A PROPOSAL OF A NEW ASEISMIC DESIGN METHOD FOR BUILDINGS IN JAPAN

by

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SUMMARY

This paper summarizes the draft of a new aseismic design method for Building Standard Law Enforcement Order and related regulations which will be amended in near future. This aseismic design method is aiming two targets. (i) The buildings shall withstand with almost no damage against the moderate earthquake motions which would occur several times during the use of the buildings. (ii) The buildings shall not collapse nor harm human lives by the severe earthquake motions which would occur less than once during the use of the buildings.

1. GENERAL

1.1 Purpose The purpose of this aseismic design method is that the buildings shall withstand with almost no damage against the moderate earthquake motions, which would occur several times during the use of the buildings, and shall not collapse nor harm human lives by the severe earthquake motions, which would occur less than once during the use of the buildings.

1.2 Scope This aseismic design method shall apply for buildings not higher than 60 meters.

2. DESIGN PROCEDURE

2.1 Design for Moderate Earthquake Motions (i) The stresses caused by the lateral seismic shear prescribed in 3.1, 3.2 and 3.3 shall not exceed the allowable stresses for temporary loads. (ii) Each story drift of the building caused by the lateral seismic shear priscribed in 3.1 shall not exceed 1/200 of the story height. This value can be released to 1/120 in case the non-structural members shall have no severe damage at the released story drift limitation.

2.2 Design for Severe Earthquake Motions The ultimate lateral shear strength of each story shall not be less than the required lateral shear, Q_R, determined in accordance with the following formula.

$$Q_R = D_S \, F_{ES} \, Q \tag{1}$$

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where, D_S = the structural coefficient which can be determined by the ductility and the damping and shall be not less than 0.3. (See A - 1)

F_{ES} = the shape factor which shall be the product of F_E and F_S. Where, F_E and F_S shall be the factors which can be determined by the eccentricity of the center of stiffness from the center of gravity and by the variation of the lateral stiffness from the mean lateral stiffness, respectively, and both shall be not less than 1.0. (See A - 2)

Q = the lateral seismic shear for severe earthquake motions priscribed in 3.1.

2.3 Exceptions (i) The design procedure of 2.1 (ii) and 2.2 may not apply for buildings listed in Table 1. (ii) The design procedure of 2.2 may not apply for buildings listed in Table 2.

3. LATERAL SEISMIC SHEAR

3.1 Lateral Seismic Shear above the Ground Level The lateral seismic shear, Q, of each story above the ground level shall be determined in accordance with the following formula.

$$Q = C_I \; W_I \qquad (2)$$

where, C_I = the lateral seismic shear coefficient of the I-th story as determined in accordance with Formula (3).

W_I = the weight of the building above the I-th story.

The weight of the building shall be the sum of dead load and the applicable portion of live load. In the heavy snow districts, the effect of snow load shall be considered.

The lateral seismic shear coefficient of the I-th story, C_I, shall be determined in accordance with the following formula.

$$C_I = Z \; R_T \; A_I \; C_0 \qquad (3)$$

where, Z = the seismic hazard zoning coefficient as shown in Fig. 1.

R_T = the design spectral coefficient, which shall be determined by the type of soil profile and the fundamental natural period of the building, as illustrated in Fig. 2.

A_I = the lateral shear distribution factor, which shall be determined by the fundamental natural period and the weight distribution of the building, as shown in Fig. 3.

C_0 = the standard shear coefficient, which shall be not less than 0.2 and 1.0 for moderate earthquake motions and for severe earthquake motions, respectively.

The fundamental period of the building, T, to determine the design spectral coefficient and the lateral shear distribution factor, shall be determined in accordance with one of the following formulae.

$$T = 0.028\,H \quad \text{for steel frame buildings.} \tag{4}$$

$$T = 0.020\,H \quad \text{for other buildings.} \tag{5}$$

where,

T = the fundamental natural period of the building in seconds.
H = the height of the building in meters.

3.2 Lateral Seismic Shear of Appendages The lateral seismic shear of the penthouses, chimneys, towers, cisterns, parapets and other appendages on buildings, q, shall be determined in accordance with the following formula.

$$q = k \quad w \tag{6}$$

where, q = the lateral seismic shear of the appendage.
k = the seismic design coefficient of appendages and shall be 1.0, but the value can be minimized down to 0.5 in case no harm will occur.
w = the weight of the appendage.

3.3 Lateral Seismic Shear of the Basement The lateral seismic shear of basement, Q_B, shall be determined in accordance with the following formula.

$$Q_B = Q_P + K \quad W_B \tag{7}$$

where, Q_P = the portion of the lateral seismic shear of the first story that will act to the basement.
K = the seismic design coefficient of the basement as determined in accordance with Formula (8).
W_B = the weight of the basement.

The seismic design coefficient of basement, K, shall be determined in accordance with the following formula.

$$K = 0.5\,(1 - \frac{H}{40})\ Z \quad C_o \tag{8}$$

where, H = the depth of the basement in meters and 20 meters in case the depth exceeds 20 meters.
Z and C_o are the same as defined in 3.1.

