0499

A SEISMIC DIAGNOSIS AND UPGRADING OF EXISTING STEEL FRAMED BUILDINGS

Yuji NAKAMURA[1], Akira MATSUO[2], Kiichiro SAWADA[3] And Toshimitsu TANAKA[4]

SUMMARY

After the Hyogoken-Nanbu Earthquake occurred on January 1995, seismic diagnoses and upgradings of existing buildings are recognized to be urgently needed in Japan. And the recommendations for the seismic diagnosis and upgrading of existing steel framed buildings was soon published by Japan Building Disaster Prevention Association (JBDPA, hereafter) on September 1996.[1] In this paper, the software programming for the recommendations has been introduced briefly and the results of the seismic diagnosis for several existing steel buildings are discussed herein

INTRODUCTION

For reinforced concrete structures, many activities of seismic diagnosis and upgrading have been already carried out in Japan, because it is anticipated that reinforced concrete structures would be seriously damaged if great Tokai Earthquake occurs. However, for steel structures, these activities have not been popular, because steel structures had not been damaged seriously so far and were believed to be safe and ductile for severe earthquake. But when the Hyogo-ken Nanbu Earthquake occurred, steel structures were seriously damaged as well as reinforced concrete structures were, and seismic diagnoses and upgradings of steel structures are also recognized to be very important recently. Then, the recommendations of seismic diagnosis and upgrading of existing steel buildings were deliberated and published by the committee of JBDPA in September 1996. Applying this recommendations to several existing, example buildings, this paper presents the good applicability of this recommendations to seismic diagnosis of existing buildings herein.

SEISMIC DIAGNOSIS METHOD

When the committee deliberated this recommendations based upon the damage analysis of steel buildings against the Hyogo-ken Nanbu Earthquake, the present Japanese national seismic regulations[2] were judged to be mostly appropriate for steel building structures. Two following equations are proposed for indexes of seismic performance of a steel building.

$$Is_i = \frac{Qu_i \cdot F_i}{Fes_i \cdot W_i \cdot Rt \cdot A_i} \tag{1}$$

$$q_i = \frac{Qu_i}{0.25 Fes_i \cdot W_i \cdot Z \cdot Rt \cdot A_i} \tag{2}$$

An index of seismic performance of a building, Isi, is calculated to every floor to X- and Y-directions of the building, using load bearing capacity, Qui and F-factor (deformability factor) in Eq.1. And qi, an index in reference to load bearing capacity of each floor, is the ratio of the existing load bearing capacity to the required capacity, assuming Ds-factor be 0.25.

[1] *Dept. of Structural Eng., Hiroshima Univ., Kagamiyama, Higashi-Hiroshima, Japan Email: ynakam@ipc.hiroshima-u.ac.jp*
[2] *Dept. of Structural Eng., Hiroshima Univ., Kagamiyama, Higashi-Hiroshima, Japan*
[3] *Dept. of Structural Eng., Hiroshima Univ., Kagamiyama, Higashi-Hiroshima, Japan*
[4] *KUBOTA, Shikitsu-higashi 1-2-47, Osaka, Japan*

In this recommendations, the following criteria are adopted for judgment on the possibility of collapse and the need for upgrading.

(1) Is < 0.3 and qi < 0.5

The possibility of collapse is high. Urgent actions for upgrading to the building are needed.

(2) Is ≥ 0.6 and qi ≥ 1.0

The possibility of collpase is low.

(3) Otherwise

The possibility of collapse is not negligible.

The load bearing capacity, Qui, of each floor of a building can be calculated with plastic analysis based upon the lower bound theorem. The F-factor is the index which is calculated with the deformability of structural elements, such as column members, beam members, column bases, and column-beam connections. The F-factors specified in this recommendations are mostly the inverse of Ds factors (0.25~0.50) stipulated in the current seismic regulations in Japan. Consequently, these values of F-factors tabulated in this recommendations shall be refined by checking further experimental and theoretical data in the future. The Fi-factor of each floor can be obtained from the minimum value of F-factors of the structural elements which compose the concerned floor frame.

