Reparability Limit of Steel Structural Buildings
Based on the Actual Data of the Hyogoken-Nanbu Earthquake

by

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ABSTRACT

For the development of performance-based design taking into consideration economic losses after earthquakes, reparability limits should be clarified in order to avoid demolishing. In this paper, the reparability limits of steel structural buildings were investigated based on the actual data of repaired or demolished buildings which were damaged by Hyogoken-nanbu earthquake both from technical and economic points of view. The investigation provided the following results on the reparability limit: 1) overall residual drift angle was 1/110; 2) maximum residual inter-story drift angle was 1/71; 3) direct restoration cost ratio was 0.86; 4) indirect restoration cost ratio was 0.40. Furthermore, based on the actual data, the relationship of residual drift angle and restoration cost ratio was investigated and the reparability limits synthesizing technical and economic aspects were defined by overall residual drift angle and maximum residual inter-story drift angle as 1/200 and 1/90, respectively.

KEYWORDS: Hyogoken-Nanbu Earthquake, Performance-Based Design, Repair Cost, Reparability Limit, Residual Drift, Steel Structures

1. INTRODUCTION

The Hyogoken-nanbu earthquake on January 17, 1995 brought vast damage to steel structural buildings [1]; however, there were rather few cases which collapsed built after the new seismic design code in 1981 [2] and we can say that the current seismic design code generally fulfilled the crucial role of protecting human life. Meanwhile, it was reported that the economic damage amounted to about 10 trillion yen and there were many cases that building owners suffered great unexpected economic losses [1, 3]. This is attributed to the fact that the usual design method passively ensures both serviceability and life safety of buildings by preserving design specifications and does not fully consider reparability, so that structural designers could not give building owners clear explanations on cost problems related to repair after earthquakes. Therefore, in order to solve this problem in future, the new design process should be required that structural designers preliminarily set the target reparability with building owners considering the relationship to repair cost, confirm the satisfaction of the target reparability through evaluation process, and explain the final performance to building owners.

After seismic events, various damaged states of buildings can be assumed between the serviceability limit and the life safety limit. In these damaged states, it is believed that especially the reparability limit, which refers to whether buildings can be repaired or not is the greatest concern for building owners, because if the buildings are forced to be demolished, they need not only the direct cost to replace the buildings but also suffer the indirect cost, which is associated with the loss of business operation during replacement downtime. Therefore, when we discuss reparability of buildings, the first thing to clarify is the reparability limit in order to avoid the worst situation of demolishing.

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The reparability limit is thought to be relevant to both technical and economic points of view. Therefore, when we refer to the reparability limit, the discussion on deformation and cost related to reparability based on actual data is indispensable. In this paper, for the development of the new design process considering reparability, based on the 12 actual data of repaired or demolished buildings which were damaged by the Hyogoken-nanbu earthquake, we analyzed them in terms of deformation and cost and tried to clarify the reparability limit of steel structural buildings both from technical and economic points of view.

2. INVESTIGATION OF REPAIRED OR DEMOLISHED BUILDINGS

The reparability limit which is determined by the actual data of repaired or demolished buildings is believed to be reliable. In this paper, in order to analyze the reparability limit, we investigated 12 steel moment resisting frame buildings damaged by the Hyogoken-nanbu earthquake. These are mainly low-to-mid-rise office buildings. The basic information of each building (A-L) is listed below with the summary of damage and repair construction. The damage level in the summary is determined by the Japanese standard [1]. The details of damage and repair construction of the buildings are described in [4].

Building A
Damage level: Intermediate
Completion Age: 1986
Total Area: 8,643m^2 Height: 28.7m
Usage: Office
Type: Moment-resisting frame
Floor: upper ground 7- penthouse 1- basement 0
[Summary of damage]
Structural damage concentrated on the 2F-5F. At the end of the beams, the damage of yielding, crack, local buckling and fracture could be seen. The damage of column could scarcely be seen. The maximum residual inter-story drift angle was 1/125 (5F). The tilt of the entire building

was 1/216. The serious damage of exterior PC panels could be seen.
[Summary of repair construction]
The 106 damaged parts near beam-to-column connections were effectively repaired by the method shown in [4]. The 104 PC panels were replaced. The building was repaired almost the same as the original one.