ACKNOWLEDGEMENT

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A-1 THE STRUCTURAL COEFFICIENT, D_S

1. The structural coefficient, D_S, can be determined in accordance with the following formula, in case the damping ratio and the ductility factor can be available by the structural experiments and analyses.

$$D_S = \frac{\beta}{\sqrt{2\mu - 1}} \quad \text{.....................} \quad \text{(A-1.1)}$$

where, $\beta = \dfrac{1.5}{1 + 10h}$

μ = the ductility factor

h = the damping ratio, and the standard value is 0.05 for reinforced concrete buildings and 0.10 for steel encased reinforced and prestressed concrete buildings.

2. In case the damping ratio and the ductility factor can not be available, the structural coefficient, D_S, can be determined based on the standard value in the following table.

Table A-1.1 Structural Coefficient, D_S

The value of D_S	Types of Structures
0.3 - 0.4	Moment frame structures with excellent ductility
0.4 - 0.5	Structures with ductile shear walls or braces
0.5 - 0.75	Structures with shear walls or braces with poor ductility
0.75 - 1.0	Structures with very poor ductility

A-2 SHAPE FACTOR, F_{ES}

Shape factor, F_{ES}, of each story can be determined in accordance with the following formula.

$$F_{ES} = F_E \, F_S \qquad \text{(A-2.1)}$$

where, F_E can be given by the following table as a function of eccentricity of stiffness, R_E, given by the following formula.

$$R_E = \frac{e}{r_e} \qquad \text{(A-2.2)}$$

where, e = the eccentricity of the center of the stiffness from the center of gravity

r_e = the elastic radius which can be defined as the square root of the tortional stiffness divided by the lateral stiffness.

Table A-2.1 Shape Factor, F_E, by Eccentricity of Stiffness, R_E

R_E	F_E
less than 0.15	1.0
$0.15 \leqq R_E \leqq 0.3$	linear interpolation
more than 0.3	1.5

And F_S can be given by the following table as a function of variation of lateral stiffness, R_S, given by the following formula.

$$R_S = \frac{r}{\bar{r}} \qquad \text{(A-2.3)}$$

where, r = the lateral stiffness which shall be defined as the value of the story height devided by the story drift caused by the lateral seismic shear for moderate earthquake motions prescribed in 3.1.

$\bar{r}$ = the mean lateral stiffness which shall be defined as the arithmatic mean of r's above ground level.

Table A-2.2 Shape Factor, F_S, by Variation of Lateral Stiffness, R_S

R_S	F_S
more than 0.6	1.0
$0.3 \leqq R_S \leqq 0.6$	linear interpolation
less than 0.3	1.5

Table 1. BUILDINGS NOT TO EXECUTE DESIGN PROCEDURE 2.1(ii) and 2.2

1	Buildings of conventional wooden construction, reinforced concrete block construction or reinforced concrete panel construction that shall meet the structural requirements stipulated in the relevant regulations.
2	Buildings not exceeding five story of reinforced concrete wall construction or reinforced concrete precast wall construction that shall meet the structural requirements stipulated by the relevant regulations.
3	Buildings not exceeding 20 meters in height of reinforced concrete construction, prestressed concrete construction or steel encased reinforced concrete construction in case each story shall meet the following formula in the logitudinal and transverse directions. $25 \cdot A_w + 7 \cdot A_c > Z \cdot W_I$ (T-1.1) where, A_w = the sum of horizontal cross-sectional area in square centimeters of reinforced concrete shear walls in the direction concerned. A_c = the sum of horizontal cross-sectional area in square centimeters of columns. Z = the seismic hazard zoning coefficient.as shown in Fig. 1. W_I = the weight in kilograms of the building above the story concerned. For steel encased reinforced concrete buildings, the coefficient, 7, for A_c in the above formula can be increased up to 10.

Table 2 *BUILDINGS NEED NOT TO EXECUTE DESIGN PROCEDURE 2.2*

Buildings not exceeding 31 meters in height of reinforced concrete construction, steel encased reinforced concrete construction or steel construction that shall meet all of the following requirements	
1	Each story above the ground level shall meet the following formula. $\frac{r}{\bar{r}} \geqq 0.6$ (T-2.1) where, r = the lateral stiffness which shall be defined as the value of the story height devided by the story drift caused by the lateral seismic shear for moderate earthquake motions prescribed in 3.1. $\bar{r}$ = the mean lateral stiffness which shall be defined as the arithmatic mean of r's above ground level.
2	Eccentricity of the center of the stiffness from the center of gravity shall be less than 0.15 of the elastic radius at each story. Where, the elastic radius shall be the square root of the torsional stiffness divided by the lateral stiffness.
3a	Each story shall meet the following formula in case of reinforced concrete construction or steel encased reinforced concrete construction. $25(A_w + A_c) > A_I\ Z\ W_I$ (T-2.2) where, A_w = the sum of horizontal cross-sectional area in square centimeters of reinforced concrete shear walls in the direction concerned. A_c = the sum of horizontal cross-sectional area in square centimeters of columns. A_I = the lateral shear distribution factor. Z = the seismic hazard zoning coefficient as shown in Fig. 1. W_I = the weight in kilograms of the building above the story concerned.
3b	Each story which has braces shall meet the following formulae. $\sigma_a \geqq (1 + 0.7\beta)\sigma_B$ (T-2.3) where, σ_a = the allowable stress for temporary loads. β = the ratio of the lateral shear of braces to the total lateral seismic shear of the story. σ_B = the stress of braces caused by the lateral seismic shear for moderate earthquake motions prescribed in 3.1. ${}_JP_u \geqq 1.2\ {}_MP_y$ (T-2.4) where, ${}_JP_u$ = the ultimate strength of the joint of the brace. ${}_MP_y$ = the yield strength of the brace.