PROGRAMMING SOFTWARE OF SEISIMIC DIAGNOSIS

In this programming software, unbraced and/or braced steel frames are considered, defining the structural elements shown in Fig.1. Column sections are square, circular tubing or H-shapes. Beam sections are H-shapes, and bracing members are angles, channels, and/or round bars. The flow diagram of this programming for an unbraced frame is shown in Fig.2. Firstly, assuming that the column bases are not uplift, the member forces of beams are calculated for the collapse mechanism of a building using Moment Distribution Method. Afterwards, the uplift forces of column bases shall be obtained from the uplift forces due to horizontal seismic forces subtracting the long-term axial forces and the weights of column basements. In the case of an unbraced frame, the shearing forces of beams shall be modified using D-values of beams of the concerned bay of the building. And, in the case of a braced frame, the shearing forces of bracing shall be modified in proportion to the uplift forces.

EXAMPLES OF SEISMIC DIAGNOSIS AND UPGRADING

The seismic diagnoses and upgradings were applied to several examples of unbraced and/or braced frames in order to check the applicability of this method.

(1) The 1st Example (Unbraced-Braced Structural Type)

This building was designed according to the former Building Standard Law. The beam plan of this building is shown in Fig.3, and the framing evaluation of Y-direction (braced frame) is shown in Fig.4. And results of the seismic diagnosis of this building are tabulated in Table 1 and 2. The seismic indexes of all floors except the first floor of this building are satisfactory with the above-mentioned criteria. Accordingly, the first floor of this building frame shall be upgraded, because F-factor of this floor is 1.2 for both directions For increasing F-factor, the lengths of reinforced concrete covering of columns of this floor shall be increased in order to obtain the value, 2.4.

(2) The 2nd Example (Unbraced-Braced Structural Type)

This building was designed according to the new seismic design law. The beam plan of this building is shown in Fig.5, and the framing evaluation (X-direction) is shown in Fig.6. The results of the seismic diagnosis of this frame are shown in Fig.7. The seismic indexes of all floors of this building are fully satisfactory with the above-mentioned criteria. Accordingly, the possibility of collapse is low, and upgrading of the frames is not needed in this case.

(3) The 3rd Example (Unbraced-Braced Structural Type)

This building was also designed according to the new seismic design law. The beam plan of this building is shown in Fig.8, and the framing elevation (X-direction) is shown in Fig.9. The results of the seismic diagnosis of this frame are shown in Fig.10. The seismic indexes of all floors of this building are fully satisfactory with the above-mentioned criteria. Accordingly, the possibility of cllapse is low, and upgrading of frames is not needed.

(4) The 4th Example (Unbraced-Unbraced Structural Type)

This building is a three-story office building, and designed according to the new seismic design law. The column sections are cold-rolled square shapes and the beam sections are H-shapes. The beam plan of this building is shown in Fig.11 and the seismic indexes are shown in Fig.12. All seismic indexes are fully satisfactory with the criteria. The possibility of collapse is low, and upgrading of the frames is not needed.

(5) The 5th Example (Unbraced-Unbraced Structural Type)

This building is a four-story office building, and was designed according to the new seismic design law. The columns are cold-rolled square tubes, and the beams are H-shapes. The column bases are embeded to reinforced concrete foundations. The beam plans of this building shown in Fig.13. The seismic indexes are shown in Fig.14.

(6) The 6th Example (Unbraced-Unbraced Structural Type)

This building is a nine story office building, and designed according to the new seismic design law. The column sections are cold-rolled square tubes and beam sections are H-shapes. The beam plan of this building is shown in Fig.15, and the seismic indexes are shown in Fig.16. All seismic indexes are fully satisfactory with the criteria, and upgrading of this building is not needed.

CONCLUSIONS

(1) The good applicability of the recommendations of the seismic diagnosis and upgrading to the existing buildings published by JBDPA was exhibited through the results from the programming software developed by the authors.

