3) In the case of ${}_wQ_{Mu} < {}_wQ_{su}$, failure type is flexural wall.

$({}_wQ_u = {}_wQ_{Mu})$

4) In the case of ${}_wQ_{Mu} \geqq {}_wQ_{su}$, failure type is shear wall.

$({}_wQ_u = {}_wQ_{su})$

$$ {}_wQ_{Mu} = 2 \cdot {}_wM_u / h_w \qquad (17) $$

However, in the case of the top story of a multistoried wall (including a single storied wall), the coeffeicient 2 of right side in Eq.(17) is replaced by 1.

where ${}_wM_u$: ultimate flexural strength of the wall at the story under consideration

h_w : total height of the wall measured from the floor considerd to the top

c) By the above calculation, the failure type of each vertical member is any one in Table 6.

Table 6. Failure Types and Ductility Index

(The Second Evaluation Method)

failure type	F-index (Section 3.2.3)
1) flexural column	calculated from ductility factor μ at ultimate strength (1.27 -3.2*)
2) flexural wall	calculated from the ratio of shear strength to flexural strength (1.0 -2.0)
3) shear column	1.0
4) shear wall	1.0
5) extremely brittle column	0.8

* There is the case that F-index is equal to 1.0 according to the particular condition as shown in Eq.(23).

iv) Classification of Vertical Members

Based on the failure types decided in the above Paragraph iii) and the values of F-index calculated in Section 3.2.3, vertical members are classified into three or less groups, each group is named for the first, the second and the third group.

In this case, the following matters are important.

a) Collecting the members of which the F-index are near each other into one group, the number of groups shall be reduced as possible. In this case, the minimum value of the F-indexes of the members in the group is used for the F-index of the group.

b) Extremely brittle columns should be an independent group.

v) Calculation of Strength Index

Strength index Ci of each group is obtained by Eq.(18).

Ci = (sum of the shear force at ultimate strength of the vertical members belonging to the i-th group) /ΣW (18)

where ΣW : sum of the weight of which the story is higher than the story under consideration (dead load + live load for calculation of lateral load)

(3) The Third Evaluation Method

i) Process

Structural index for the third evaluation method is calculated in the following process.

a) Ultimate flexural strength Mu and ultimate shear strength Qsu of columns, walls and beams are calculated according to the way shown in Paragraph ii).

b) Using the result of a), failure type of each member and ultimate moment of each nodel point is determined, and then, failure type and lateral shear force of vertical member are calculated by a nodal limit analysis. However, walls are calculated by an approximate limit analysis assuming the distribution of lateral load and the failure mechanism.

c) In the same way as the second evaluation method, vertical members at each story are classified into three or less groups, and strength index of each group is calculated.

ii) Calculation of Ultimate Strength of Members

a) Ultimate flexural strength and ultimate shear strength of walls and columns are obtained by Eq.(10) -Eq.(15) in the same manner as the second evaluation method.

b) Ultimate flexural strength and ultimate shear strength of beams are calculated by Eq.(10) -Eq.(15) respectively substituting N=0 or $\sigma_0=0$ into these equations. However, for the calculation of ultimate flexural strength of beams, the following Eq.(19) is also applicable. In addition, the effect of the reinforcements arranged in slabs and the effect of the bars at the middle depth of beams may be considered.

$$Mu = 0.9a_t \cdot \sigma_y \cdot d \qquad (19)$$

where, a_t : total area of tensile bars (cm^2)

σ_y : tensile yield stress of tensile bars (kg/cm^2)

d ; effective depth of a beam cross-section (cm)

iii) Determination of Failure Type and Lateral Shear Force at Ultimate Strength

a) columns

Considering the case that the lateral capacity of columns depends on the ultimate strength of beams, failure types and lateral shear force of columns at ultimate strength are determined by nodal limit analysis.

1) Failure types of beams and columns are determined in the same way as the second evaluation method, and the end moments of members at the nodal points are calculated.

2) According to Figure 6, comparing the sum of the end moments of beams with that of columns at each nodal point, if the sum of the end moments of beams is less than that of columns, each half of it is used for the ultimated end moment of the upper and lower column at the nodal point. If the sum of the end moments of columns is less than that of beams, they are used for the ultimate end moments of columns as they are. In this case, the failure type and F-index of the member that controls the ultimate condition of the nodal point are used for the failure type and F-index of the nodal point.

3) After calculating failure types and ultimate end moments about all nodal points, the failure type and lateral shear force at ultimate strength of a column are determined as follows.

