PRACTICES OF SEISMIC RETROFIT OF EXISTING CONCRETE STRUCTURES IN JAPAN

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SUMMARY

Collected data by Japan Concrete Institute on practices of seismic retrofit of existing concrete buildings in Japan are introduced in this paper. Use of buildings, year of completion, number of stories, etc. of 157 practices are shown. Seismic performance of eighty percent practices were computed based on "Criterion on the Evaluation of Seismic Safety of Existing Reinforced Concrete Buildings" by the Japan Building Disaster Prevention Association. Seismic performances before and after retrofit by the criterion are discussed.

INTRODUCTION

A large number of concrete structures were damaged by severe earthquake motions. The damaged structures, however, had been originally designed to resist the severe earthquake. The facts that structures were damaged were mostly considered that they had faults. Therefore the damaged structures were not only repaired to return to their originals but also strengthened. Besides strengthening, increasing ductility, reduction of dead load were adopted in order to increase seismic performances of the structures. The all above mentioned works are included in the word "retrofit" in this paper.

A number of buildings were damaged by the Tokachi-Oki Earthquake, 1968. Especially columns of the reinforced concrete buildings were failed in shear. Many of the damaged buildings were retrofitted by re-placing concrete of

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column and by adding shear walls (Ref. 1).

The articles on shear reinforcement of "AIJ Standard" were revised (Ref. 2) in order to increase seismic performance of the reinforced concrete column. Thereafter buildings designed by the old standard were considered that they should have been evaluated their seismic performance. After several methods were proposed, "Criterion on the Evaluation of Seismic Safety of Existing Reinforced Concrete Buildings (Ref. 3)" and "Design Guidelines for Aseismic Retrofitting of Existing Reinforced Concrete Buildings (Ref. 4)" were published by the Japan Building Disaster Prevention Association. They are now indispensable to retrofit buildings and they have promoted seismic retrofitting works in Japan.

A task committee on seismic retrofit was organized in Japan Concrete Institute (JCI) in order to publish a manual on seismic retrofit in 1981. The task committee consists of engineers and researchers working for governmental offices, Japan National Railway, public corporations, construction companies, design offices and universities.

The task committee collected data on practices of seismic retrofit in order to search how the seismic retrofit are done in practice and what are the points to investigate. Questionnaires were distributed to many fields, to get data as many as possible.

The collected data are described in this paper and the authors are the members of the working group to discuss practice of seismic retrofit organized under the above mentioned task committee.

The panel discussion on seismic strengthening of existing concrete structures was held by JCI in 1983. T. Hayashi, one of the authors, discussed the collected data there (Ref. 5).

SUBJECT BUILDINGS

Place

Reinforced concrete buildings retrofitted against severe earthquakes and collected by JCI are distributed in Japan as shown in Fig. 1. The most number of building, forty seven, are in Tokyo area, which is the most populated area in Japan. The next is Shizuoka Prefecture, thirty four, where a severe earthquake is predicted near future. The buildings in the above two areas are retrofitted without earthquake damages. In Miyagi Prefecture, where a severe earthquake occured in 1978, twenty two buildings were retrofitted to increase their seismic performances.

Use of Buildings

Use of the collected buildings are classified and are shown in Fig. 2. The school building shares 42.7% and, the percentage of the governmental office is 28.7%. Most of the two kinds of buildings shall be used as shelters or head quarters when a severe earthquake occures. Only 18% of the all buildings are private.

Number of Story

41.4% of the all buildings are three story buildings and secondaly 26.1% are four story buildings. The both three and four story building share two third. Most school buildings of reinforced concrete are three or four storied, because they are most economical.

Year of Completion

The time limit of the investigation was October 1982. The practices of retrofit before then were collected.

The earliest building was originally completed in 1933 and the latest one was completed in 1975. The years when the original buildings were completed are shown in Fig. 3 after 1954. From 1963 to 1970 are the highest period. As above mentioned, the computation method of shear reinforcement of AIJ Standard was revised in 1971. Therefore number of retrofitted buildings decreases after 1971 but it is not small.