(2) It is judged that the frames designed according to the new seismic design law be satisfactory with the seismic diagnosis criteria using Is and q defined in Eq.1 and 2 in the recommendations respectively.

REFERENCES

[1] Japan Building Disaster Prevention Association, "Recommendations for Seismic Diagnosis and Upgrading of Existing Steel Buildings", September 1996 (in Japanese)

[2] The Ministry of Construction, "The Building Standard Law of Japan", August 1994

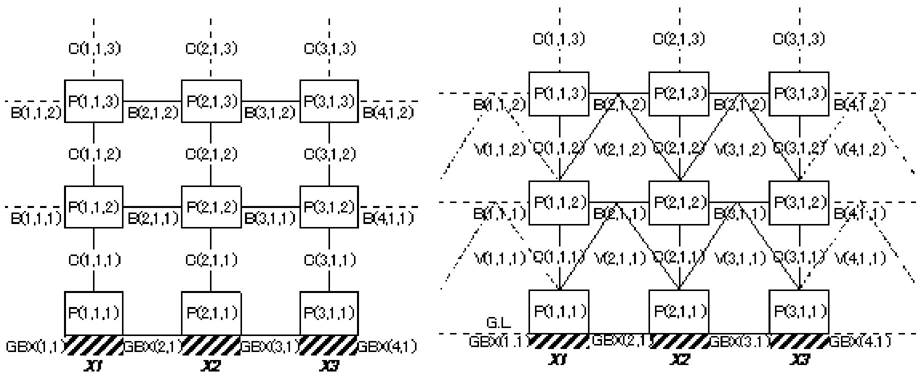

Figure 1: Numbering of Structural Elements for Braced and Unbraced Frames

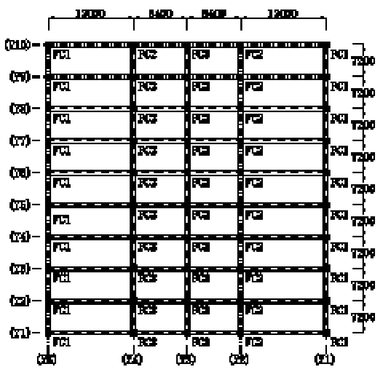

Figure 3 : Beam Plan of Ex.1 Building (mm)

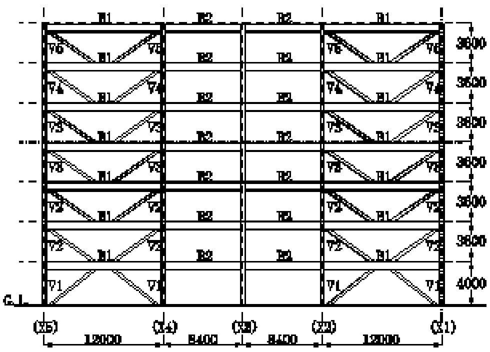

Figure 4 : Framing Elevation (Y-direction) of Ex.1 Building (mm)

Table 1: Results of Diagnosis of Ex.1 Building (X-direction)

Floor	Qu_i (tonf)	F-Factor	Is_i	q_i
7	1712.	2.5	1.26	2.02
6	1759.	2.5	0.87	1.40
5	2297.	2.5	0.90	1.44
4	2876.	2.5	0.96	1.54
3	3057.	2.5	0.91	1.46
2	3729.	2.5	1.36	1.64
1	3079.	3.3	0.39	1.29

Table 2: Results of Diagnosis of Ex.1 Building (Y-direction)

Floor	Qu_i (tonf)	F-Factor	Is_i	q_i
7	1725.	2.4	1.42	2.36
6	1906.	2.4	1.09	1.81
5	2476.	2.4	1.13	1.88
4	2658.	2.4	1.04	1.74
3	3284.	2.4	1.15	1.92
2	3441.	2.4	1.12	1.87
1	3344.	1.2	0.52	1.72

