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# IMPORTANCE FACTOR BASED ON DAMAGE CONTROL FOR ELECTRIC POWER STRUCTURES

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## SUMMARY

This paper describes a criteria of an importance classification and an importance factor for determining design seismic coefficient for electric power structures, so as to rationalize the aseismic design for those structures.

The criteria of the importance classification is defined by recognizing various damages of power facilities mainly RC structures. The importance factor of RC structures is determined by comparing yield seismic coefficients calculated by one-mass model with tri-linear elasto-plastic spring of dynamic responses so as to correspond target plasticity rate. In the process of setting the importance factor, convenience for rehabilitation after earthquake are taken into consideration.

## INTRODUCTION

Electric power facilities considered in this paper are dams, power-plants, fuel storage tanks, transmission lines etc. They are a lot of kinds of structures having various importance level, if damages due to earthquakes are concerned: damages of some of those structures might affect seriously to the society, and that of other structures might not have any influence to supplying ability of electricity. Each kind of structures has been designed and constructed individually considering seismic force and importance level adequately with help of regulating codes or design standards.

On the other hand, two kinds of requirements have appeared in recent years in electric power technology. As the social system comes to be highly developed, significance of electric power supply on social security against earthquake disaster has been increasing, and at the same time it is also required to reduce the construction cost of electric power facility if it is able to reduce rationally using updated knowledges of earthquake engineering.

This paper describes the criteria of importance classification and importance factor of each classification for determining design seismic coefficient for electric power structures.

## BASIC PRINCIPLES FOR SEISMIC IMPORTANCE

As the importance of any structures is determined from the seriousness of the influence that is estimated in case of expected damages due to coming strong earthquakes, it is recognized to be rational that earthquake resistant characteristics of structures are classified in some ranks according to the importance of the structure for strong earthquakes that have quite low possibility to occur during their durable years. In other words, rationalization of aseismic design is enabled to execute owing to making differences of degree of damages of various kinds of structures in the way that aseismic design method is determined so that more important structures are able to maintain higher endurability of earthquake resistance.

It is also important a) for the important structures to design not to collapse due to strong quakes with longer return period such as 200 years, b) for less important structures, from the point of view of maintenance and repair work, to design not to be damaged due to moderate quakes which have high probability to occur during the durable years at most 75 years.

Based upon the principles mentioned above, design conditions for each importance factor was determined by the methods as follows: a) In the cases of the same conditions of such as region or ground, more important structures are given higher seismic coefficient to ensure the safety of the structures for seismic force. b) More important structures are given higher accuracy of aseismic design.

## CRITERIA OF IMPORTANCE FACTOR

According to the basic principles for the seismic importance stated above, items to pay attention to decide the importance are selected as follows, referring to the past classifications in bygone standards of Japan, and damages of power industry caused by past quakes: 1) influence to the society and environment, 2) influence to recovery for earthquake disasters of society, 3) serious disturbances for function of electric power facilities and 4) simple damage of facilities. Importance classification and their definitions are as shown in Table 1 with four ranks, i.e. I to IV.

Table 1 Criteria of Importance Factor

| Rank | Definition |
|---|---|
| I | Damages of those structures may cause great losses or serious effects on lives, properties, or environment other than the own company; and also may cause serious effects on economic and social activity.<br>Those structures which have to prevent an expansion of disasters due to earthquakes, or which have a great roll for restoration of disasters are in this category. |
| II | Damages of those structures may cause losses of function of electric power facilities such as generation, transmission, transformation, etc., and may cause great amount of losses of electric power supply: or result in huge cost for restoring those structures. |
| III | Damages of those structures may cause losses of function of electric power facilities such as generation, transmission, transformation, etc., and may cause relatively less amount of losses of electric power supply. |
| IV | Other than I , II and III. |

## PROCEDURES TO DETERMINE IMPORTANCE FACTOR

A comprehensive flow chart of procedures to determine the importance factor is shown in Figure 1.