In Fig. 3 the total numbers of reinforced concrete buildings completed in Japan are illustrated. The total numbers increase linearly up to 1973. The ratios of number of retrofit to the total number are also illustrated in the figure. The ratios considerably decrease from 1958 to 1975.

METHOD OF RETROFITTING

Evaluation Criterion

In order to improve the seismic performance, computational method and criterion to determine retrofit are necessary. The criterion and design guidelines by the Japan Building Disaster Prevention Association, as mentioned before, were used commonly. 80% of the retrofittings were designed based on them.

According to the criterion, the seismic performance is evaluated by means of seismic index Is-index which is computed from strengths and ductilities of members, structural profile and time-dependent deterioration. Three method of calculation for Is-index, the first evaluation method to the third evaluation method, are described in the criterion. The Is-index of the first evaluation method is calculated from the sectional area of walls and columns and roughly estimated structural profile and time dependent deterioration.

Reinforcement and axial force applying to vertical members; walls and columns, are considered for the calculation of strengths and ductilities. for the second evaluation method. More precise methods for calculation of structural profile and time dependent deterioration factor.

Collapse mechanism due to horizontal load and the rotation of foundation under wall are taken under consideration for the third evaluation method.

Method and Purpose

In order to improve seismic performance, (1) to increase strength of structure against horizontal load and (2) to increase ductility of structure by avoiding shear failure of member and (3) to decrease the weight of the building are adopted in practice.

Adding shear walls are generally designed to increase the strength. Wing walls are also adopted for the same purpose when large openings are necessary. Steel braces are also adopted but details at the connection to the old concrete members are difficult.

Reinforcement of web of column by means of steel plate of welded wire fablic is fairly done in order to increase ductility of the building. In addition to the reinforcement, extremely short columns formed by walls are changed longer by cutting slit between the columns and the walls.

As a result of adding shear walls, strengthenings of foundation are necessary in some cases to carry the increased weight. The construction works of foundation are generally expensive.

The concrete above the asphalt layer for water proofing or non-bearing walls are removed in order to decrease the self weight of the building.

The methods of retrofittings are shown in Fig. 4. More than one method are adopted simultaneously in many cases. 85% of the retrofitted buildings were added shear walls in order to increase the strengths. Steel braces are, however, adopted in only three cases.

The columns, to which previous severe earthquakes damaged, of about 30% of the buildings were retrofitted.

Repairing works with epoxy resine were done about 20%.

SEISMIC PERFORMANCE BY CRITERION

As mentioned before, 80% of the buildings were based on the criterion by the Japan Building Disaster Prevention Association. Seismic performances by the criterion, namely Is-indices, are discussed hereafter. The evaluation methods; the above-mentioned three methods, adopted for retrofitting are listed in Table 1.

The relation between Is-index by the first evaluation method and that by the second method before retrofitting is shown in Fig. 5. The correlation between them is 0.814. The relation between the indices by the second and by the third methods is shown in Fig. 6. The correlation, 0.779 is a little smaller that between the first and the second. The relation between the indices by the first and by the third is shown in Fig. 7, but it has the smallest correlation, 0.570.

The relation between Is-Index before retrofitting and that after retrofitting are shown from Fig. 8 to Fig. 11. The effect by adding shear walls is clearly shown in Fig. 8. The Is-indices increased, up to four times by the walls. The effect by reinforcement of columns is shown in Fig. 9. The Is-indices do not increase so large as adding walls. The maximum increasing ratio before to after is about 2.0. The effect by adding wing walls are not so large, but almost same as that by reinforcement of columns, shown in Fig. 10.

The all methods of retrofittings including their combinations are shown in Fig. 11. The Is-indices after retrofittings are distributed upper than 0.4 and the ratio before to after retrofitting are varied from 1.0 to 4.0.

CONCLUSIONS

From the collected data, several remarkable points can be described as follows.

(1) 80% of the data are from public buildings. Two third of them are government offices and school buildings.

(2) The criterion by the Japan Building Disaster Prevention is used for the design of retrofit about 80%.