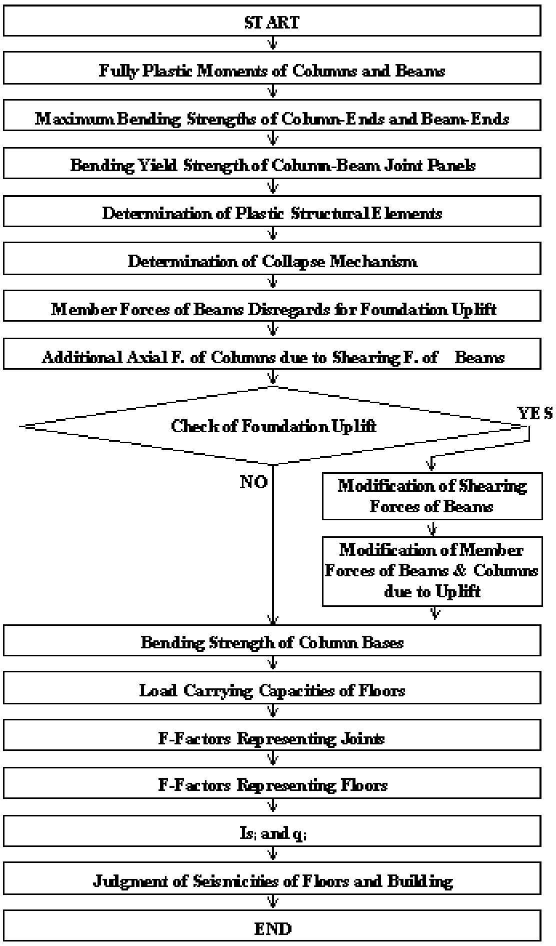

Figure 2: Flow Diagram of Diagnosis of Unbraced Frames

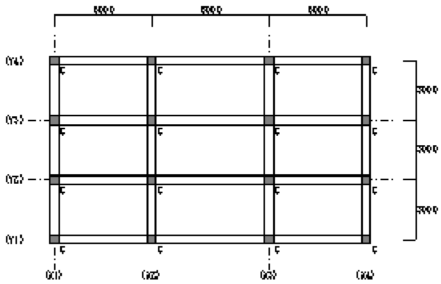

Figure 5: Beam Plan of Ex.2 Building

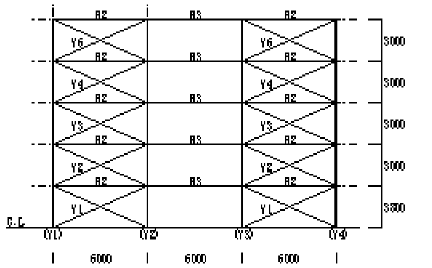

Figure 6: Framing Elevation (X-direction) of Ex.2 Building

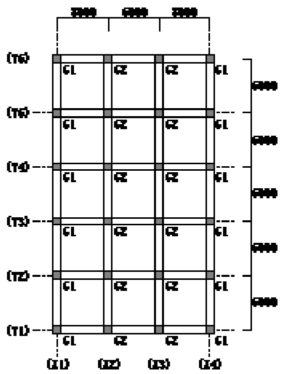

Figure 8: Beam Plan of Ex.3 Building

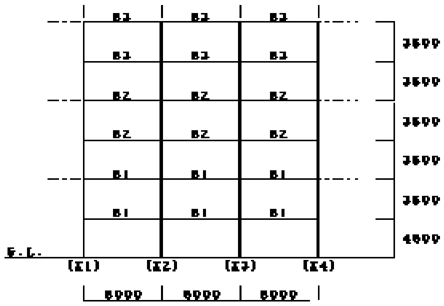

Figure 9: Framing Elevation (X-direction) of Ex.3 Building

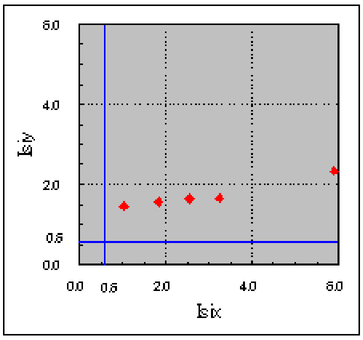

Figure 7: Is_i of Ex.2 Building

