Study on design input motion for seismic design in consideration of local site characteristics in Hokkaido, JAPAN

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ABSTRACT:

This study was carried out to research seismic design, taking into consideration the local site characteristics. While in previous studies, acceleration response spectra used for seismic design was established using strong motion records in Hokkaido, and the seismic design based on the local earthquake risk was proposed. However, as a result of a more detailed investigation of calculated acceleration response spectra, it was found that intensity of spectra was uneven in area with similar earthquake risk. Therefore, to optimize the seismic design, a re-examination of the acceleration response spectra was carried out. The results indicated that, hypocentral distance held little influence over intensity and form of the acceleration response spectra, but site amplification factors (the ratio of peak ground surface velocity to peak bedrock velocity) had a substantial effect. Therefore, this study suggests methods to establish the acceleration response spectra using the site amplification factors.

KEYWORDS:
strong motion records, site amplification factors, design input motion, local site characteristics

1. INTRODUCTION

In the seismic design of a structure, to determine the seismic external force, the seismic activity, ground characteristics, etc. of object area shall be taken account. Earthquake risk of Hokkaido is high even in Japan, and there are a great number of strong motion records available in Hokkaido.[1),2)]. Therefore, this study was carried out to research seismic design, taking into consideration the local site characteristics of Hokkaido.

Many of the highway bridges in Japan were designed for seismic resistance according to "Specifications for highway bridges -Part V Seismic Design[3)]." In this standard, two design input motion were used for seismic design of a bridge. One of them is based on the acceleration response spectra, which are established by seismic category, strong ground motion level, etc., other is calculated by using the fault model. It was considered that the strong ground motions based on characteristics using the calculated fault model was more relevant to establish the strong ground motion, taking into consideration local site characteristics. However, so that elucidation of information necessary to calculations such as details of the active fault (such as scale, frequency, and mechanism) and the ground (such as the deepest and shallowest points) would not interfere with the data, and since there exist structures too small for applicable data, the establishment of acceleration response spectra using seismic resistance designs were the target of this study.

This study on acceleration response spectra for use in seismic design was carried out using strong motion records obtained from the 2003 Tokachi-oki Earthquake (Mj8.0), a large offshore earthquake, and the 2004 Rumoi-shicho Nanbu Earthquake (Mj6.1), an epicentral earthquake. In those results, it was observed that the acceleration response spectra, calculated according to the observation record, exceeded the acceleration response spectra determined by the standard of seismic design in Zone A, the area of highest earthquake risk, which classified into three areas according to earthquake risk[4)].

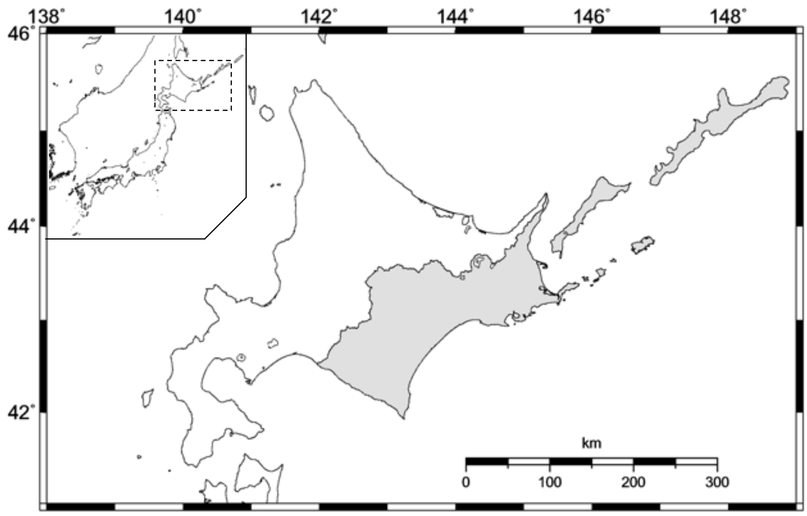


Figure 1. Location of target area (Zone A)

