17th World Conference on Earthquake Engineering, 17WCEE
Sendai, Japan - September 13th to 18th 2020

ASEIMIC DESIGN LEVEL USING RESPONSE SPECTRUM AND IT'S APPLICATION

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Abstract

New equations for base shear coefficient are discussed in considering the acceleration response spectrum with keen peaks. The new base shear coefficient (C_o) is defined as the product of the coefficient of eccentricity ratio(F_{es}), the coefficient of a damping factor(F_h), and the coefficient of horizontal resistant force($\overline{D_s}$). This coefficient of horizontal resistant force is the function of the ductility factor(μ), the natural period (T_s), the period of a response spectrum peak and its acceleration. As a result, the response analysis shows that the proposed equations give the safe side of the horizontal resistant force.

$$C_o = F_{es} F_h \overline{D}_s \quad (1)$$

$$F_h = \sqrt{\frac{1+\alpha h_o}{1+\alpha h_{eq}}} \qquad \alpha = 25$$
$$\overline{D_s} = D_{si} C_{oi} \quad (2)$$
$$C_{oi} = 0.816 * Acc(T)/980$$

For Minimum requirement

$$D_{sc} = \begin{cases} \dfrac{1}{\sqrt{2\mu - 1}} + \beta \dfrac{T_c - T}{T_c} & T \le T_c \\ \dfrac{1}{\sqrt{2\mu - 1}} \dfrac{T_c}{T} & T > T_c \end{cases} \qquad \beta = \begin{cases} 0.1 & Bi-linear \\ 0.5 & Slip \end{cases} \quad (3)$$

For customer order requirwement

$$D_{si} = \begin{cases} \dfrac{1}{\sqrt{2\mu - 1}} + \beta \dfrac{T_i - T}{T_i} & T \le T_i / 0.8 \\ 0 & T > T_i / 0.8 \end{cases} \quad (4)$$

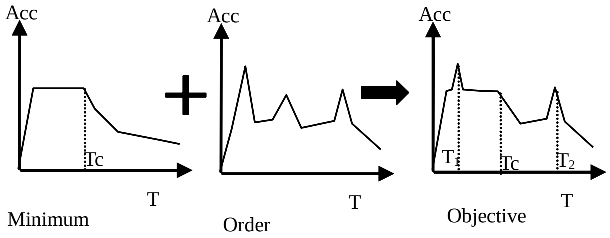

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Fig.1 Acceleration response spectrum for structural design

Keywords: Acceleration response spectrum; Structural design; Base shear coefficient

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1. Introduction

It is difficult to estimate input earthquake motions accurately in response analysis. Then the response spectra are used to define the input earthquake motions in structural design. In Japan, base shear coefficient is given in structural code. This base shear coefficient is related the acceleration response spectrum in ref.[1]. Therefore, it is useful that the base shear coefficient is calculated from any acceleration response spectrum. In this paper, new equations for base shear coefficient are discussed in considering the acceleration response spectrum with keen peaks. The new base shear coefficient (C_o) is defined as the product of the coefficient of eccentricity ratio(F_{es}), the coefficient of a damping factor(F_h), and the coefficient of horizontal resistant force(D_s). This coefficient of horizontal resistant force is the function of the ductility factor(μ), the natural period (T_s), the period of a response spectrum peak and its acceleration. This proposed base shear coefficient is discussed by the average of the maximum ductility factors by 10 input motions.

2. Target acceleration spectrum and analysis supposition

2.1 Target acceleration spectrum

The target acceleration spectra are shown in Fig.1. This acceleration spectrum is the sum of Minimu requirement spectrum and the order spectrum. The minimum requirement spectrum has the corner period (Tc), and the order spectrum has the peak periods(T_i).

The input earthquake motions are shown in Fig.2. There 10 input earthquake motions in each spectrum. Each input earthquake motion has random phase and 163.84 sec duration time. The minimum requirement spectrum has the 0.86 sec corner period and 1200gal constant acceleration spectrum region. The target spectrum A has both minimum requirement spectrum and 1400gal peak at 0.4sec natural period. The target spectrum B has both minimum requirement spectrum and 2000gal peak at 0.4sec natural period. The target spectrum C has minimum requirement spectrum, 1400gal peak at 0.4sec natural period and 1400gal peak at 1.2sec natural period. The input earthquake motions are multiplied 0.8 for response analysis of 1 DOF model.