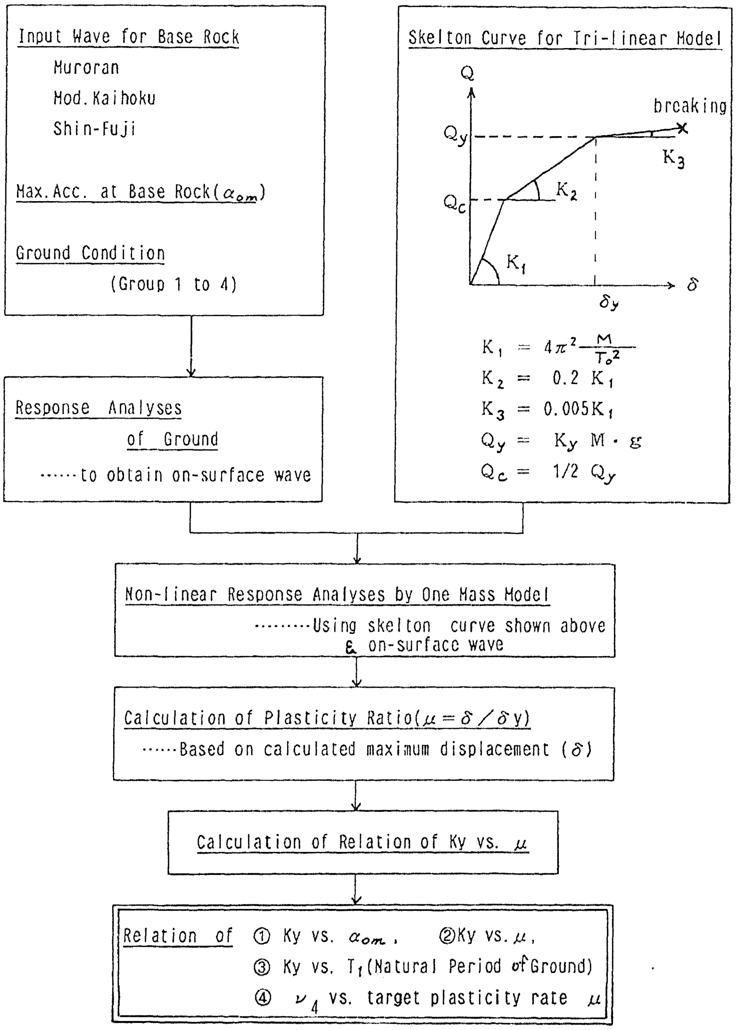

Figure 1 Flow Chart of Determination of Importance Factor

**Expected Maximum Acceleration on Ground** Expected maximum acceleration maps for return period of 75 and 200 years on the outcropping foundation (Vs > 700 m/s) in Kanto Region and its vicinity were drawn up using probability model with seismicity in the area. When these maps were drawn up, reliable seismic data were rearranged to estimate their reliability for the area. The maps are shown in Figure 2 and 3. Using this maximum acceleration and representative ground condition in Kanto Region and its vicinity, on-surface accelerations have been calculated.

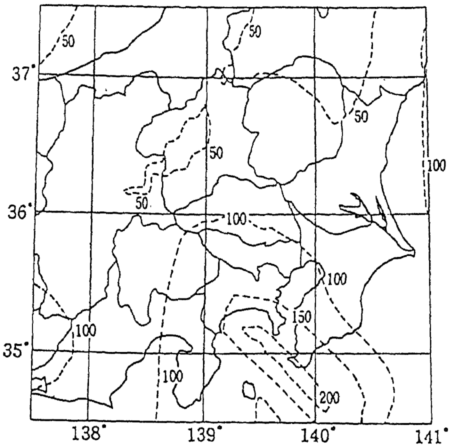

Figure 2 Expected Max.Acc.Distribution Map on Outcropping (Return Period of 75 yrs.)

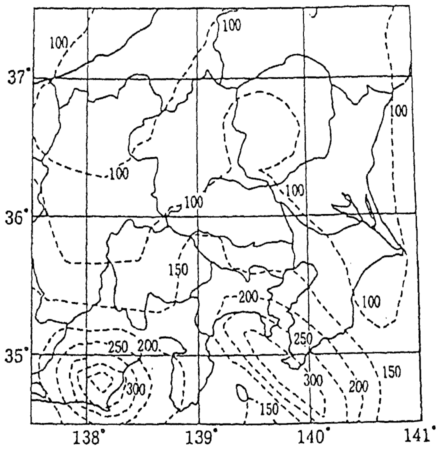

Figure 3 Expected Max.Acc.Distribution Map on Outcropping (Return Period of 200 yrs.)

