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RESEARCH ON RELATIONSHIP BETWEEN THE BEHAVIOR FACTOR DS AND DUCTILITY FACTOR

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ABSTRACT

Severe damage to the structure occurs when the deformation of structure exceeds the elastic limit and reaches to the ultimate capacity limit. Therefore, it is important to assure that structures remain within a certain limit outside of the elastic range. For that purpose, some procedures are employed in the structural design, among which introducing the structural behavior factor, a reciprocal of Ds-value in Japanese standard, is widely used for its easiness.

However, the procedure with behavior factor cannot reflect the effects of changes in natural period and damping on the structural responses, so that a large uncertainty exists in assessing the structural response since the changes are affected various factors such as input ground motion, elastic natural period of structure, hysteresis characteristics, and so on.

On the other hand, it is needed to find the ground motion index that gives smaller uncertainty in the structural response in order to establish an accurate damage estimation framework.

This research examines the ground motion index that gives the ductility corresponding to the behavior factor used in the structural design, and proposes the adequate index for each parameter of ground motion and of structure.

INTRODUCTION

Severe damage to the structure occurs when the deformation of structure exceeds the elastic limit and reaches to the ultimate capacity limit. Therefore, it is important to assure the structures remain within a certain limit.

For the Japanese design standard, required ultimate strength against large earthquakes is obtained by the following equations.

$$Qun = Ds \cdot Fes \cdot Qud \tag{1}$$

Ds : Ds factor
Fes : eccentricity factor

$$Qud = Z \cdot Rt \cdot Ai \cdot Co \cdot W \tag{2}$$

Z : zone factor
Rt : vibration characteristic coefficient
Ai : shear coefficient distribution in vertical direction
Co : base shear coefficient (=1.0)
W : weight

As shown above, Qud is modified by Ds and Fes. Ds is a reduction factor of load reflecting the energy absorption due to in elastic behavior, and Fes is a increment factor of load reflecting the excessive deformation in vertical and horizontal directions.

According to the Newmark's formula, Ds and ductility factor μ are related to each other by the formula below, assuming that structures possess elasto-plastic load-deformation characteristics.

$$\mathrm{Ds} = \frac{1}{\sqrt{2\mu - 1}} \tag{3}$$

However the relationship by eq.(3) is derived from the static equilibrium of energy, other factors controlling the dynamic behavior, such as characteristics of input ground motion, natural period and hysteresis loop of structures, damping factor and so on, are not included. So that the variability in these factors may bring large uncertainty into the structural response.

Therefore, the realistic safety of structure may differ by the combination of the factors above though the required ultimate strength (Qun) is identical.

This research investigates the relationship between Ds and μ by using Monte Carlo simulation (hereinafter called MCS), focusing the effect of Ds and natural period.

ANALYSIS

Modeling

The analysis model was taken as a single degree of freedom system with fixed base. Parameters employed were natural period and Ds-value; for the former six (6) periods, 0.2, 0.3, 0.5, 1.0, 2.0 and 3.0 sec, were assigned, and for the latter four (4) values, 0.25, 0.4, 0.55 and 1.0 were assigned.

Skeleton curves of the model structures were assumed bi-linear as show in Fig.1 with various Ds-values. Hysteretic loop follows Masing's Law.

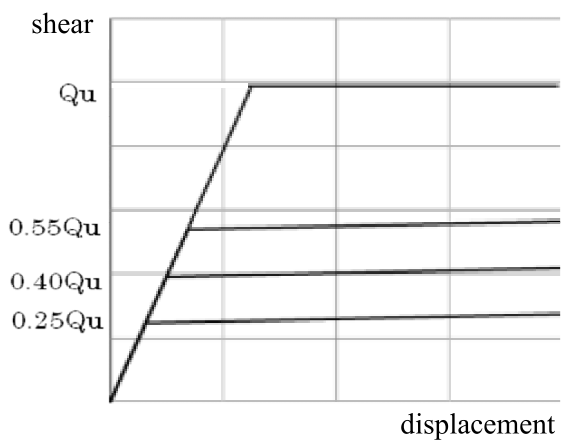

Figure 1 Skeleton curves of analysis models

Input Earthquake Ground Motion

Ten (10) observation records provided by the Building Center of Japan were used as input ground motion for MCS. It is noted that the peak acceleration of each record was normalized by 400cm/s^2, which corresponds to the level-2 earthquake.

Figure 2 shows the mean response spectrum from 10 response spectra. Response acceleration at 0.5sec and its vicinity reaches to 1000 cm/s^2, which is compatible to the base shear coefficient of 1.0.

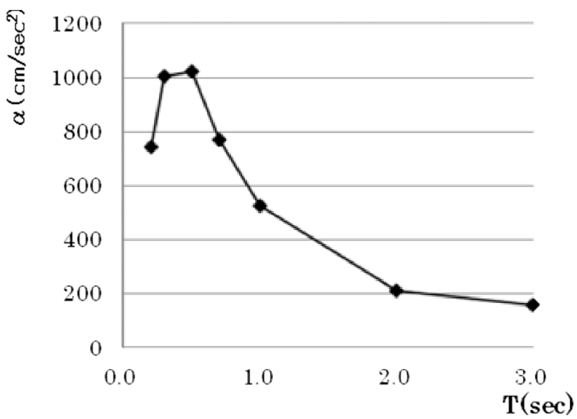

Figure 2 Response acceleration spectrum

Examination by MCS

Examination procedures is as follows

[1] Conduct MCS using ten (10) input ground motions for each model structure with given natural period and capacity,
[2] Arrange the results by MCS so that mean and scattering of response ductilities are obtained, and,
[3] Compare the ductilities by MCS and those by given Ds-values.