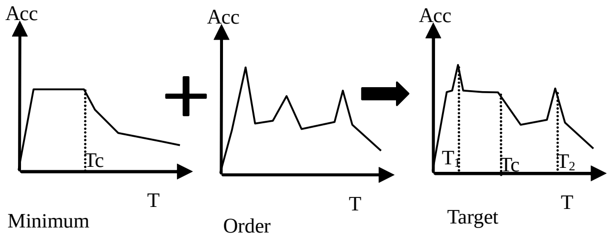
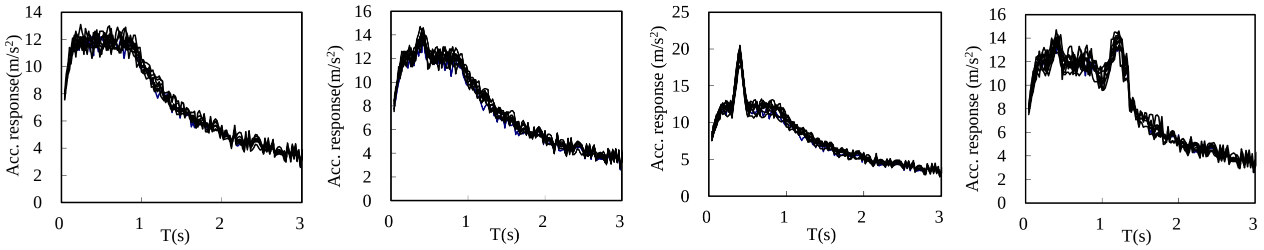


Fig.1 – Acceleration response spectrum for structural design



a) Minimum requirement b) Target spectrum A c) Target spectrum B d) Target spectrum C

Fig.2 – Acceleration response spectrum of input earthquake motions(h=0.05)

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2.2 Proposed base shear coefficient

The proposed base shear coefficient (C_o) in Eq.(1) is defined as the product of the coefficient of eccentricity ratio(F_{es}), the coefficient of a damping factor(F_h), and the coefficient of horizontal resistant force(D_s). This coefficient of horizontal resistant force is the function of the ductility factor(μ), the natural period (T_s), the period of a response spectrum peak and its acceleration in Eq.(3) – (7). Three restoring force characteristics are considered in this paper(Fig.3). The coefficient γ is the bearing force of Bi-linear component over the whole bearing force. The parameters of restoring force characteristic are the natural period(T) and the bearing force(Co). The natural periods are set from 0.2 to 3.0sec. The bearing force is calculated by Eq.(1) – (7). The damping factor(ho) is 0.05 basically, are 0.02 and 0.10 for parameter analysis.

$$C_o = F_{es} F_h \overline{D}_s \tag{1}$$

$$F_h = \sqrt{\frac{1+\alpha h_o}{1+\alpha h_{eq}}} \tag{2}$$

$$\alpha = 25$$

$$\overline{D_s} = D_{si} C_{oi} \tag{3}$$

$$C_{oi} = 0.816 * Acc(T)/980 \tag{4}$$

For Minimum requirement

$$D_{sc} = \begin{cases} \frac{1}{\sqrt{2\mu-1}} + \beta \frac{T_c - T}{T_c} & T \le T_c \\ \frac{1}{\sqrt{2\mu-1}} \frac{T_c}{T} & T > T_c \end{cases} \tag{5}$$