(3) The 85% of the buildings are retrofitted by adding shear walls. The effect by walls are fairly large measured by Is-index by the above-mentioned criterion. The steel brace, however, is adopted only two percent of all. The steel brace itself is strong and light, but the connection to old structure is difficult. Research to improve the detail of connection is desired.

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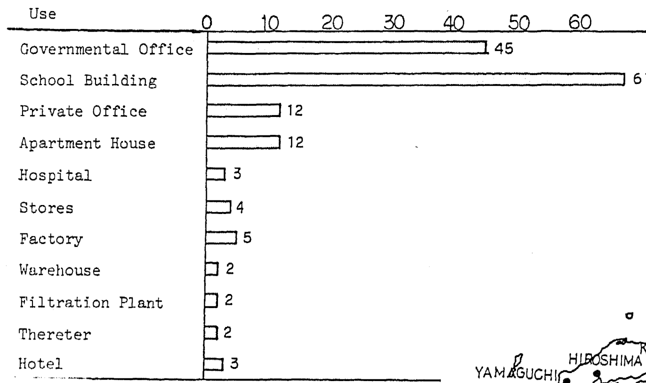

Fig.2 Use of Building

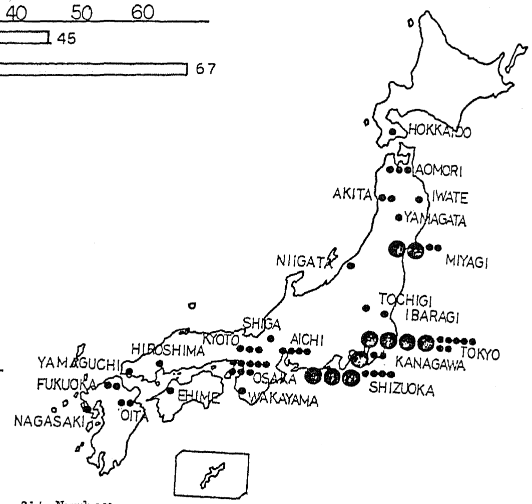

Fig.1 Location of Retrofitted Building