Static Seismic Coefficient Static seismic coefficient applied to RC structures in this paper is defined as shown below.

$$K_H = k_0 \cdot \nu_1 \cdot \nu_2 \cdot \nu_3 \cdot \nu_4$$

where
$K_H$ : static design seismic coefficient
$k_0$ : standard design seismic coefficient (=0.2)
$\nu_1$ : seismic zone factor
$\nu_2$ : ground condition factor
$\nu_3$ : structural factor
$\nu_4$ : importance factor

Determination of Importance Factor ( $\nu 4$ ) In order to make differences of seismic safety according to the importance of the structures, static design seismic coefficients are varied by the importance factor using elasto-plastic deformation phenomena of RC structures during earthquakes.

The procedures of determining the importance factor are as follows: response analyses of one mass model with tri-linear elasto-plastic spring were carried out, using various parameters such as natural period of the structure by initial elasticity of tri-linear spring, yield coefficient $k_y$ , peak ground accelerations, four types of representative ground conditions, and three types of input acceleration waves at the outcropping foundation. Response displacements were used to calculate plasticity ratio defined as maximum response displacement divided by yield displacement as shown below.

$\mu = \delta / \delta_y$ where $\mu$ : plasticity ratio $\delta$ : maximum response displacement

$\delta_y$: yield displacement

As ductility ratio ( breaking displacement divided by yield displacement ) of RC structures is reported to be approximately more than 4.0 according to the results of experiments, relation between plasticity ratio and damages used for determining importance factor are described below.

i) Within plasticity ratio of under 1.0, RC structures behave almost in elastic manner, and keep soundness as structures: usually no rehabilitation works are needed.

ii) In the region of plasticity ratio of nearly 2.0, the degree of damage of RC structures is so slight that only small cracks can be seen, keeping relatively soundness as structures. Rehabilitation works can be done easily such as resin injections.

iii) In the region of plasticity ratio of nearly 3.0, there appear separation and collapse of concrete between surface and reinforcement, although there exists bearing capacity for load. It is sufficiently able to repair using resin injection or maintaining of paste works in proper occasion after damage.

iv) In the region of plasticity ratio over 4.0, there appear serious collapse of concrete and buckling of reinforcement, immediate recovery works are needed. As large scaled recovery works are inevitable in this degree of damages, plasticity ratio of over 4.0 is not admitted to behave for any rank of structures, considering uncertainty of actual dynamic behavior during earthquakes.

After considering the results mentioned above, relation between importance factor and target plasticity ratio was calculated as shown Figure 4. And resulted importance factor corresponding to the importance rank is as shown in Table 2.

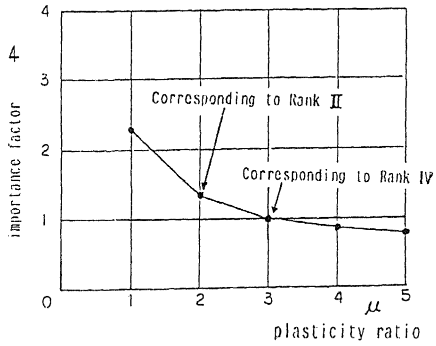

Figure 4 Relation of $\mu$ vs. $\nu_4$

Table 2 Importance Factor for RC Structures

| Rank | Importance Factor($\nu_4$) |
|---|---|
| I | * |
| II | 1.4 |
| III | 1.2 |
| IV | 1.0 |

*Individually defined according to each structure.

## CONCLUSION

By adopting the above-mentioned method to the aseismic design, it is possible to determine a design seismic coefficient rationally for electric power structures, considering social security, power supply function and recovering works after earthquakes. Other than importance factor for RC structures, importance factor for soil structures had been also studied corresponding to the rank of RC structures considering equivalent return period, and studies for seismic zone factor, ground condition factor and structural factor were also carried out.

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