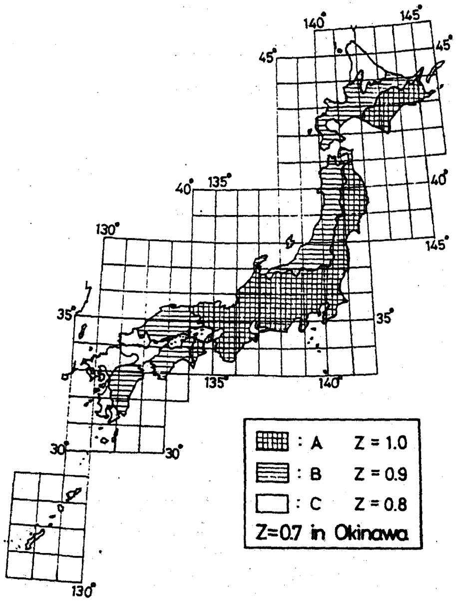

Fig. 1 Seismic Hazard Zoning Coefficient, Z

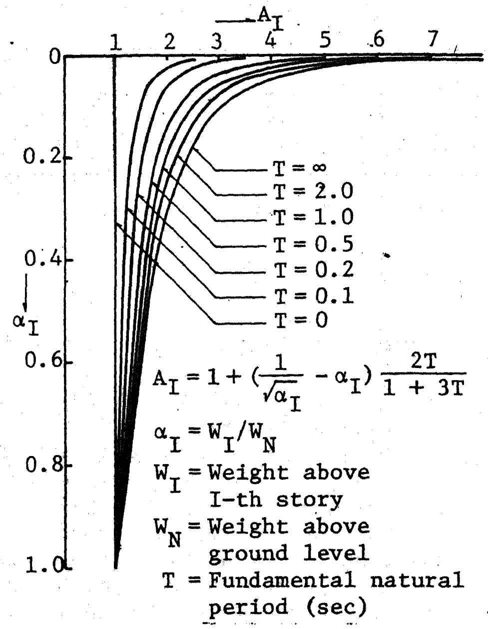

Fig. 3 Lateral Shear Distribution Factor, A_I

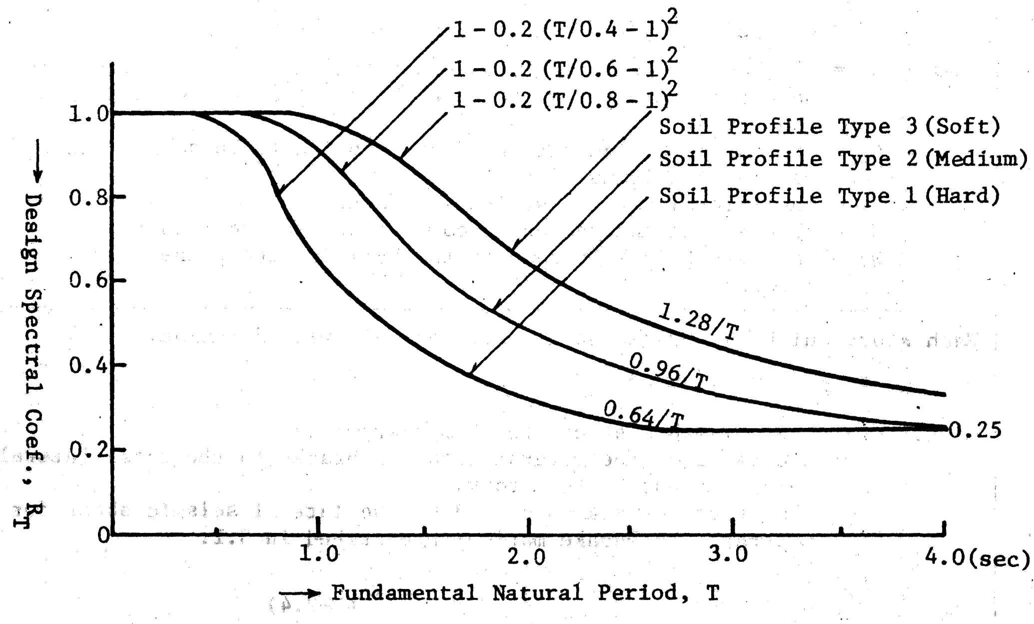

Fig. 2 Design Spectral Coefficient, R_T