Failure type of column : the failure type of the nodal point of which F-index is lower comparing the two nodal points at top and bottom end of the column.

Lateral shear force ${}_cQ_u$ at ultimate strength of column :

${}_cQ_u$ = (sum of ultimate moments at top and bottom end of the column)/(clear height of the column)

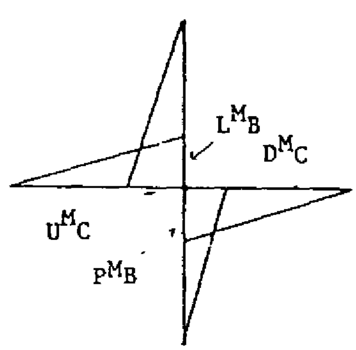


Figure 6. Failure Type of Nodal Point

note 1) In the case of $({}_uM_c + {}_bM_c) > ({}_LM_B + {}_RM_B)$, $\frac{1}{2}({}_LM_B + {}_RM_B)$ is used for each ultimate end moment of columns at the nodal point. The failure type of beams is used for the failure type of the nodal point.

note 2) In the case of $({}_{U}M_C + {}_{D}M_C) \lesseqgtr ({}_{L}M_B + {}_{R}M_B)$, ${}_{U}M_C$ and ${}_{D}M_C$ are used for ultimate end moments of columns at the nodal point as they are.

note 3) ${}_{U}M_C$, ${}_{D}M_C$, ${}_{L}M_B$ and ${}_{R}M_B$ are calculated considering the effect of the rigid zone.

b) Walls

As shown in Figure 7, multi-storied wall is idealized by cutting off from the other framing members at the mid-span of connecting beams. The lateral load applied to the idealized wall may be taken as the least value of the following three lateral loads determined uner inverse triangular distribution of lateral loads ; the lateral load by which the wall reaches to their flexural yield strength, shear failure strength or overturning capacity. Lateral shear force at ultimate strength of the wall at each story is calculated from the above lateral load, and this failure type is used for the failure type of the wall at each story.

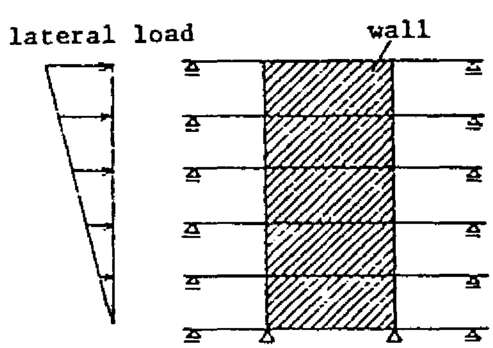


Figure 7. Multi-Storied Wall

The wall which is not multi-storied is treated in the same way as multi-storied wall, based on an assumption of the failure mechanism that is as actual as possible.

By the above calculation, the failure type of each vertical member is any one in Table 7.

Table 7. Failure Types and Ductility Index

(The Third Evaluation Method)

failure type	F-index (Section 3.2.3)
1) flexural column	F-index in Table 6
2) flexural wall	
3) shear column	
4) shear wall	
5) extremely brittle column	
6) beam yield type column	3.0
7) beam shear failure type column	1.5
8) overturing type wall	3.0

iv) Classification of vertical members based on failure types and ductility indexes, and calculation of strength indexes of the groups are performed in the same manner as the second evaluation method.

3.2.3 Ductility Index, F

1) Calculation of F-index

F-index of vertical members is calculated as follows according to the number of the evaluation method and failure type of the member determined in Section 3.2.2.

i) The First Evaluation Method

Following the classification of vertical members shown in Table 1, F-index shown in Table 8 is used in the first evaluation method.

Table 8. Ductility Index

(The First Evaluation Method)

name	F-index
column ($h_o/D > 2$)	1.0
extremely short column ($h_o/D \leqq 2$)	0.8
wall	1.0

ii) The second Evaluation Method

Following the classification of vertical members shown in Table 2, F-index shown in Table 9 is used in the second evaluation method. Here, F-indexes of flexural columns and flexural walls are obtained respectively by Eq.(20) and Eq.(21) because of their well ductility. However, F-index of columns with wing walls is taken as equal to 1.0.

a) flexural columns

$$F = \phi\sqrt{2\mu - 1} \qquad (20)$$

where, μ : ultimate ductility factor, calculated by Eq.(22)