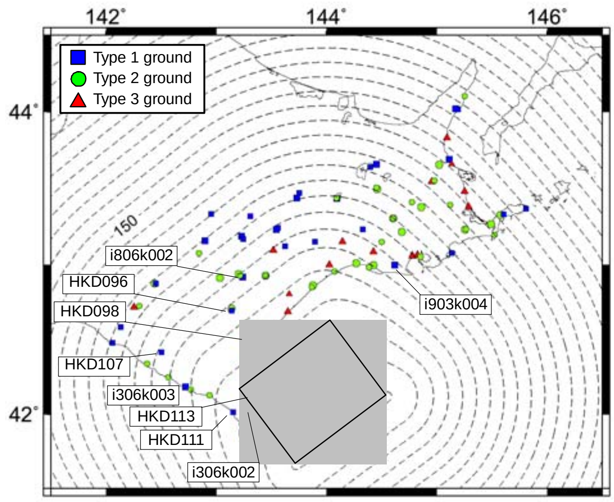
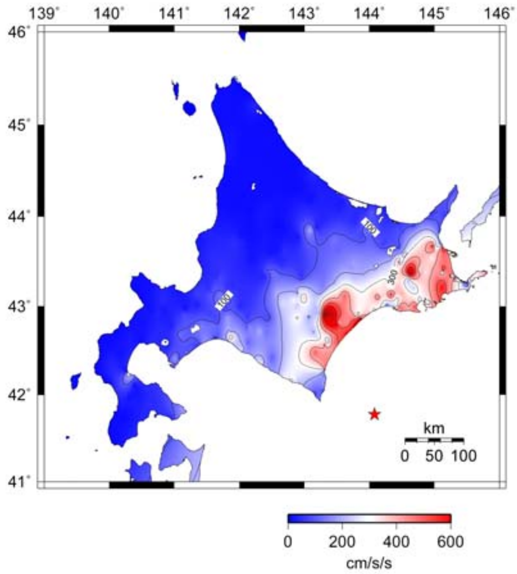


Figure 2. Location of seismic stations, which recorded a strong ground motion at 2003 Tokachi-Oki Earthquake (broken lines: contour of shortest fault plane distance)

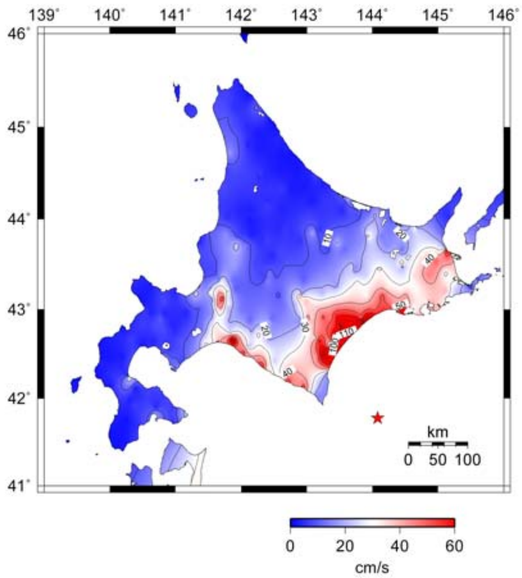
However, as a result of a more detailed investigation of calculated acceleration response spectra, it was found that intensity of spectra was uneven in Zone A. Then it was considered that it is not appropriate to make the spectrum of this area represent at one spectra Thus the acceleration response spectra was re-examined by subdividing area of Zone A. Since the ground motion of Zone A was dominated by the 2003 Tokachi-oki Earthquake, the ground motion of this earthquake was the only subject to be examined. Figure-1 shows location of target area (Zone A). In this paper, the acceleration response spectra are calculated with damping ratio 5%.