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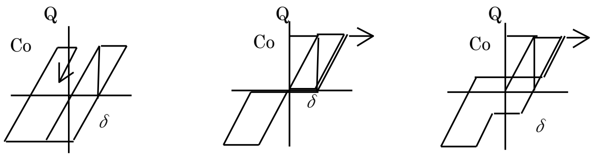
$$D_{si} = \begin{cases} \frac{1}{\sqrt{2\mu-1}} + \beta \frac{T_i - T}{T_i} & T \le T_i/0.8 \\ 0 & T > T_i/0.8 \end{cases} \tag{6}$$

$$\beta = \begin{cases} 0.1 & Bi-linear \\ 0.5 & Slip \\ 0.5 - 0.4\gamma & Composite \end{cases} \tag{7}$$



a) Bi-linear b) Slip c) composite

Fig. 3 – Restoring force characteristic

The adequacy of the proposed base shear coefficient is checked up by the average ductility factor subjected to input earthquake motions over the set ductility factor (μ). Hereinafter, the ratio of the average

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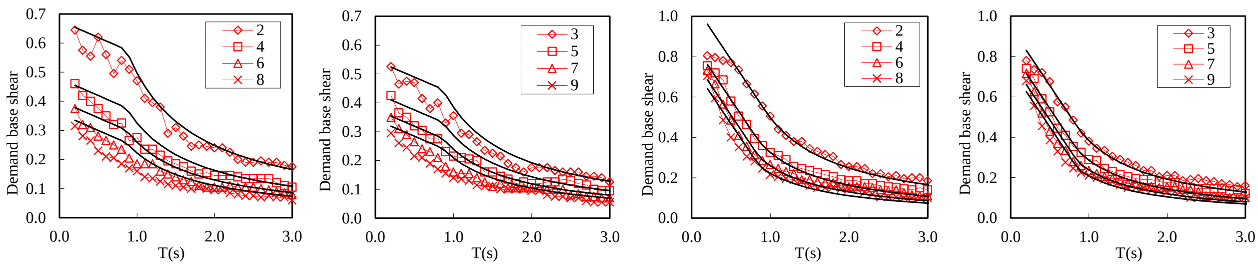
ductility factor subjected to input earthquake motions over the set ductility factor (μ) is called the ductility factor ratio.

3. Verification

The acknowledgements provide an opportunity to express appreciation to those who contributed significantly to the preparation of the paper. They may be written in free style, and must be brief.

4.1 Verification of proposed base shear coefficient on minimum requirement

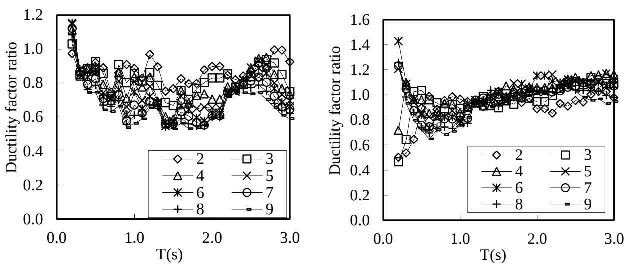
Firstly, the proposed base shear coefficient is checked by minimum requirement input earthquake motions. The comparison between the demand base shear coefficient and the proposed base shear coefficient is shown in Fig.4. The ductility factor ratio is also shown in Fig.5. The legend symbols in these figures are the set ductility factors. Hereinafter, the same legend symbol is used in figures. The ductility factor ratio is between 0.6 and 1.2. The error is not small, but these figures also show the verification of the proposed base shear coefficient.



a) Bi-linear characteristic b) Slip characteristic

Fig. 4 – Demand base shear coefficient subjected to minimum requirement

(h=0.05, Red line: calculated, Black line: Eq.(1), legend symbol means the set ductility factor)



a) Bi-linear characteristic b) Slip characteristic

Fig. 5 – Ductility factor ratio subjected to minimum requirement (h=0.05)

Next, the ductility factor ratio of composite characteristic is shown in Fig.6. The maximum ductility factor ratio is 1.2. And the ductility factor ratios when set ductility factor is greater than3 are about 0.6. These indicate that the proposed base shear coefficient is too much safe.

