluded that the influences of site conditions on ground motion can not be neglected. Therefore, when compiling the new nationwide seismic zoning map, it is necessary to consider the site conditions.

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