Building B
Damage level: Intermediate
Completion Age: 1993
Total Area: 1,099m^2 Height: 26.4m
Usage: Office
Type: Moment-resisting frame
Floor: upper ground 7- penthouse 1- basement 0
[Summary of damage]
Structural damage concentrated on the 3F-5F. At the end of the beams, the damage of yielding, crack, local buckling and fracture could be seen. The damage of column could scarcely be seen. The maximum residual inter-story drift angle was 1/71 (4F). The tilt of the entire building was 1/110.
[Summary of repair construction]
The 16 damaged parts near beam-to-column connections were effectively repaired by the method shown in [4]. As the unusual case, the interior finish work was not conducted during the repair construction and additional work was scheduled on other occasions. The building was repaired almost the same as the original one except the interior parts.

Building C
Damage level: Severe
Completion Age: 1978
Total Area: 1,350m^2 Height: 12.3m
Usage: Public train station
Type: Moment-resisting frame (3F)
Civil engineering structure (1F-2F)
Floor: upper ground 3- penthouse 0- basement 0
[Summary of damage]
At the end of the beams, the damage of yielding, crack, local buckling and fracture could be seen. The tilt of the building part was 1/34 (3F).
[Summary of repair construction]

Building C was a public train station. It had a large residual drift (1/34). Although it was judged to be demolished at first, it was straightened by using wire and tension jack because of the public use. The condition that it had one floor and all 32 column bases were pin-connected enabled the straightening repair construction to be a lot easier (cheap repair cost and short repair period). The building was repaired almost the same as the original one.

Building D
Damage level: Intermediate
Completion Age: 1992
Total Area: 21,021m^2 Height: 52.8m
Usage: Office
Type: Moment-resisting frame (1F-4F: SRC)
Floor: upper ground 14- penthouse 2- basement 0
[Summary of damage]
Structural damage spread over the 3F-14F. Near beam-to-column connections, the damage of yielding, crack, local buckling and fracture could be seen. The damage of column could scarcely be seen. The maximum residual inter-story drift angle was 1/46 (8F). The tilt of the entire building was 1/120. The serious damage of exterior PC panels could be seen.
[Summary of repair construction]
Building D had a large residual drift (8F:1/46). Although straightening repair construction was studied at first, it was given up in the end because of the technical and economic problems. Instead of straightening repair construction, reinforcing construction using many eccentric braces was adopted. The 54 damaged parts near beam-to-column connections were effectively repaired by the method shown in [4]. As for non-structural members, many exterior panels were partially repaired or replaced. The seismic performance was restored almost the same as the original one.

Building E
Damage level: Intermediate
Completion Age: 1989
Total Area: 908m^2 Height: 37.5m

Usage: Office
Type: Moment-resisting frame (BF-1F: SRC)
Floor: upper ground 8- penthouse 2- basement 2
[Summary of damage]
Fracture damage could be seen at the 2 columns of the 1F. Structural damage could scarcely be seen above the 2F except some damaged parts of yielding and local buckling near beam-to-column connections at the 2F. The maximum residual inter-story drift angle was 1/100 (1F). The tilt of the entire building was 1/226. The damage of exterior PC panels could be seen.
[Summary of repair construction]
The 8 damaged parts near beam-to-column connections were effectively repaired by the method shown in [4]. The 2 columns were replaced by jack-up. The all PC panels were replaced. The building was repaired almost the same as the original one.

Building F (Demolished)
Damage level: Severe
Completion Age: 1984
Total Area: 1,584m^2 Height: 18.8m
Usage: Office
Structural Type: Moment-resisting frame
Floor: upper ground 5- penthouse 0- basement 0
[Summary of damage]
Structural damage concentrated on the 1F-4F. Near beam-to-column connections, the damage of yielding, crack, local buckling and fracture could be seen. At the 2F-3F in the NS direction, the ratio of fracture of the beams was 54%. The damage of column could scarcely be seen. The maximum residual inter-story drift angle was 1/48 (3F). The tilt of the entire building was 1/100. The serious damage of exterior PC panels and interior finishes could be seen.
[Summary of repair construction]
Building F was demolished.