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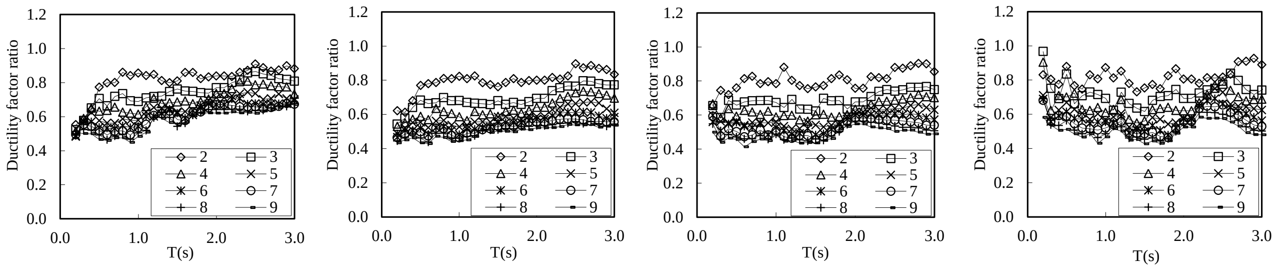
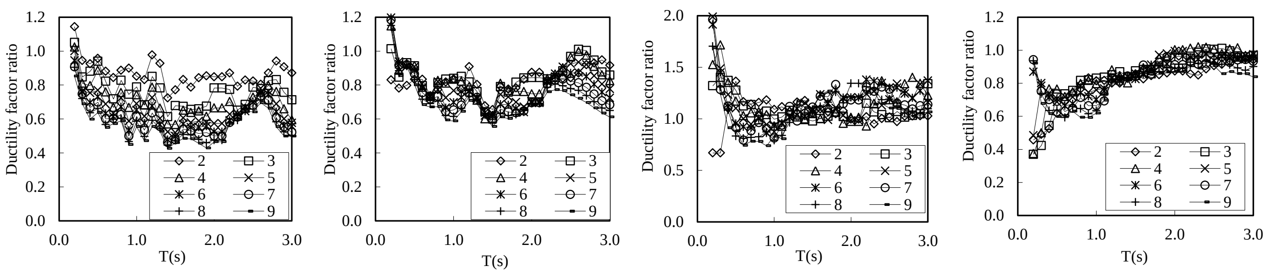


a) γ =0.2 b) γ =0.4 c) γ =0.6 d) γ =0.8

Fig. 6 – Ductility factor ratio of composite characteristic subjected to minimum requirement (h=0.05)

4.2 Influence of damping

The influence of the damping factor is discussed in this section. The ductility factor ratios when h is 0.02 or 0.10 are shown in Fig.7, 8. The ductility factor ratio of slip characteristic is over than 1.2 when the period is less than 0.3 sec. The ductility factor ratio of composite characteristic is about 0.6 when the set ductility factor is over than 3. Except these cases, the proposed base shear coefficient is appropriate. It must be considered that the maximum ductility factor ratio is 1.2, in case of the structural design.



h=0.02 h=0.10 h=0.02 h=0.10

a) Bi-linear characteristic b) Slip characteristic

Fig. 7 – Ductility factor ratio subjected to minimum requirement

4.3 Influence of acceleration spectrum

The influence of the acceleration spectrum is discussed in this section. The ductility factor ratios in Target spectrum A – C are shown in Fig.9 - 11. The ductility factor ratio of slip characteristic is less than 0.6 subjected to Target spectrum C when the period is less than 1.2 sec. The ductility factor ratio of composite characteristic is also less than 0.6 subjected to Target spectrum C when the period is less than 1.2 sec. The proposed base shear coefficient gives too much safe side of base shear. Except these cases, the proposed base shear coefficient is between 0.6 and 1.2. It must be considered that the maximum ductility factor ratio is 1.2, in case of the structural design.