ϕ : $\dfrac{1}{0.75(1 + 0.05\mu)}$

b) flexural walls

$$\begin{aligned} {}_wQ_{su} / {}_wQ_u &\leqq 1.3 \quad ; \quad F = 1.0 \\ 1.3 < {}_wQ_{su} / {}_wQ_u &< 1.4 \quad ; \quad F = -12.0 + 10 \times ({}_wQ_{su} / {}_wQ_u) \qquad (21) \\ 1.4 \leqq {}_wQ_{su} / {}_wQ_u & \quad ; \quad F = 2.0 \end{aligned}$$

where, ${}_wQ_{su}$: ultimate shear strength of the wall

${}_wQ_u$: shear force at ultimate strength (at ultimate flexural strength) of the wall

iii) The Third Evaluation Method

In the same way as the second evaluation method, F-index is determined according to Table 9. However, following the classification shown in Table 5, the latter articles of Table 9 are also applied.

Table 9. Ductility Index (The Second and The Third Evaluation Method)

failure type	F-index	evaluation method
flexural column	calculated by Eq.(20) 1.27 - 3.2*	second, third
flexural wall	calculated by Eq.(21) 1.0 - 2.0	" , "
shear column	1.0	" , "
shear wall	1.0	" , "
extremely brittle column	0.8	" , "
beam yield type column	3.0	third
beam shear failure type column	1.5	"
overturning type wall	3.0	"

* There is the case that F-index is equal to 1.0 according to the particular condition as shown in Eq.(23).

(2) Determination of Ultimate Ductility Factor μ of Flexural Columns

Ultimate ductility factor μ of flexural columns is obtained by Eq.(22). However, if any one of the conditions described in Eq.(23) is corresponded, the value of F-index should be 1.0.

$$\mu = \mu o - k_1 - k_2 \qquad (1 \leqq \mu \leqq 5) \qquad (22)$$

where $\mu o = 10 \cdot ({}_cQ_{su} / {}_cQ_u - 1)$

$k_1 = 2.0$ (k_1 may be zero provided that shear reinforcement spacing is less than eight times the diameter of longitudinal bars.)

$$k_2 = 30\left(\frac{{}_c\tau_u}{F_c} - 0.1 \right) \geqq 0$$

$_cQ_{su}$: ultimate shear strength of the column

$_cQ_u$: lateral shear force of the column at the ultimate condition

$c\tau u$: $_cQ_u/(b \cdot j)$

b : width of the column

j : distance beween the center of tensile stress and that of compressive stress of the column section; 0.8D may be used for it.

F_c : compressive strength of concrete

Conditions in which F-index should be taken as 1.0 ;

$$\left.\begin{array}{l} N_s/(b \cdot D \cdot F_c) > 0.4 \\ c\tau u/ F_c > 0.2 \\ p_t > 1\% \\ h_o/ D \leqq 2 \end{array}\right\} \quad (23)$$

where, N_s : axial force of the column at the failure mechanism

p_t : tensile reinforcement ratio of the column section

h_o : clear height of the column

3.3 Seismic Sub-Index of Ground Motion, G

G-index may be taken as equal to 1.0 at present.

3.4 Seismic Sub-Index of Structural Profile, S_D

3.4.1 General

This index quantitatively represents the effect of the structural profile, the distribution of stiffness etc. on the seismic safety of buildings, and is used to modify E_o-index.

S_D-index is determined for two method, the first and the second evaluation method, according to the required accuracy.

3.4.2 Judgement Items

Items applied in each method are as follows.

(1) Items in The First Evaluation Method

i) Items Concerning Floor Plan Profile

Irregurality of Plan, length-width ratio in plan, dent in plan, clearance of expansion joints, presence of open hall (the size and eccentricity) and other special profiles in plan.

ii) Items Concerning Sectional Profile

Presence of underground stories, uniformity of story height, presence of piloti and other special profiles in section.

(2)Items in The Second Evaluation Method

In the second evaluation method, the following items are examined in addition to the items considered in the first evaluation method.

i) Items Concerning Horizontal Rigidity

Eccentricity between the center of gravity and the center of rigidity in plan.

ii) Items Concerning Sectional Rigidity

Weight-stiffness ratio of a story to that of the immidiately above story.

3.4.3 Calculation of S_D-index

The influence factor qi, which represents the degree of influence of each judgement item, is calculated using the grading factor Gi and the adjusting factor Ri for the range of the influence. Then S_D-index is obtained by the mutual multiplication of qi as shown in Eq.(24) and Eq.(25).

The degree of influence is adjusted according to the classification shown in Table 10, using respectively R1i and R2i in the first and the second evaluation method.