2. STRONG GROUND MOTION RECORD

As in previous studies, the strong ground motion records were obtained from WISE (Warning Information System of Earthquake of Hokkaido Development Bureau)[5] and K-NET (Kyoshin NET of National Research Institute for Earth Science and Disaster Prevention)[6]. Figure-2 shows location of seismic stations, which recorded a strong ground motion at 2003 Tokachi-Oki Earthquake used in the study, obtained from both WISE



(a) Maximum acceleration



(b)Maximum velocity

Figure 3. Maximum strong ground motion at 2003 Toakchi-Oki earthquake

and K-NET. Figure-3(a) (b) shows distribution map of maximum acceleration and maximum velocity in the 2003 Tokachi-oki Earthquake, respectively. Large strong motion records ware observed in the area close to the epicenter.

3. CLASSIFICATION BY DISTANCE FROM HYPOCENTER

Generally, it is known that the scale of the strong grand motion depends on the distance from the seismic center, Here, the interaction between the accelerated response spectra and the distance from the seismic center is examined. There are two indexes, hypocentral distance and shortest fault plane distance as the index of the distance from the seismic center. The fault which causes earthquake has had the extent, so in recent years shortest fault plane distance is used in attenuation relation in place of hypocentral distance and epicentral distance. For that reason, shortest fault plane distance was used in this study.
There are many estimates available for the fault plane in the 2003 Tokachi-oki Earthquake, in this study the data

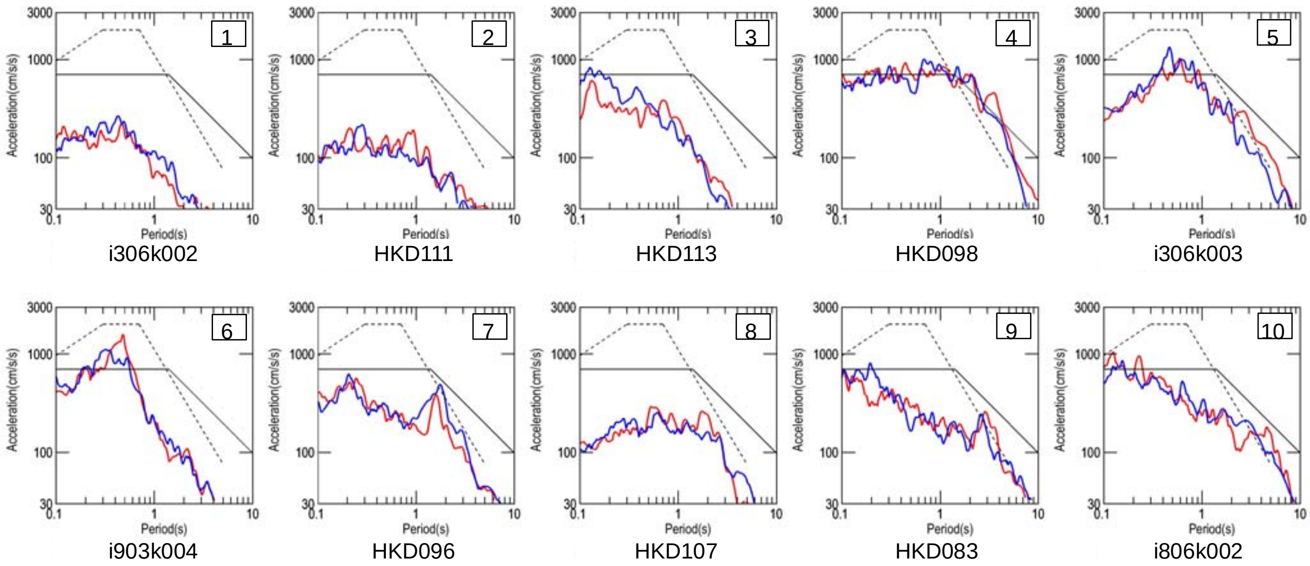


Figure 4. Acceleration response spectra at 10 stations closest to the shortest fault plane (Type I ground)

Table-1. Classification of the acceleration response spectra by form

Category	Shape of observed acceleration response spectra
A	Sites which exceed the Specifications for Highway Bridges
B	Sites at the same level as the Specifications for Highway Bridges (Type II)
C	Sites at the same level as the Specifications for Highway Bridges (Type I)
D	Sites with excessive short-period areas (less than 0.5 seconds)
W	Sites with excessive limited period bands
X	Sites in which one component exceeds the Specifications for Highway Bridges
Y	Sites in which fewer than two components fall below the Specifications for Highway Bridges
Z	Sites whose Specifications for Highway Bridges were less than 1/2

from the Geographical Survey Institute[7] was used. In the aforementioned Figure-2, contour of the shortest fault plane distance were shown.