Building G
Damage level: Intermediate
Completion Age: 1983
Total Area: 627m^2 Height: 27.8m
Usage: Office

Type: Moment-resisting frame
Floor: upper ground 8- penthouse 1- basement 1
[Summary of damage]
Structural damage concentrated on the 4F-6F. At the end of the beams, the damage of yielding, crack, local buckling and fracture could be seen. The damage of column could scarcely be seen. The maximum residual inter-story drift angle was 1/98 (7F). The tilt of the entire building was 1/286. The damage of exterior PC panels could be seen.
[Summary of repair construction]
The 11 damaged parts near beam-to-column connections were effectively repaired by the method shown in [4]. The PC panels were repaired. The building was repaired almost the same as the original one.

Building H
Damage level: Minor
Completion Age: 1979
Total Area: 18,084m^2 Height: unknown
Usage: Complex facility (Hotel, Store, Station)
Type: Moment-resisting frame + K-brace (BF-5F: SRC)
Floor:upper ground 12- penthouse 2- basement 2
[Summary of damage]
Structural damage could be seen above the 6F. Fracture of braces and shear buckling of beam webs connected with braces could be seen. Some damaged parts near beam-to-column connections could be seen. The damage of column could scarcely be seen. The maximum residual inter-story drift angle and the tilt of the entire building were unknown. The damage of exterior PC panels could be seen.
[Summary of repair construction]
The 13 damaged parts near beam-to-column connections were repaired. The 35 damaged parts by fracture of braces and shear buckling of beam webs connected with braces were repaired. The building was repaired almost the same as the original one.

Building I
Damage level: Minor
Completion Age: 1986

Total Area:34,188m^2 Height: unknown
Usage: Parking facility
Type: Moment-resisting frame + Brace
Floor: upper ground 9- penthouse 2- basement 0
[Summary of damage]
Near the column bases connected with braces, 5 cracks could be seen. Serious damage could not be seen in other structural and non-structural members. The maximum residual inter-story drift angle was 1/208 (4F). The tilt of the entire building was 1/416.
[Summary of repair construction]
The repair of the 4 damaged parts near the column bases could be recognized. The building was repaired almost the same as the original one.

Building J (Demolished)
Damage level: Severe
Completion Age: 1988
Total Area: 429m^2 Height: 16.0m
Usage: Office
Type: Moment-resisting frame
Floor: upper ground 5- penthouse 0- basement 0
[Summary of damage]
Building J had a large residual drift. The maximum residual inter-story drift angle was 1/48 (1F). The tilt of the entire building was 1/50. These large residual drifts seem to be mainly caused by damage of foundation beams and local buckling of the column at the 1F. Near beam-to-column connections, relatively minor damage could be seen. The serious damage of exterior PC panels and interior finishes could be seen.
[Summary of repair construction]
Building J was demolished.

Building K
Damage level: Intermediate
Completion Age: 1988
Total Area: 2,771m^2 Height: 30.7m
Usage: Office
Moment-resisting frame
Floor: upper ground 9- penthouse 0- basement 1
[Summary of damage]
The residual drift could hardly be recognized,

but the disorder of the elevators led to the investigation of structural damage. Structural damage concentrated on the 2F-4F. Near beam-to-column connections, the damage of yielding, crack, local buckling and fracture could be seen. The maximum residual inter-story drift angle and the tilt of the entire building was 1/1000.
[Summary of repair construction]
The 67 damaged parts near beam-to-column connections were repaired. The building was repaired almost the same as the original one.

Building L
Damage level: Severe
Completion Age: 1977
Total Area: 1,403m^2　Height: 25.0m
Usage: Office
Type: Moment-resisting frame
Floor: upper ground 8- penthouse 0- basement 1
[Summary of damage]
Structural damage concentrated on the 1F. Fracture (3 columns), local buckling (3 columns) of the 1F could be seen. All anchor bolts of exposed-type column bases were fractured. The maximum residual inter-story drift angle was 1/5 (1F). The tilt of the entire building was 1/37. The serious damage of exterior PC panels could be seen.
[Summary of repair construction]
Building L had a large residual drift (1F:1/5). The damage concentrated on the first floor. Although it was judged to be demolished at first, difficult straightening repair construction was conducted because of the owner's strong will to avoid business indirect cost losses. First, the building above the second floor was jacked up. Second, all columns of the first floor were replaced by new ones. Third, new sliding construction technique was introduced to cancel residual drifts. Finally, the building above the second floor was jacked down and all the base parts were welded again. The contractor said that this new construction technique had contributed to much cheaper repair cost and shorter repair period. The building was repaired almost the same as the original one.