(1) Equation To Be Used in The Caluculation of S_D-Index

i) S_D-index for The First Evaluation Method

$$S_D = q_{1a} X q_{1b} X \cdots\cdots X q_{1k} \qquad (24)$$

where, $q_{1i} = [\ 1 - (1 - Gi)\ X\ R_{1i}\ ]$

$(i = a,b,c,d,e,f,g,i,j,k)$

$q_{1i} = [\ 1.2 - (1 - Gi)\ X\ R_{1i}\ ]$

$(i = h)$

ii) S_D-Index for The Second Evaluation Method

$$S_D = q_{2a} X q_{2b} X \cdots\cdots X q_{2k} \qquad (25)$$

where, $q_{2i} = [\ 1 - (1 - Gi)\ X\ R_{2i}\ ]$

$(i = a,b,c,d,e,f,g,i,j,k,l,m,n,o)$

$q_{2i} = [\ 1.2 - (1 - Gi)\ X\ R_{2i}\ ]$

$(i = h)$

iii) S_D-Index for The Third Evaluation Method

S_D-indexes for the second evaluation method are used for the third evaluation as they are.

$$S_{D3} = S_{D2}$$

(2) Classification of Items

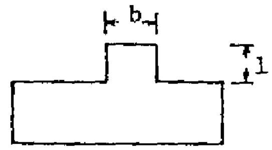
The classification of items and the values of G-factors and R-factors are shown in Table 10.

Table 10. Classification of Items and List of G and R-factor

Items				Gi 1.0	Gi 0.9	Gi 0.8	R R_{1i}	R R_{2i}	application
the 1st and the 2nd evaluation method (1,2)	floor plan profile (P)	a	irregularity	regular a_1	middle a_2	irregular a_3	1.0	0.5	These items are applied to all of the stories using the factors which are gained about the most disadvantageous story.
		b	length-width ratio	$b \leqq 5$	$5 < b \leqq 8$	$8 < b$	0.5	0.25	
		c	dent	$0.8 \leqq c$	$0.5 \leqq c < 0.8$	$c < 0.5$	0.5	0.25	
		d	clearance of expansion joints*1	$\frac{1}{100} \leqq d$	$\frac{1}{200} \leqq d < \frac{1}{100}$	$d < \frac{1}{200}$	0.5	0.25	
		e	size of open hall	$e \leqq 0.1$	$0.1 < e \leqq 0.3$	$0.3 < e$	0.5	0.25	
		f	eccentricity of open hall	$f_1 \leqq 0.4$ and $f_2 \leqq 0.1$	$f_1 \leqq 0.4$ and $0.1 < f_2 \leqq 0.3$	$0.4 < f_1$ or $0.3 < f_2$	0.25	0	
		g	other special profile*2				0.5	0.25	
	sectional profile (S)	h	underground stories	$1.0 \leqq h$	$0.5 \leqq h < 1.0$	$h < 0.5$	1.0	1.0	
		i	uniformity of story height	$0.8 \leqq i$	$0.7 \leqq i < 0.8$	$i < 0.7$	0.5	0.25	
		j	presence of piloti	no	all of the floor	uneven distribution of piloti	0.5	0.25	
		k	other special profile*3				0.5	0.25	
the 2nd evaluation method (2)	horizontal rigidity (RP)	l	eccentricity between the center of gravity and the center of rigidity	$l \leqq 0.1$	$0.1 < l \leqq 0.15$	$0.15 < l$		1.0	These items are applied to each story about the longitudinal and rigid directions.
		m							
	sectional rigidity (SR)	n	weight-stiffness ratio of a story to that of the immidiately above story	$0.8 \leqq n \leqq 1.2$	$1.2 < n \leqq 1.7$ or $0.6 \leqq n < 0.8$	$1.7 < n$ or $n < 0.6$		1.0	
		o							

Notes concerning Table 10;

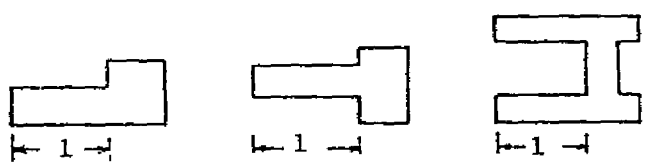
a_1 : The plan is almost symmetric about each direction, and the area of a lump is less than or equal to ten percent of the floor area. Lumps are considered in the case of $l/b \geqq 1/2$.