Figure-4 shows the acceleration response spectra of 10 stations closest to the shortest fault plane in case of Type I ground. It has been recognized that the record of seismic stations where the shortest fault plane distance were close from both WISE and K-NET, these sites tended to have a large acceleration response spectrum. However, there were cases in which the spectrum was small even if the shortest fault plane distance was close and cases where the spectrum was large even if the distance was far. For this reason, it was difficult to calculate the spectra dependent upon the distance from the epicenter.

The destruction process of the hypocenter of the 2003 Tokachi-oki Earthquake is complicated, and according to the directivity effect of the fault destruction, it is considered that the scale of the strong ground motion cannot only be represented by the shortest fault plate distance, and the response spectra differ in complex ways not only in their amplitude, but in their largest periods. For that reason, the effect of the response spectra on ground conditions for the observation sites unable to be classified only by ground type was thought to be high.

4. CLOSED EVALUATION OF RESPONSE SPECTRA

As Figure 4 shows, a variation in size and form of response spectra even for the same ground type is visible, but it is considered that they can be classified according to the form's characteristics. Table-1 shows the

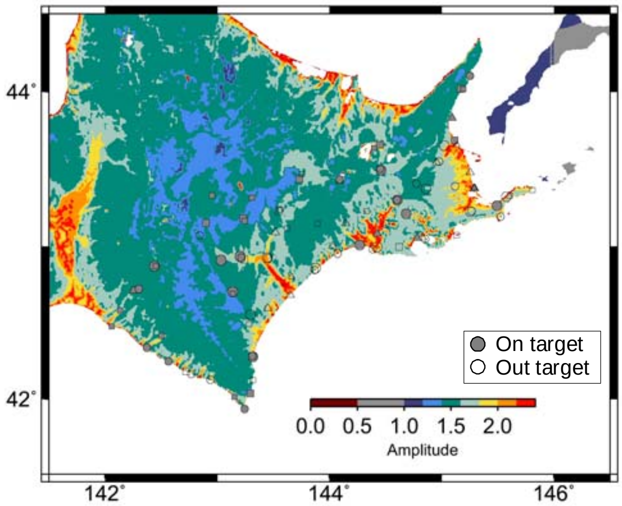


Figure 5. Seismic stations which classification are between category Y and Z

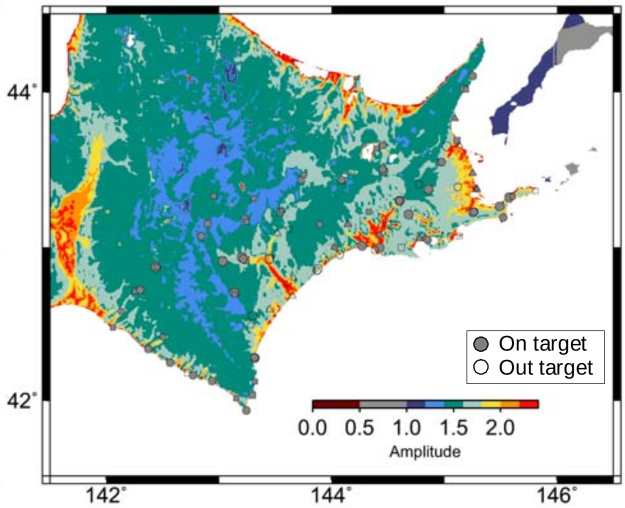
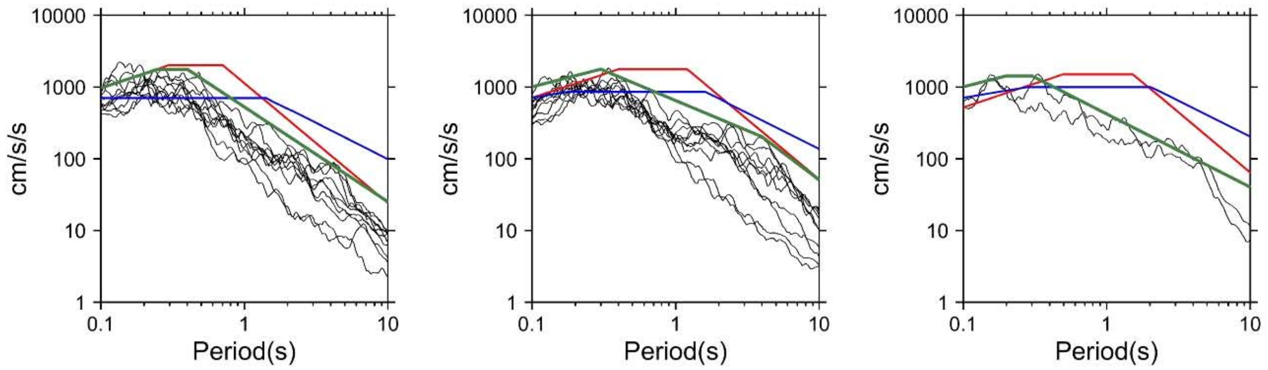