3. ANALYSIS OF REPARABILITY LIMIT OF STEEL STRUCTURES

3.1 Analysis from a Technical Point of View

When we discuss reparability in terms of the difficulty of repair construction, we can say that a residual drift angle is one of the most important factors of all engineering parameters. This is because straightening repair construction of an inclined building is extremely difficult, while the repair construction of local damage of the end of beams and columns by local buckling, fracture, yielding and crack can be relatively easy by using the usual methods [5-9]; Besides, the non-structural members and architectural equipment can be partially replaced if damage is severe. Therefore, in this study from a technical point of view, we focused on residual drift and investigated both overall residual drift angle θ_R and maximum residual inter-story drift angle $\theta_{max, r}$ from the actual data. The overall residual drift angle and maximum residual inter-story drift angle are defined as:

$$\theta_R = \frac{u_R}{H} \qquad (1)$$

$$\theta_{max,r} = \max_{1 \le i \le N} \left[\frac{u_r}{h} \right]_i \qquad (2)$$

where u_R is the residual drift of the top of the building and H is the height of the building; $\left[\frac{u_r}{h} \right]_i$ is the residual inter-story drift angle of the i-th story.

The actual data of overall residual drift angle and maximum residual inter-story drift angle are shown in Table 1, 2, respectively. These data are arranged in order of large values. The actual data of building H are unknown. From these tables, we defined the reparability limits of overall residual drift angle and maximum residual inter-story drift angle at general level. This general level means that buildings can be restored by partial repair without any difficult straightening repair construction or large-scale

reinforcing construction. Therefore, the reparability limits are determined as the maximum value except the data of building F, J, C, D and L (See chap. 2).

From the analysis of the actual data of these tables, the reparability limits of overall residual drift angle and maximum residual inter-story drift angle are defined as the follows:

$$\theta_{R,\lim} = \frac{1}{110} \qquad (3)$$

$$\theta_{\max,r,\lim} = \frac{1}{71} \qquad (4)$$

where $\theta_{R,\lim}$ is the reparability limit of overall residual drift angle and $\theta_{\max,\ r,\ \lim}$ is the reparability limit of maximum residual inter-story drift angle.

3.2 Analysis from an Economic Point of View

Whether a building can be repaired or not after an earthquake should be determined mainly in terms of cost if it can be technically repaired. In this study, we tried to define the reparability limit in terms of direct restoration cost and indirect restoration cost. Direct restoration cost means the costs required when a building is restored by repair or replacement construction and indirect restoration cost means the costs lost when a building cannot be used during repair or replacement construction period, like business cost losses.

When we discuss the reparability limit from an economic point of view, we can say that the ratio of repair cost to replacement cost (Fig. 1.) is one of the most useful factors of all cost-related indexes.
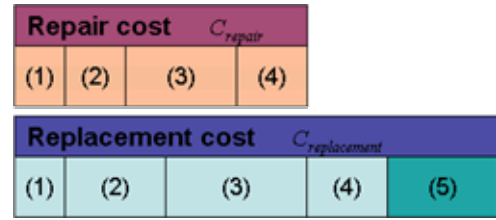
- Restoration cost -
(1) Temporary work
(2) Structural frame
(3) Non-structural member
(4) Architectural equipment
(5) Demolishing

Fig. 1. Breakdown of repair and replacement cost.

Thus, in this study, the reparability limit related to direct restoration cost is determined by the maximum value of the direct restoration cost ratio $R_{c,d}$ which is defined as:

$$R_{c,d} = \frac{C_{repair,d}}{C_{replacement,d}} \qquad (5)$$

where $C_{repair,d}$ is direct repair cost and $C_{replacement,d}$ is direct replacement cost.

Similarly, the reparability limit related to indirect restoration cost is determined by the maximum value of the indirect restoration cost ratio $R_{c,ind}$ which is defined as:

$$R_{c,ind} = \frac{C_{repair,ind}}{C_{replacement,ind}} \qquad (6)$$

where $C_{repair,ind}$ is indirect repair cost and $C_{replacement,ind}$ is indirect replacement cost.