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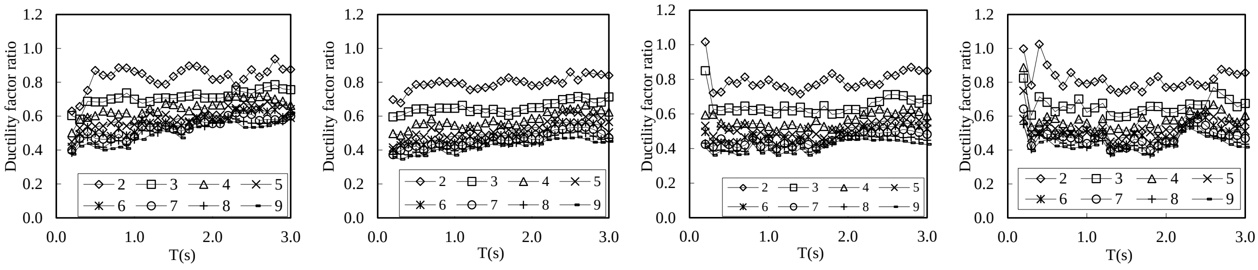
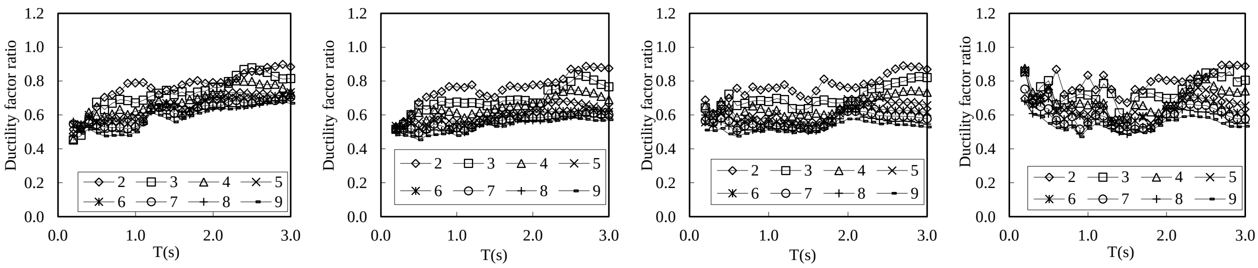


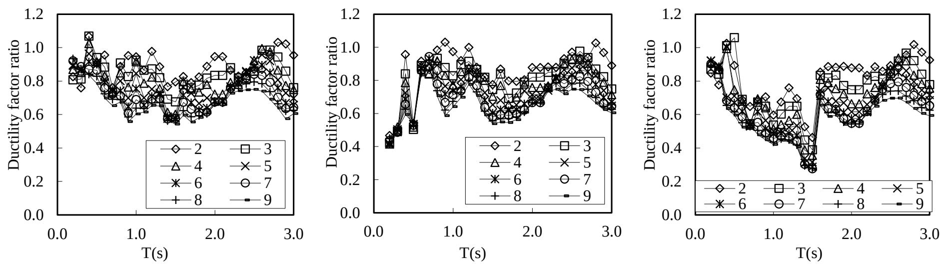
a) h=0.02



b) h=0.10

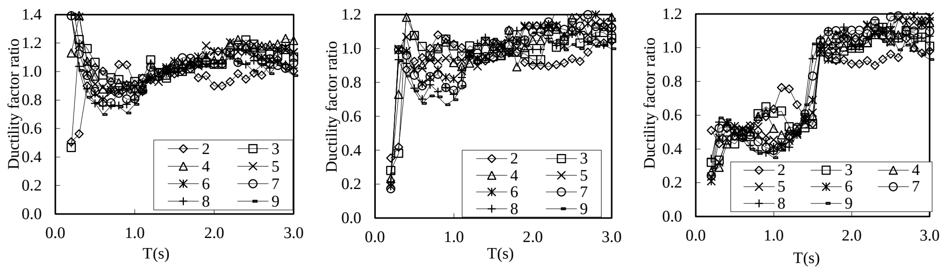
γ =0.2 γ =0.4 γ =0.6 γ =0.8

Fig. 8 – Ductility factor ratio of composite characteristic subjected to minimum requirement



a) Target spectrum A b) Target spectrum B c) Target spectrum C

Fig. 9 – Ductility factor ratio of Bi-linear characteristic subjected to Target spectrum A – C (h=0.05)



a) Target spectrum A b) Target spectrum B c) Target spectrum C

Fig. 10 – Ductility factor ratio of Slip characteristic subjected to Target spectrum A - C (h=0.05)