Figure 6. Seismic stations which classification are between category W and Z

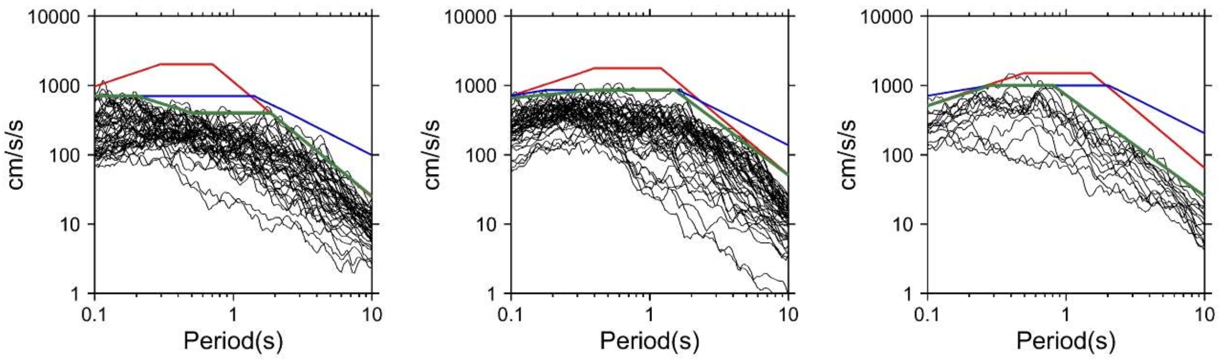
classifications according to shape of the response spectra. Category A is comprised of sites whose acceleration response spectra exceed seismic resistance standard, Category B is comprised of sites whose acceleration response spectra were at the same level as epicentral earthquakes of the standard, and Category C is comprised of sites whose acceleration response spectra were the same level as large offshore earthquakes. Categories A to C are ranked by sites whose intensities exceed seismic design standard. In Figure 4, "HKD100" belongs to Category A, "i804K001" belongs to Category B, and "HKD091" belongs to Category C. Category D is comprised of sites that exceed the standard and have a short period zone of less than 0.5 seconds. This spectra had a small effect on the structure whose natural period is long, but a large effect on the structure whose natural period is short. "i807k001" belongs to this category. Category W is comprised of sites which exceeded the allotted narrow period band, Category X of sites whose two-component spectra contained only one component, and Category Y of sites with fewer than two-component spectra. Category Z is comprised of sites whose the standard were less than 1/2. In sum, Categories W through Z were comprised of sites whose intensities were less than seismic resistance design standards. "i903k003" belongs to Category W, "HKD109" belongs to Category X, "i907K002" belongs to Category Y, and "i306K002" belong to Category Z.