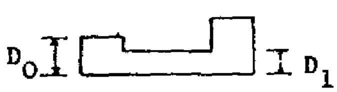
a_2 : The plan is more irregular than that of a_1, and the area of a lump is less than or equal to thirty percent of the floor area in the plan of L-type, T-type, U-type and others.

a_3 : The plan is more irregular than that of a_2, and the area of a lump is more than thirty percent of the floor area in the plan of L-type, T-type, U-type and others.

b : b = (length of the long side)/(length of the short side) ;
In the plan of L-type, T-type, U-type and others, $2 \cdot l$ is used for the length of the long side.



c : $c = D_1/D_0$



d : This is applied to the buildings which have expansion joints.
d = (clearance of expansion joints)/(height of the part connected by expansion joints)

e : e = (area of open hall)/(area of the floor including the area of open hall) ; However, a stair hall surrounded in reinforced concrete walls is not regarded as an open hall.

f : f_1 = (distance between the center of the plan and the center of the open hall)/(length of the short side)

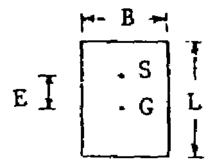
f_2 = (distance between the center of the plan and the center of the open hall)/(length of the long side)

h : h = (area of basement floor)/(building area)

i : i = (height of the immediately above story)/(height of the story under consideration) ; When the top story is examined, the immediately above story in this equation is replaced with the immediately below story.

j : In the case that the floor is supported by only piloti, moreover, the distribution of piloti is eccentric, it is treated as eccentric distribution. When the building is complete flaming structure, however, it is not considered as piloti.

l : $l = E/\sqrt{B^2 + L^2}$



S : center of gravity

G : center of rigidity

Here, horizontal rigidity of each plan may be obtained by [Σ(column sectional area) + α X Σ (wall sectional area)]*[4] of each plane.

n : n = [(weight-stiffness ratio of the immediately above story)/(weight-stiffness ratio of the story under consideration) X β ; When the top story is examined, the immediately above story in this equation is replaced with the immediately below story.

Where,(weight-stiffness ratio) = (rigidity at the story under consideration)/(sum of the weight at the higher stories than the story under consideration), (rigidity at the story) = [Σ(column sectional area) + Σ(wall sectional area) X α]/(height of the story), $\beta = (N - 1)/N$.

N : the number of the stories above the story under consideration, $\beta = 2.0$ at the top story.

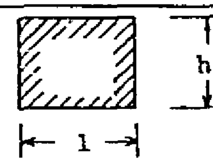
*1 : In the case that expansion joints are utilized in the building, each part divided by expansion joints is considered as one unit.

*2 : This item is used in the case that the plan is remarkably special profile.

*3 : This item is used in the case that the section is remarkably special profile.

*4 : The value of α is variable according to (height of the wall)/(length of the wall).

h/l	α	
	wall surrounded by framing members	wall not surrounded by framing members
$3.0 \leqq h/l$	1.0	0.3
$2.0 \leqq h/l < 3.0$	1.5	0.5
$1.0 \leqq h/l < 2.0$	2.5	0.8
$h/l < 1.0$	3.5	1.2



3.5 Seismic Sub-Index of Time-Depended Deterioration, T

3.5.1 General

T-index aims to evaluate the effect of the structural defects, such as cracks, deflections, superannuations and others on the seismic safety of buildings. Therefore, determination of T-index should be performed essencially according to the detailed site investigation. However, considering the conveniency of this evaluation method and the accuracy about the other sub-indexes (E_0-index, S_D-index and others) used in the calculation of seismic index of structure, I_s, investigation method is classified into three steps, namely the first investigation, the second investigation and the third investigation. T-index is determined in principle according to these investigations and is respectively used at the calculation of I_s-index in the first, the second and the third evaluation method.

3.5.2 The First Evaluation Method

T-index for the first evaluation method is determined following the result of the first investigation shown in Table 11. The minimum value of the T-values in C column of Table 11 is used for T-index of the first evaluation method.

3.5.3 The Second Evaluation Method

T-index for the second evaluation method is calculated by Eq.(26) in accordance with the resultant of the second investigation shown in Table 12.

$$\left.\begin{aligned} T &= (T_1 + T_2 + T_3 + \cdots\cdots\cdots + T_N)/N \\ T_i &= (1 - P_{si})(1 - P_{ti}) \end{aligned}\right\} \qquad (26)$$

where T_i : T-index of i-story

N : number of stories examined

P_{si} : sum of the demerit points at i-story concerning about structural cracks and deflections. However, it may be taken as equal to zero if the investigation is not needed.

P_{ti} : sum of the demerit points at i-story concerning about deterioration and superannuation. However, it may be taken as equal to zero if the investigation is not necessary.

