Frequency Dependency of Coda Wave Quality Factors and its relation with Standard Penetration Resistance

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1. Introduction

The characterization of the surface geology is important for the design of earthquake resistant structures. Field and laboratory tests are available for design parameters to be evaluated. One of the oldest and most commonly used in situ test in geotechnical engineering is the Standard Penetration Test (SPT). Relations between the Standard Penetration Resistance, N-value, and important soil characteristics have been developed. However, until now it has been difficult to relate it with soil attenuation properties such as the quality factor.

It has been recognized that the later portions of accelerograms, i.e. the coda part, which appears after the passage of body and surface waves, reflect the surface geology. Using adequate spectral analysis techniques it is possible to recover soil attenuation characteristics from them. Since 1995 Hyogo-ken Nanbu earthquake, seismic recording station networks have been deployed in Japan. Geotechnical information at each station as well as strong ground motion records are now easily available. This information is useful for the determination of design parameters specifically quality factors.

The aim of the present study is to find a relation between quality factors and N-values using strong ground motion records.

2. Methodology

The coda parts of the accelerograms recorded at 13 stations for one particular event were analyzed. For the present study coda wave is defined as the portion of the record after the peak ground acceleration (PGA) whose amplitude is below a certain percentage of the PGA.

The Sompi method [1] was used to obtain amplitude and phase spectra as well as frequency dependent quality factors for each record. The Sompi method is a spectral analysis technique based on a non-conventional autoregressive (AR) model. Conventional AR-models estimate the present observation from the past observations by minimizing the estimation error. This implicitly assumes that past observations are noise free. On the other hand, the Sompi AR-model assumes that observations, both past and present, consist of signal and noise thus giving an unbiased estimation of the linear relationship among the successive observations. The Sompi method was applied three times on each record considering three thresholds for the amplitude of coda waves, i.e. 10%, 20% and 30% of the PGA.

In order to verify the accuracy of the Sompi method its results were used to synthesize a signal, which was compared with the original one. The synthesis was performed applying the method proposed in [2] using the parameters obtained from the spectral analysis. The basis of this method is to superpose the weighted modes of vibration of the soil profile. Each component weight depends on the source function considered. For this study, a single force point source was assumed.

The Standard Penetration Resistance, N-value, was obtained from the station network database. An average N-value was calculated for each recording station considering the characteristics of the upper 10m of soil deposit. Quality factors and quality factor frequency dependencies were plotted against epicentral distances. Quality factors were plotted against N-values too.

3. Data

This study focused on the Kagoshima-ken Hokusei-bu earthquake. It consisted of two large events on March 26 and May 13, 1997 causing damage to some structures.

The seismic stations considered in this study are part of the Kyoshin Net, a seismic station network installed all over Japan by Science and Technology Agency. The selected stations are located in the Kagoshima prefecture, within 70 km from the epicenter of the March 26 event since the most significant damages occurred in this area. The accelerograms and surface soil characteristics at each station were available from the Kyoshin Net database.

4. Results

For each station three relations between quality factors and frequencies, corresponding to the three amplitude thresholds of coda waves, were developed through the least-square method:

$$\log(Q)=A\log(f)+B \quad (1)$$

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Quality factors for both NS and EW components were considered indistinctly since coda waves reflect the free oscillations of the surface layers. Vertical accelerograms were not considered because horizontal components are dominant over vertical ones. In all cases the quality factors increase with the frequency, i.e. A is positive. Since higher frequency corresponds to waves with short wave length, this implies that the deeper zones beneath the site are more attenuative. The variation of relation (1) at each station for the different coda wave amplitude thresholds is not significant.

The characteristic quality factor, Q_c, for each case was defined as the average value within the range from 1 to 5Hz. A particular case corresponding to station KGS001 is shown in Fig. 1. The relation among the different parameters obtained in the study is shown in Fig. 2.