Figures 5 and 6 show Categories Y through Z and Categories W through Z, respectively. Classified seismic stations are filled in grey; not classified seismic stations are not colored in. These figures also show the site amplification factors (the degree of amplification at peak velocity) according to Matsuoka and Midorikawa[8].It was found that the sites classified in Categories W through Z and in Categories Y through Z were situated without regard to their distances from the hypocenter. It was also found that there are seismic stations with small acceleration response spectra within sites with small degrees of amplification. Conversely, it was found that sites whose maximum velocity had a high degree of amplification also had large acceleration response spectra. Sites in Categories A through C exceeded acceleration response spectra of the standards. These areas used acceleration response spectra established in the reference 4) for their seismic designs. While the sites in Categories X through Z were area-classified as Zone A, their acceleration response spectra were smaller than design standard, so new spectra were established for these sites (acceleration response spectrum XZ). Category D and W are detailed as follows. Category D exceeded acceleration response spectra of the standards, but the period band was a short period area of less than 0.5 seconds. For the structure whose natural period is short, this area's acceleration response spectra was established (acceleration response spectrum D). Considering the characteristic period of highway structures, this spectrum was thought to fall well below the standard. Category W exceeded acceleration response spectra for the standard, and since it was restricted to period bands disconnected from the natural period of highway structures, it had the same acceleration response spectrum as spectrum XZ.



(a) Type I Ground (b) Type II Ground (c) Type III Ground

Figure 7. Acceleration response spectra for Type D



(a) Type I Ground (b) Type II Ground (c) Type III Ground

Figure 8. Acceleration response spectra for Type XZ

5. ACCELERATION RESPONSE SPECTRA FOR SEISMIC DESIGN

5.1 Category D

The acceleration response spectra in Figure 7 classify the sites in Category D by ground type. These spectra generate tangent-like acceleration response spectra. Figure 7 shows the generated standard acceleration response spectra. Type II and Type III grounds had period bands of less than 0.3 seconds and exceeded the acceleration response spectra in the standard, but areas with longer periods fell below the acceleration response spectra in the standard.

5.2 Category XZ

The acceleration response spectra in Figure 8 classify the sites in Categories X through Z by ground type. These spectra generate tangent-like acceleration response spectra. Figure 8 shows the generated acceleration response spectra.

Figure 6 shows response spectra from the seismic station which added acceleration response spectrum XZ to spectra with restricted period bands that exceeded acceleration response spectrum W.

It was found that there was a high correlation between sites with these special characteristics and site amplification factors (the degree of amplification at peak velocity). Among those with some scattering, it was