3.5.4 The Third Evaluation Method

In the third evaluation method, the same value of T-index as the value determined in the second evaluation may be used in principle. However, in the case that C-index is calculated using the result of detailed investigation, T-index may be taken as 1.0.

3.5.5 Investigation of Buildings

(1) The First Investigation

The first investigation is performed about the checking items shown in Table 11 according to the explanation by the building manager and the site observation by the investigator.

(2) The Second Investigation

The second investigation is in principle examined on the following matters according to the observation of the building surface and brief measurement by the investigators. However, in accordance with the degree of the cracks and deterioration, the following matters are investigated after taking away a part of finished materials.

i) the degree and extent of structural cracks and deflections

ii) the degree and extent of deterioration and superannuation. This investigation is in principle performed about the degree and extent of several items shown in Table 12 at each story. However, the story impossible to be examined is neglected.

3) Detailed Investigation

In the case that drawing and specification have the defects, detailed investigation is performed about the following items concerning columns, beams and walls. In order to gain the information for the modification and supplement of the data that is necessary to calculate E_0-index, test pieces are extracted from the structure, a part of finish materials is taken away, a part of concrete is chipped and so on.

i) strength and elastic modulus of concrete

ii) confirmation about arrangements and sections of reinforcements

iii) reestimation of the sectional capacity of members considering the construction condition, cracks and loss

iv) reestimation of the strength of materials considering the neutralization and superannuation of concrete and the rust of reinforcements

Table 11. Calculation Table of T-Index in The First Investigation

A checking items	B degree	C T-value mark the corresponding matter	D items related to the second investigation
deflection	The building is inclined, or unequal settlement has arisen undoubtedly.	0.7	structural cracks and deflection
	The site is reclaimed ground or rice field before.	0.9	
	The deflection of beams and columns is visible with the unaided eye.	0.9	
	The above matters do not correspond to the building	1.0	
cracks of walls and columns	The leakage of rain water is observed and reinforcement is in rust.	0.8	structural cracks and deflection
	The inclined cracks of columns are clearly visible with the unaided eye.	0.9	
	There are numbers of cracks in the external wall.	0.9	
	The leakage of rain water is observed, but reinforcement is not in rust.	0.9	
	The above matters do not correspond to the building	1.0	

fire damage	There is the trace of fire damage.	0.7	structural cracks, deflection, deterioration and superannuation
	The building was damaged by fire, but the trace is not clear.	0.8	
	no experience	1.0	
usage	Chemicals were or have been used.	0.8	deterioration and superannuation
	The above matter does not correspond.	1.0	
years elapsed	more than or equal to thirty years	0.8	deterioration and superannuation
	more than or equal to twenty years	0.9	
	less than twenty years	1.0	
condition of finish materials	The separation of external finish materials is remarkable by the superannuation	0.9	deterioration and superannuation
	The deterioration or separation of internal finish materials is remarkable	0.9	
	There is no particular trouble	1.0	

Table 12. Sum Up Table of Demerit Points in The Second Investigation (floor)

note : Mark the corresponding matters and then sum up them.

members \ Extent \ degree \ items		structural cracks and deflection		
		a	b	c
		1. cracks following uneven settlement 2. shear cracks or inclined cracks of beams, walls and columns clearly visible with the unaided eye	1. deflection of slabs and beams interfering with non-structural elements 2. shear cracks or inclined cracks of beams, walls and columns not clearly visible with the unaided eye 3. flexural cracks or vertical cracks of beams and columns clearly visible with the unaided eye	1. brief structural cracks not corresponding with a or b 2. deflection of slabs and beams not corresponding with a or b
I floor	i	0.017	0.005	0.001
	ii	0.006	0.002	0
	iii	0.002	0.001	0
II beam (girder)	i	0.050	0.015	0.004
	ii	0.017	0.005	0.001
	iii	0.006	0.002	0
III wall, cloumn	i	0.150	0.046	0.011
	ii	0.050	0.015	0.004
	iii	0.017	0.005	0.001
sum of demerit points	sub-total			
	total	p_s =		

i, ii, iii denotes more than 1/3 of total number of floors, from 1/3 to 1/9 and less than 1/9, respectively.

deterioration and superannuation		
a	b	c
1. expansion cracks of concrete by the rust reinforcement 2. corrosion of reinforcement 3. cracks by fire 4. deterioration of concrete by chemicals and so on	1. melt of rust on reinforcement by leakage water 2. neutralisation of concrete to the place of rein-forcement 3. remarkable separa-tion of finish materials	1. remarkable dirt or stain by leakage water and chemicals and so on 2. brief separation or superannuation of finish materials
0.017 0.006 0.002	0.005 0.002 0.001	0.001 0 0
0.050 0.017 0.006	0.015 0.005 0.002	0.004 0.001 0
0.150 0.050 0.017	0.046 0.015 0.005	0.011 0.004 0.001
P_t =		

4. Calculation of Seismic Index of Non-structural Index, I_N

4.1 General Rule

Seismic Index of non-structural elements, I_N is an index evaluating the safety against the injury of non-structural members, especially considering the injury thar the separation and fall of finish materials on external walls by earthquake injure people directly or disturb their refuge.