Table 1. Actual measurement value of overall residual drift angle.

Building	C	L	J	F	B	D	A	E	G	I	K
θ_R	1/34	1/37	1/50	1/100	1/110	1/120	1/216	1/250	1/286	1/416	1/1000

Table 2. Actual measurement value of maximum residual inter-story drift angle.

Building	L	C	D	J	F	B	G	E	A	I	K
$\theta_{max,r}$	1/5	1/34	1/46	1/48	1/48	1/71	1/98	1/100	1/125	1/208	1/1000

However, indirect cost is very difficult to predict in a design process because it is affected by various indeterminate factors. Therefore, in this paper, on the assumption that indirect cost is approximately proportional to the period of repair or replacement construction, we regarded indirect restoration cost ratio as the ratio of repair construction period to replacement construction period:

$$C_{repair,ind} \approx k \cdot T_{repair} \qquad (7)$$

$$C_{replacement,ind} \approx k \cdot T_{replacement} \qquad (8)$$

$$R_{c,ind} \approx \frac{T_{repair}}{T_{replacement}} \qquad (9)$$

where k is constant, T_{repair} is repair construction period and $T_{replacement}$ is replacement construction period.

On the basis of the above definitions, we investigated direct restoration cost ratio and indirect restoration cost ratio from the actual data by following the next note.

Note :
1) Direct repair cost: Real repair cost (1995) is used.
2) Direct replacement cost: The sum of the initial construction cost (1995) into which is converted from the real initial construction cost by multiplying an age-modification factor and the virtual demolition cost estimated by an expert engineer is used.
3) Repair construction period: Real repair construction period is used. (All buildings were repaired under completely closed condition.)

4) Replacement construction period: The sum of the initial construction period and the virtual demolition period estimated by an expert engineer is used.
5) The values of building B, C, D and L (marked as * in the tables) are reference values. Building B doesn't include the repair of the interior as an unusual construction condition. As mentioned in 3.1, building C, D and L exceed the general technical reparability limits.

The actual data of direct restoration cost ratio and indirect restoration cost ratio are shown in Table 3, 4, respectively. These data are arranged in order of large values. From these tables, we defined the reparability limits of direct restoration cost ratio and indirect restoration cost ratio. The reparability limits are determined as the maximum values except the data of building B, C, D and L (marked as * in the tables). From Table 3, the maximum value of direct restoration cost is 0.86 (building A), which is below 0. This means that there was no case that a building was repaired by using the repair cost above the replacement cost. From Table 4, the maximum value of indirect restoration cost ratio is 0.40 (building A).

From these analyses, the reparability limits of direct restoration cost ratio and indirect restoration cost ratio are determined as 0.86, 0.40, respectively.

$$R_{c,d,\lim} = 0.86 \qquad (10)$$

$$R_{c,ind,\lim} = 0.40 \qquad (11)$$

where $R_{c,d,\lim}$ is the reparability limit of direct restoration cost ratio and $R_{c,ind,\lim}$ is the reparability limit of indirect restoration cost ratio.

Table 3. Direct restoration cost ratio. (*: Reference value.)

Building	A	G	L*	I	C*	E	D*	H	K	B*
$R_{c,d}$	0.86	0.73	0.62	0.60	0.56	0.55	0.51	0.44	0.18	0.17

Table 4. Indirect restoration cost ratio. (*: Reference value.)

Building	D*	A	B*	L*	E	K	C*	G	H	I
$R_{c,ind}$	0.41	0.40	0.36	0.35	0.28	0.26	0.26	0.24	0.15	0.12

In addition, Eq.12 is confirmed from the fact that both the values of direct restoration cost ratio and indirect cost ratio are below 1.

$$\frac{C_{repair,d} + C_{repair,ind}}{C_{replacement,d} + C_{replacement,ind}} < 1 \qquad (12)$$

4. THE RELATIONSHIP BETWEEN RESIDUAL DRIFT ANGLE AND RESTORATION COST RATIO

Considering the difficulties of the prediction of repair cost and repair construction period in the current database, we tried to predict direct restoration cost ratio and indirect restoration cost ratio (which is defined as the ratio of repair construction period to replacement construction period) from a structural damage index because these ratios within the reparability limits assume to be approximately proportional to a structural damage index. In this study, we used residual drift angle as a structural damage index because it is the only identifiable index which can be obtained from actual data.