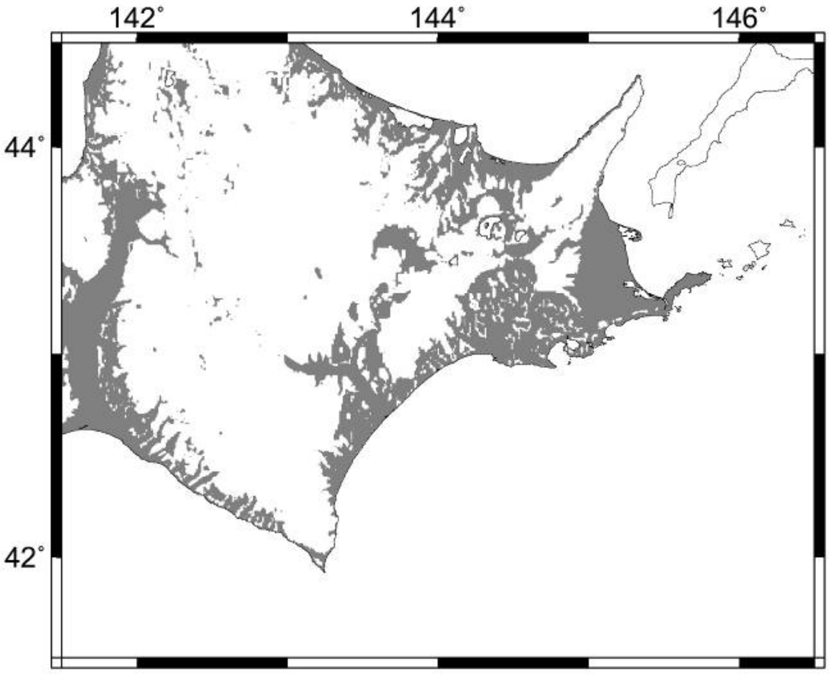


Figure 9. Degree of Amplification at Maximum Velocity with 1.6 as the Cutoff

found that there were a greater number of ground types whose degree of amplification at greatest velocity was less than 1.6 with these spectral characteristics. So, using the degree of amplification at greatest velocity of 1.6 as a cutoff, it was thought that the acceleration response spectra in Figure 8 could be applied to areas with a smaller degree of amplification. Figure-9 shows a distribution map using the degree of amplification at greatest velocity of 1.6 as a cutoff point.

6. CONCLUSIONS

To research seismic design, taking into consideration the local site characteristics, an examination of acceleration response spectra as used in seismic designs was carried out using ground motion records in Hokkaido.

As the results, the acceleration response spectra which calculated from ground motion records were difference in spectral forms (such as the amplitude or the dominant period) even among the same area classifications. One spectrum could not be accurately represented over a large range, so instead of dividing it up into smaller pieces, it was thought that more accurate acceleration response spectra could be established. Therefore, the acceleration response spectra in areas classified as Zone A were divided into small portions with special attention paid to the spectral forms. The results of this were further established into two types of standard acceleration response spectra. Furthermore, because there was a correlation between the intensity of the acceleration response spectra and the site amplification factors (the degree of amplification at peak velocity), these newly established spectra could be used to determine a new applicable range. Specifically, in sites where the special amplification characteristic was less than 1.6, standard acceleration response spectra with spectral characteristics lower than the Specifications for Highway Bridges were able to be established.

Since this study focused only on ground motion records obtained from 2003 Tokachi-oki Earthquake, there is room for argument on the validity of establishing standard acceleration response spectra from this limited ground motion records. Thus, further studies must be done using up-to-date earthquake observation data, allowing this study's results to be amended as necessary. Furthermore, since it was difficult to establish standard acceleration response spectra for epicentral earthquakes, there is a need to estimate ground motion using the fault model.

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REFERENCES

1) Takashi SATOH, Kenji IKEDA, Takakichi KANEKO, Takaaki IKEDA and Shigeru MIWA, "DESIGN INPUT GROUND MOTION BASED ON REGIONAL SEISMISITY", 13th World Conference on Earthquake Engineering

2) Hisashi KONNO, Takashi SATOH, Shin-ya OKADA, Kenji IKEDA, Takaaki IKEDA and Shigeru MIWA, "EVALUATION OF AMPLIFICATION CHARACTERESTICS OF SUBSURFACE GROUND FOR SETTING DESIGN INPUT GROUND MOTION", 13th World Conference on Earthquake Engineering

3) Japan Road Association, Specifications for Highway Bridges, Part V Seismic design, 2000.

4) Takashi SATO, Hiroaki NISHI, Takaaki IKEDA, Noboru KAMIAKITO and Atsushi TAKADA, "Study on acceleration response spectra for seismic design based on observed records in Hokkaido, JAPAN", The 14th World Conference on Earthquake Engineering

5) Takashi SATO, "DEVELOPMENT OF A WARNING INFORMATION SYSTEM OF EARTHQUAKE", 12th World Conference on Earthquake Engineering, Paper No.1268, 2000.

6) http://www.k-net.bosai.go.jp/

7) Geographical Survey Institute, http://www.gsi.go.jp/WNEW/PRESS-RELEASE/2003/0926-2.htm

8) Saburoh Midorikawa and Masashi Matsuoka, "GIS-Based Integrated Seismic Hazard Evaluation using the Digital National Land Information", Butsuri-tannsa, Vol48, No.6, pp.519-529, 1995.