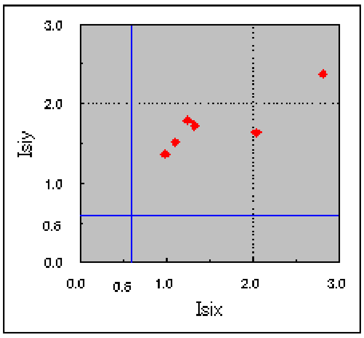

Figure 10: Is_i of Ex.3 Building

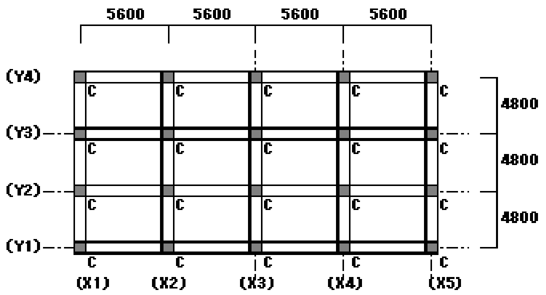

Fig 11: Beam Plan of Ex.4 Building

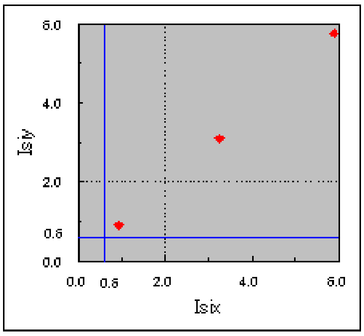

Figure 12: Is_i of Ex.4 Building

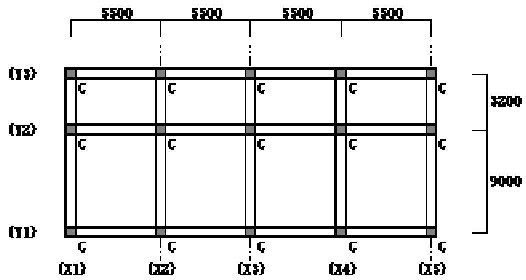

Figure 13: Beam Plan of Ex.5 Building

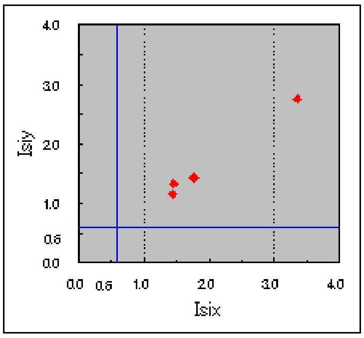

Figure 14: Is_i of Ex.5 Building

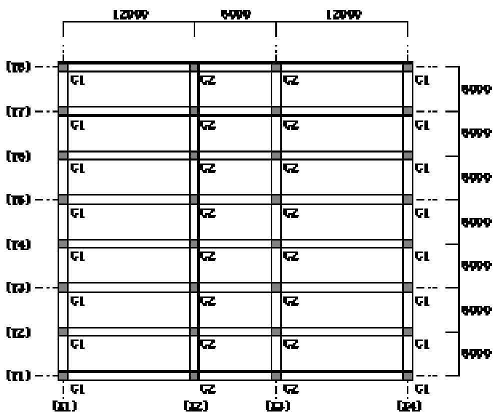

Figure 15: Beam Plan of Ex.6 Building

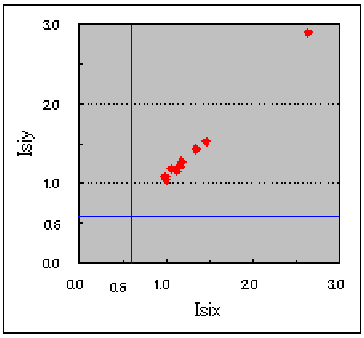

Figure 16: Is_i of Ex.6 Building