Fig. 2 shows the relationship between overall residual drift angle and direct restoration cost ratio. Fig. 3 shows the relationship between overall residual drift angle and indirect restoration cost ratio. The data of building B, C, D, H and L are not plotted in the graphs because of the reasons mentioned in Chap. 2 and 3. The data of demolished buildings (building F and J) are not also plotted in the graphs. The lines in Fig. 2 and 3 show the regression lines. In both graphs, there are some scatters between the plots and the regression line, but from a broader perspective, this relationship can be regarded as linear. It is speculated that one of the reasons of these scatters is that residual drift can become the index to express structural damage to some extent, while it just shows the final damage of a building and does not always perfectly correspond to the damage of the entire building.

When we predict both direct restoration cost ratio and indirect restoration cost ratio from these regression lines, the predicted equations are defined as follows:
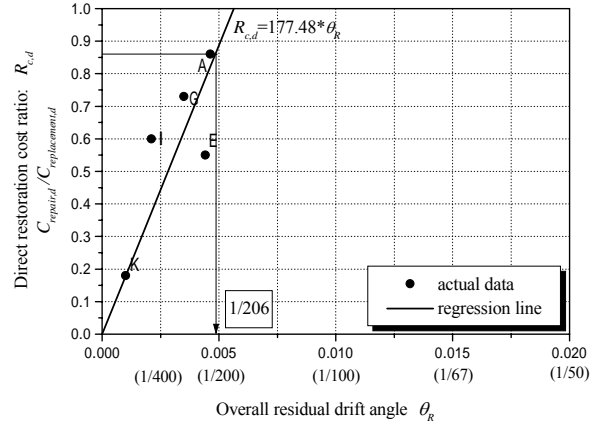

Fig. 2. Relationship between overall residual drift angle and direct restoration cost ratio.
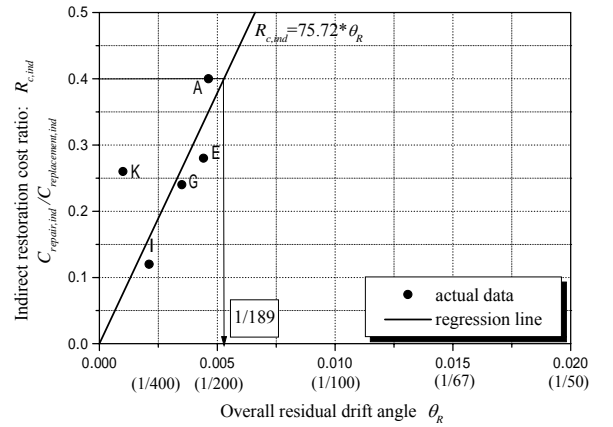

Fig. 3. Relationship between overall residual drift angle and indirect restoration cost ratio.

$$R_{c,d,p} = 177.48 \cdot \theta_R \qquad (13)$$

$$R_{c,ind,p} = 75.72 \cdot \theta_R \qquad (14)$$

where $R_{c,d,p}$ is the predicted value of direct restoration cost ratio; $R_{c,ind,p}$ is the predicted value of indirect restoration cost ratio; θ_R is overall residual drift angle.

From Eq.13, the value of overall residual drift angle corresponding to the reparability limit of direct restoration cost ratio (0.86) is defined as 1/206. From Eq.14, the value of overall residual drift angle corresponding to the reparability

limit of indirect restoration cost ratio (0.40) is defined as 1/189. From these two values, the smaller value 1/206 is adopted from a safety viewpoint. Eq.15 shows the definition of the reparability limit of overall residual drift angle recommended for design practices:

$$\theta_{R,\lim,c} = \frac{1}{200} \qquad (15)$$

where $\theta_{R,\lim,c}$ is the reparability limit of overall residual drift angle recommended for design practices

Fig. 4 shows the relationship between maximum residual inter-story drift angle and direct restoration cost ratio. Fig. 5 shows the relationship between maximum residual inter-story drift angle and indirect restoration cost ratio. The lines in Fig. 4 and 5 show the regression lines. When we predict both the direct restoration cost ratio and indirect restoration cost ratio from these regression lines, the predicted equations are defined as follows:

$$R_{c,d,p} = 78.35 \cdot \theta_{\max,r} \qquad (16)$$

$$R_{c,ind,p} = 31.78 \cdot \theta_{\max,r} \qquad (17)$$

where $R_{c,d,p}$ is the predicted value of direct restoration cost ratio; $R_{c,ind,p}$ is the predicted value of indirect restoration cost ratio; $\theta_{\max,r}$ is maximum residual inter-story drift angle.