The evaluation is composed of the first, the second and the third evaluation method, and I_N-index is calculated about each wall surface at each story in all methods.

4.2 The First Evaluation Method

4.2.1 General

In the first evaluation method, I_N-index is obtained by Eq.(27) about each wall surface at each story of buildings.

$$I_N = 1 - B \cdot H \qquad (27)$$

where, B : sub-index of structural type

H : sub-index of degree of influence

For B and H-index in Eq.(27), the values of the rectangular part including the structural type that will be destroyed earliest (B-index is the highest) at the wall surface under consideration are adopted.

4.2.2 Sub-Index of Structural Type, B

B-index is obtained by Eq.(28) using sub-index of flexibility, f and sub-index of actual consition, t.

$$B = f + (1 - f) \cdot t \qquad (28)$$

(1) Sub-Index of Flexibility, f

f-index is gained by Table 13 using grade of flexibility of structures, g_S and grade of flexibility of non-structural elements, g_N.

g_s and g_N are shown respectively in Table 14 and 15.

Table 13. Sub-Index of Flexibility, f

non-structural elements \ structure		rigid ← g_s → flexible: I	II
rigid ↑ g_N	I	0.5	1.0
↓ flexible	II	0	0.5

Table 14. Grade of Flexibility of Structures, g_s

g_s	condition of structure
rigid I	Ductility capacity is low. For instance, the building with many short columns.
↕	
flexible II	Ductility capacity is high. For instance, the building with little walls.

Table 15. Grade of Flexibility of Non-Structural Elements, g_N

g_N	non-structural elements
rigid I	Deflection capacity is low. For instance, concrete block, glass block, fixed sash window, stone facing, tile facing, mortar plastering, ALC boad and so on.
↕	
flexible II	Deflection capacity is high. For instance, metal and PC curtain wall, movable sash, stray and placing tile, naked concrete and so on.

(2) Sub-Index of Actual Condition, t

t-index is obtained by Table 16 in accordance with the existance of trouble experience.

Table 16. Sub-Index of Actual Condition, t

trouble experience	t
exist or unknown	1.0
no	0.5

4.2.3 Sub-Index of Degree of Influence, H

H-index is obtained by Table 17 according to the environment directly below the wall surface and the existance of suppression matters such as eaves, set back and others.

Table 17. Sub-Index of Degree of Influence, H

environment	suppression matters	
	exist	no
road (including private road, public square and others)	1.0	0.3
the others	0.5	0.1

4.3 The second Evaluation Method

4.3.1 General

In the second evaluation method, I_N-index is calculated by Eq.(29) about each wall surface at each story of buildings.

$$I_N = 1 - \frac{\sum_j B_j \cdot W_j \cdot H_j \cdot L_j}{\sum_j L_j} \qquad (29)$$

where, B_j : sub-index of structural type

W_j : sub-index of wall surface area

H_j : sub-index of degree of influence

L_j : length of unit of wall surface

In the application of Eq.(29), the wall surface is devided into units (rectangular parts) in the horizontal direction. The total sign Σ in Eq.(29) represents the total of these units.

In addition, in the case that a unit consists plural structural types, the structural type considered to be destroyed earliest (B-index of it is the highest) stands for the unit.

4.3.2 Sub-Index of Structural Type, B

B-index is obtained by Eq.(30) using sub-index of flexibility, f and sub-index of actual condition, t.

$$B = f + (1 - f)t \qquad (30)$$

(1) Sub-Index of Flexibility, f

f-index is obtained by Table 18 using grade of flexibility of structures, g_s and grade of flexibility of non-structural elements, g_N.

g_s and g_N are shown respectively in Table 19 and 20.