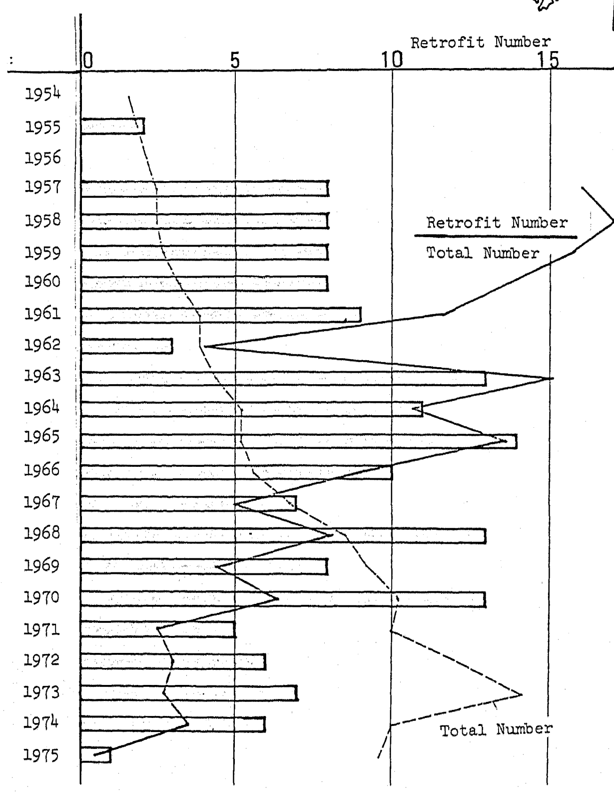

Fig.3 Year of Completion

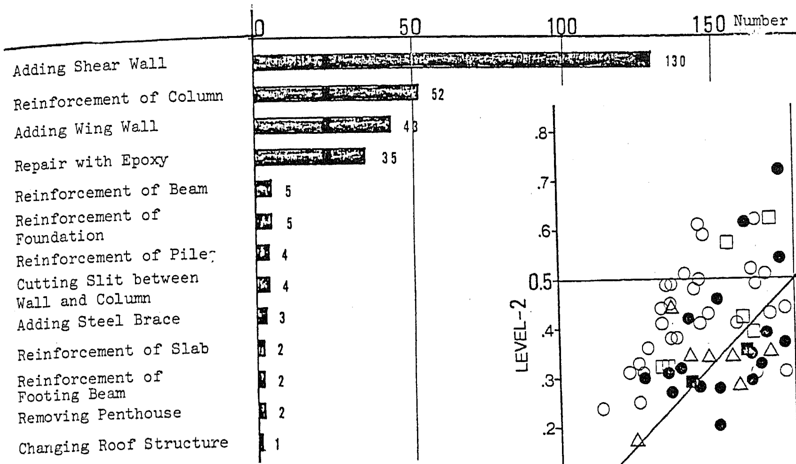

Fig.4 Method of Retrofit

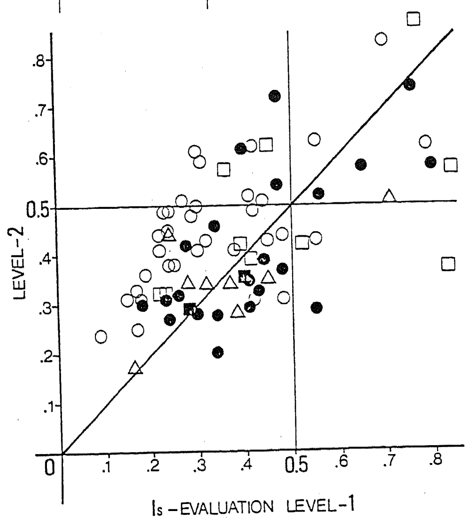

Fig.5 Relation between Is-index by the First Evaluation Method and that by the Second Evaluation Method

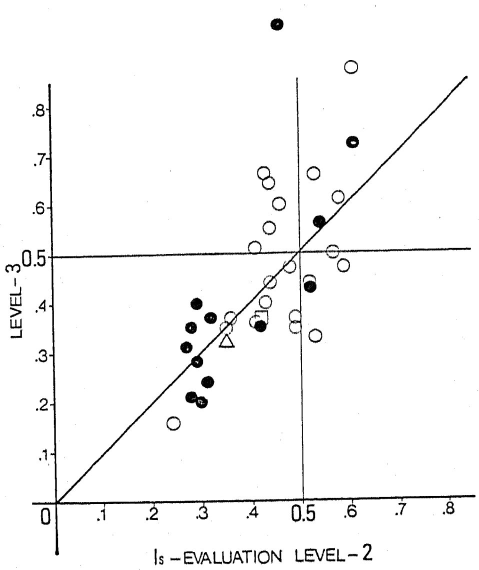

Fig.6 Relation between Is-index by the Second Evaluation Method and that by the Third Evaluation Method

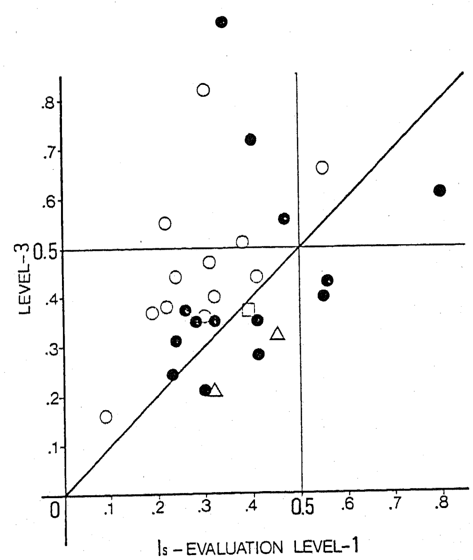

Fig.7 Relation between Is-index by the First Evaluation Method and that by the Third Evaluation Method