From Eq.16, the value of maximum residual inter-story drift angle corresponding to the reparability limit of direct restoration cost ratio (0.86) is defined as 1/91. From Eq.17, the value of maximum residual inter-story drift angle corresponding to the reparability limit of indirect restoration cost ratio (0.40) is defined as 1/79. From these two values, the smaller value 1/90 is adopted from a safety viewpoint. Eq.18 shows the definition of the reparability limit of maximum residual inter-story drift angle recommended for design practices:
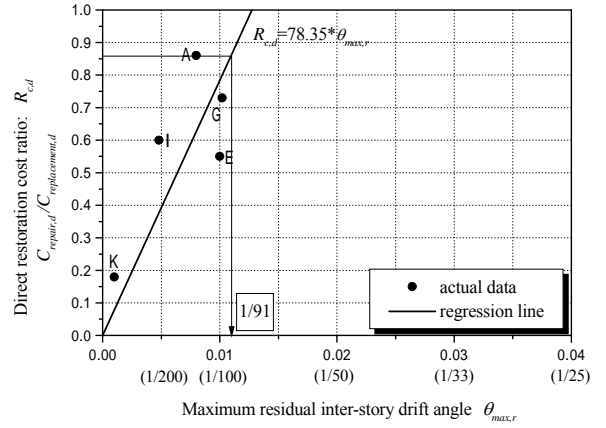

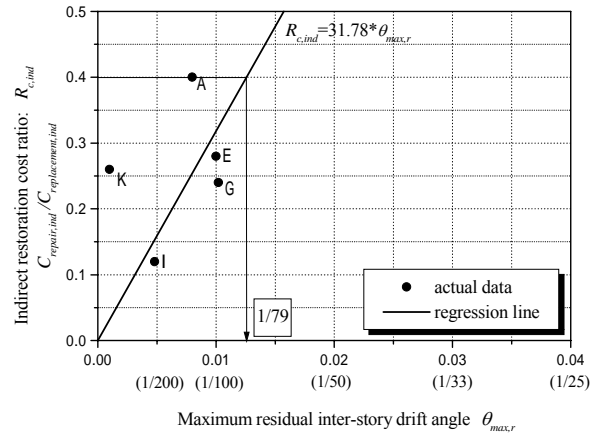Fig. 4. Relationship between maximum residual inter-story drift angle and direct restoration cost ratio.

Fig. 5. Relationship between maximum residual inter-story drift angle and indirect restoration cost ratio.

$$\theta_{\max,r,\lim,c} = \frac{1}{90} \qquad (18)$$

where $\theta_{\max,r,\lim,c}$ is the reparability limit of maximum residual inter-story drift angle recommended for design practices

5. CONCLUSIONS

In this paper, based on the actual data of repaired or demolished buildings damaged by the Hyogoken-nanbu earthquake, we analyzed residual drift and restoration cost relevant to the reparability and tried to clarify the reparability

limit of steel structural buildings from both technical and economic points of view. As for the technical point, we adopted residual drift angle as the index of difficulty of repair construction and analyzed both the overall residual drift angle and maximum residual inter-story drift angle. As for the economic point, we adopted restoration cost ratio and analyzed direct restoration cost ratio and indirect restoration cost ratio. The results obtained by the investigation are shown as follows:

1) The reparability limit of overall residual drift angle was 1/110.

2) The reparability limit of maximum residual inter-story drift angle was 1/71.

3) The reparability limit of direct restoration cost ratio was 0.86.

4) The reparability limit of indirect restoration cost ratio was 0.40.

Furthermore, based on the actual data, the relationship of residual drift angle and restoration cost ratio was investigated and the reparability limits synthesizing technical and economic aspects were defined by overall residual drift angle and maximum residual inter-story drift angle as 1/200 and 1/90, respectively.

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