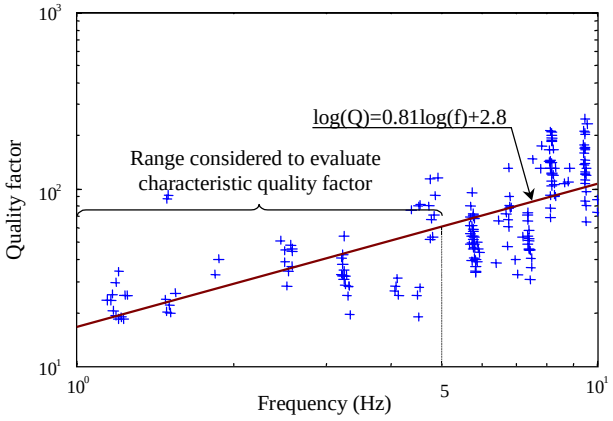

Figure 1. Results of the analysis for station KGS001 (Coda wave amplitude=10%PGA)

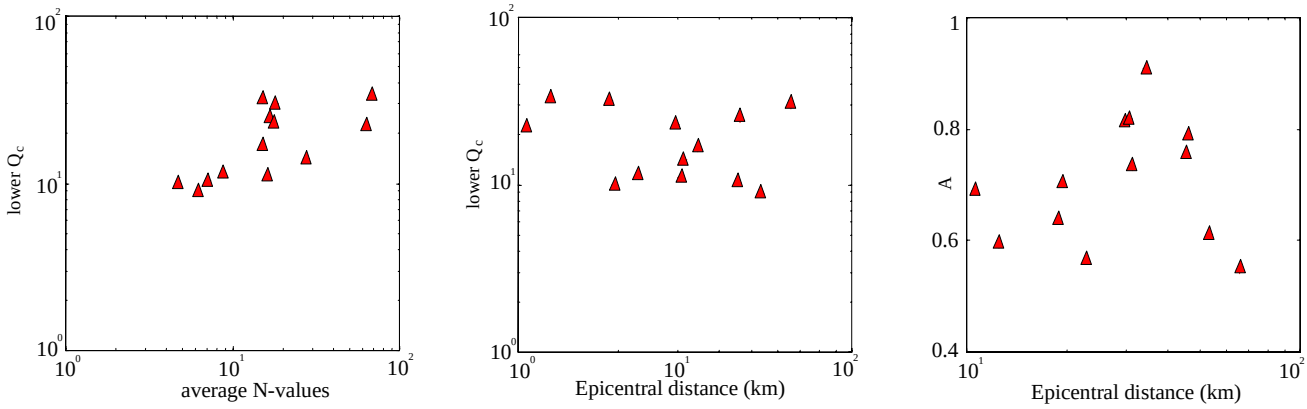

Figure 2. Results of the study

From the previous plots it is found that there is a relation between the lower Q_c and the average N-values. Unfortunately, the number of analyzed stations is not enough to express this relationship quantitatively. More stations and events should be analyzed before proposing a reliable relation between Q_c and N-values.

As expected from the nature of coda waves, no dependency was found between epicentral distance, A and lower Q_c. This implies that the distance between the seismic station and the epicenter, which is a measure of the coda wave excitation level, does not affect the quality factors or its frequency dependency.

5. Summary

The aim of the present study is to find a relation between quality factor and N-value by using strong ground motion records. The records of the Kagoshima-ken Hokusei-bu earthquake at several stations of the Kyoshin Net were analyzed. The quality factor was obtained from the coda part of the seismic waves using Sompi method. The results of Sompi method were verified using the methodology proposed in [2].

For this study, the coda wave was defined as the portion of the record after the peak ground acceleration (PGA) whose amplitude is below a certain percentage of the PGA. Even though it was found that the variation of the amplitude threshold did not affect considerably the relation between quality factors and frequencies, further analysis is needed to validate the proposed definition of coda wave.

Dependence between quality factors and N-values was recognized. However, the number of stations considered was not enough to propose a quantitative relation between Q_c and N-value. Further analysis is needed to formulate such expression. No dependency was found between epicentral distance, quality factor and quality factor frequency dependency.

6. References

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