Table 18. Sub-Index of Flexibility, f

structure / non-structural elements		rigid ← g_s → flexible 1	2	3	4
rigid	1	0.3	0.8	0.9	1.0
↑	2	0	0.3	0.8	0.9
g_s ↓	3	0	0	0.3	0.8
flexible	4	0	0	0	0.3

Table 19. Grade of Flexibility of Structures, g_s

g_s		condition of structure	approximate F-index
rigid	1	Ductility capacity is low. For instance, the building that extremely brittle columns nearly determine the seismic capacity.	0.8
	2	Ductility capacity is rather low. For instance the building that shear columns or shear walls nearly determine the seismic capacity.	1.0
	3	Ductility capacity is rather high. For instance, the building that flexural columns or flexural walls nearly determine the seismic capacity.	1.3
flexible	4	Ductility capacity is high. For instance, the building that flexural walls nearly determine the seismic capacity and that is especially ductile.	3.0

Table 20. Grade of Flexibility of Non-Structural Elements, g_N

g_N		non-structural elements (examples of walls, openings and external finish materials)		
rigid	1	Deflection capacity is low ; wet system		
		concrete block, glass block	fixed sash window (steel sash)	stone facing
↑	2	Deflection capacity is rather low ; dry system		
		ALC boad	fixed sash window	tile facing, mortar plastering
↓	3	Deflection capacity is rather high ; elements monolithic with walls placing in site ; prefabricated elements		
		metal or PC curtain wall	movable sash	spray or placing tile
flexible	4	There are no elements which easily separate or fall ; sufficient consideration against earthquake		
		monolithic wall in site	(no openings)	no finish materials

(2) Sub-Index of Actual Condition, t

t-index is obtained by Table 21 in accordance with the combination of g_H and g_Y. g_H and g_Y are respectively grade of the trouble history of non-structural elements and grade of years passed.

Table 21. Sub-Index of Actual Condition, t

trouble history and the grade, g_H \ Passed years and the grade, g_Y		1 less than 3 years	2 3 - 10 years	3 more than 10 years
1	The building has an experience of trouble, but it is not repaired.	1.0	1.0	1.0
2	The trouble history of the building is unknown.	0.2	0.3	0.5
3	The building has no experience of trouble, or it was repaired entirely.	0	0.2	0.3

4.3.3 Sub-Index of Wall Surface Area, W

W-index is calculated by Eq.(31).

$$W = a + b \frac{h_j}{h_s} \tag{31}$$

where, $a = 0.5$

$b = 0.5$

h_j : height of corresponding structural type

h_s : standardized height = 3.5 m

4.3.4 Sub-Index of Degree of Influence, H

H-index is gained by Eq.(32) using sub-index of environments, e and sub-index of the arrest of falls, c.

$$H = \sum_k e_K \cdot c_K \tag{32}$$

In the application of Eq.(32), e_K and c_K are gained from every horizontal surface which is inside of the influence angle (the angle between the wall surface and the inclined plane with inclination of 1/2 from the top of the wall), and they are sumed up. However, when the kinds of e_K or c_K are more than two in a horizontal surface, the maximun value of them is used in the surface.

(1) Sub-Index of Environments, e

e-index is obtained by Table 22 in accordance with the environment (the possibility of people's being there) directly blow the wall surface.

Table 22. Sub-Index of Environment, e

environments	e
public road	1.0
private road, road in site, corridor, public square, veranda	0.7
open space where people may come, plantation	0.2
open space where people may not come, adjacent building	0

(2) Sub-Index of The Arrest of Falls, c

c-index is obtained by Table 23 according to the existance of suppression matters such as eaves, set back and so on or the other conditions.

Table 23. Sub-Index of The Arrest of Falls, c

suppression matters	c
the case that the influence angle is entirely intercepted by eaves, set back and so on	0
the pojected horizontal surface directly below the eaves that partially intercept the influence angle	0
the horizontal surface at the same story as that of the walls considered	0.5
the others	1.0

4.4 The Third Evaluation Method

In the calculation of sub-index of structural type, the practical investigation about the actual condition of the structural type (detail, state of construction, degree of superannuation and so on; they influence the deflection capacity) is performed, and then based on the resultant, the way in the second evaluation method is applied.

5. Synthetic Evaluation of Seismic Safety

Using the above mentioned I_S-index and I_N-index, the seismic safety of buildings should be evaluated synthetically.

Based on the result of the evaluation, in addition, taking account of various conditions such as the use, importance and age of buildings, judgement of seismic safety of buildings are performed according to the judgement standard that is established elsewhere. Therefore, it is desirable to make the evaluation list (the karte) clearly sta~ed the number of the evaluation, the items of I_S and I_N-index, the opinion about the result of evaluation and others.