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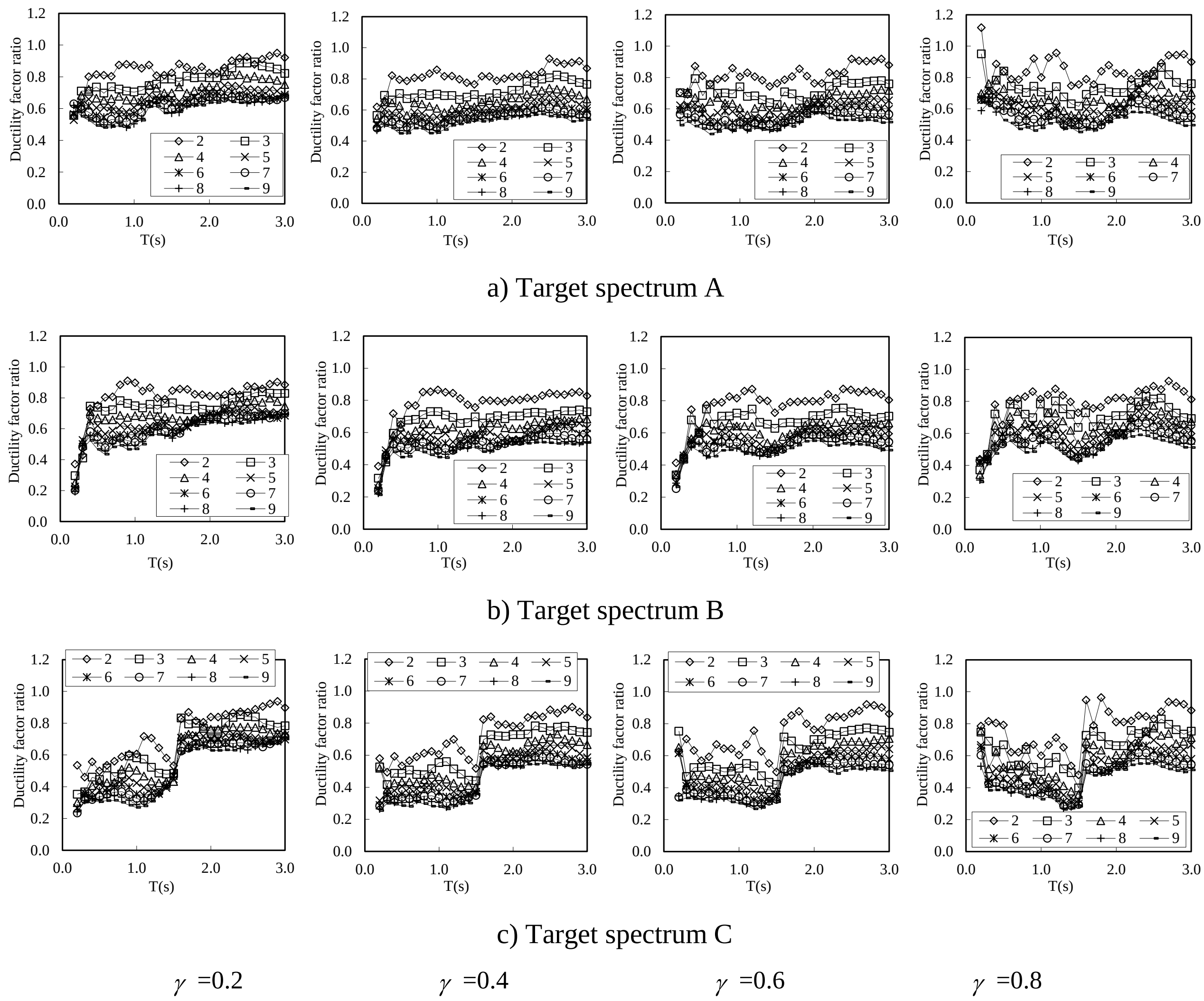

Fig. 11 – Ductility factor ratio of composite characteristic subjected to Target spectrum A - C (h=0.05)

4. Conclusion

In this paper, new equations for base shear coefficient are discussed in considering the acceleration response spectrum with keen peaks. The result may be summarized as follows; the proposed base shear coefficient is between 0.6 and 1.2. It must be considered that the maximum ductility factor ratio is 1.2, in case of the structural design.

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