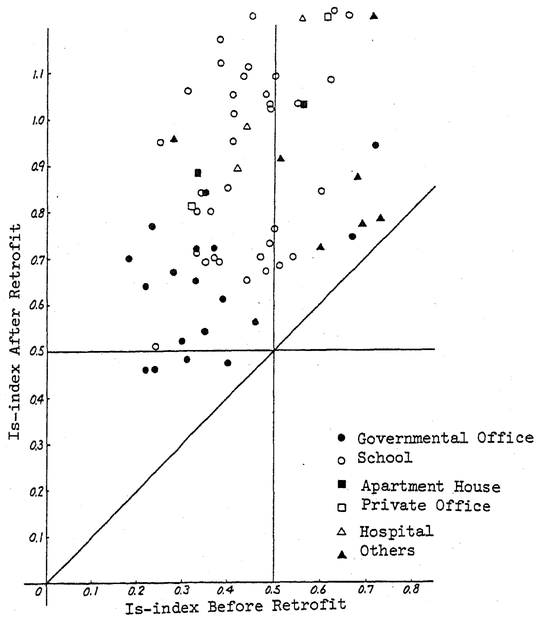

Fig.8 Relation between Is-index before Retrofit and that after Retrofit By Adding Shear Wall

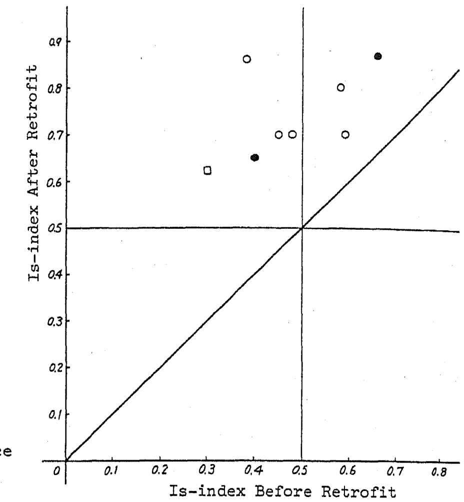

Fig.9 Relation between Is-index before Retrofit and that after Retrofit by Reinforcement of Column

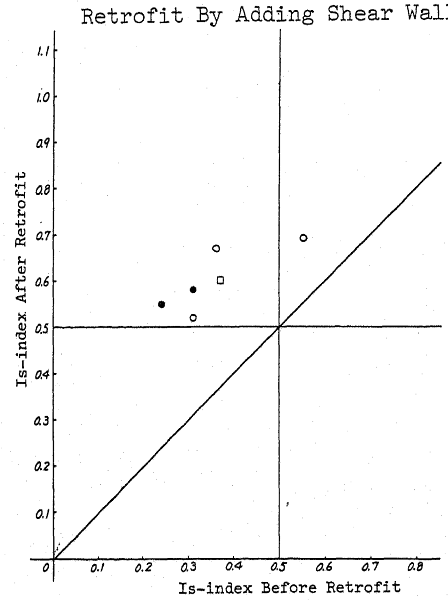

Fig.10 Relation between Is-index before Retrofit and that after Retrofit by Adding Wing Wall

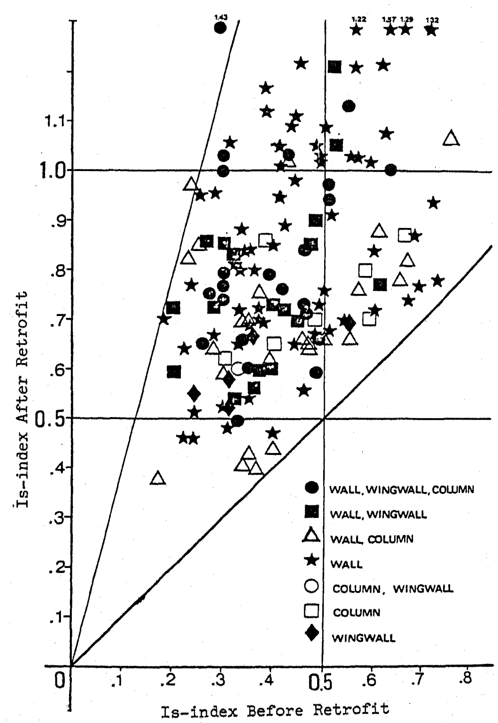

Fig.11 Relation between Is-index before Retrofit and that after Retrofit by the All Methods