RESULT AND CONSIDERATION

Ductility factors by MCS and those by Ds values are shown in Fig. 3. It is noted that the ductility factor by eq.(4) is also shown in the figure since it is said that ductility factor based on the constant displacement law (eq.(4)) may be preferable for the structures with longer natural period.

$$Ds = \frac{1}{\mu} \tag{4}$$

From the Fig.3, the following were obtained;

- Eq.(3) gives the good estimation for the structures whose natural period is 0.5 sec. The equation underestimates the ductility for the structures with shorter natural period, and overestimates ductility for the structure with longer natural period.
- Eq.(4) is better estimate than eq.(3) for the structures whose natural period is 1.0 sec or longer.
- The shorter the natural period is , the longer the uncertainty is ductility factor is. Therefore it may be preferable to give a large margin for the structures with short natural period in design.

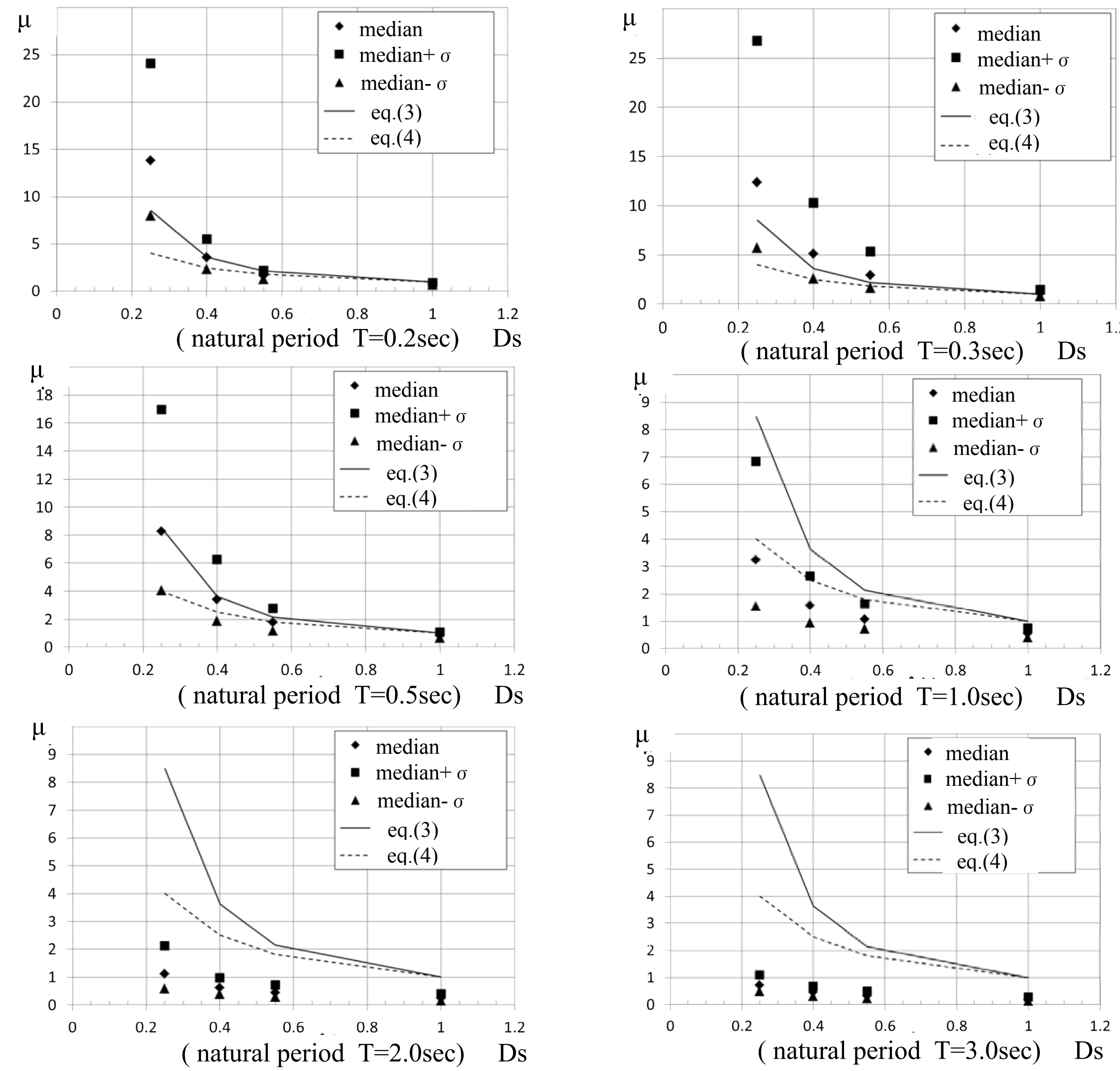

Figure 3 Relationship between Ds and ductility factor

CONCLUSION

In order to investigate the relationship between Ds-value and ductility factor, MCS were conducted followed by the outcomes listed below;

- Ds-value that is based on the energy equivalent gives the good estimation of ductility factor for the structure with natural period ground 0.5 sec.
- For short period structures and lower period structures Ds-value can over- and underestimates the ductility factor.
- Estimate by the constant displacement law is preferable for the structure whose natural period is 0.5 sec or longer.

Effects of other factors, such as hysteretic loop and damping, will also be examined as the next step in this research.