RESEARCH ON SEISMIC EVALUATION AND RETROFIT OF CONDOMINIUM IN JAPAN

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Abstract

The Japanese condo buildings, constructed before 1981 didn't satisfy seismic performance defined by so-called “New Seismic Design Method”. Therefore, seismic evaluation and seismic retrofit on existing condo buildings were requested to conduct by "The Law for Promotion of Seismic Retrofit of Buildings" in 1995. This research was carried out on the basis of the reports of seismic evaluation and seismic retrofit on existing 237 condo buildings in metropolitan area by JSCA (that stands for Japan Structural Consultants Association).

According to the results, seismic performance of condos were very low and they have risk to be destroyed by big earthquakes but lots of those condo’s retrofit are not made a start because of the lack of retrofit funds and difficulty to form a consensus to the retrofit in the condo management society. Retrofit methods adopted to the buildings with the low Is (Structural Seismic Index) value are conventional method and new developed method. Recently exterior frame methods come to popular, because it make the construction wok possible to be conducted while people are staying in condos. Exterior frame methods have some problems to be careful on design, like axial force and shear force transfer, low strength concrete of existing building.

To promote seismic retrofit without delay, the supports of public funds and continuous advices to the condo residents are necessary. The gradual method of reinforcement is also necessary too. Lastly, structural engineers have to make effort to reduce the burden i.e. dangerous condo buildings i.e. Social Negative Legacy, for the next generation.

1. Introduction

In Japan, there is a great concern about big earthquakes like local earthquakes just under the city and ocean-trench earthquakes. The existing buildings constructed before 1981(this year the new aseismic design law were enforced), are requested to conduct seismic evaluation and retrofit by "The Law for Promotion of Seismic Retrofit of Buildings" in 1995. Moreover, seismic evaluation and retrofit for the buildings including condos near the emergency transportation road in the big city like Tokyo have started by the revision of above Promotion Law in 2013 to ensure the escape route safety for evacuees.
JSCA Seismic Evaluation and Retrofit Plan Committee (Chairperson Takayuki Teramoto) conducted certification of seismic evaluation and retrofit of these 646 buildings from 2014 until 2017 fiscal year. This paper shows the results of these buildings (including condos) evaluation and retrofit plan and proposal how to promote seismic retrofits of condos, those were not progressing well.

2. Analysis of Seismic Evaluation Results on Condos

Fig.1 shows minimum Is values of a check results of 237 condos which takes 36.6% of 646 buildings and minimum Is values means the smallest Is value throughout all floors and X,Y directions of the building. Average Is is 0.49. It is unsafe performance level.*Fig.2* shows ratio of 3 groups. Group1 is good seismic performance i.e. Is$\geqq$0.6 and no need of reinforcement, 64 condos, 27.0% of total. Group2 is unsafe performance level i.e. Is$<$0.6 and had been certificated reinforcement plans by JSCA, 104 condos, 44.0%

of total. Group3 is also unsafe performance level i.e. Is＜0.6 and have no reinforcement plans, 69 condos, 29.0% of total.

There is also fear that near 70 % of the condos which aren't reinforced yet, by the situation that it can't be confirmed whether certificated 104 condos would be reinforced or not.

Fig.3 indicates structural type classification and its number of Is≧0.6 condos. That reinforcement of these condos is unnecessary. In addition to usual RC and SRC construction, WRC, W-PC, HPC are predominant structure type because of its volume of walls.

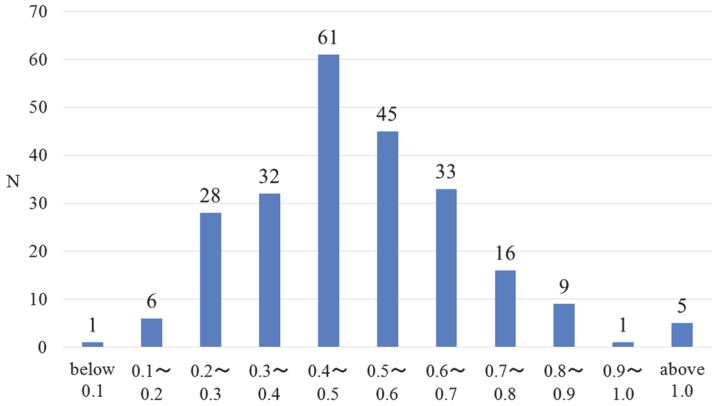


Fig. 1 Smallest Is of all condos by the result.

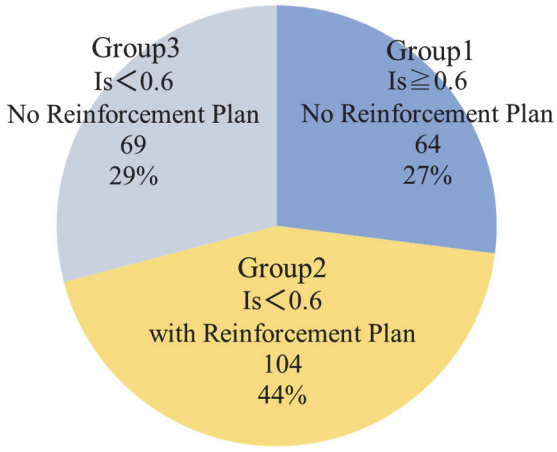


Fig. 2 The ratio of the reinforcement on condos by the result.

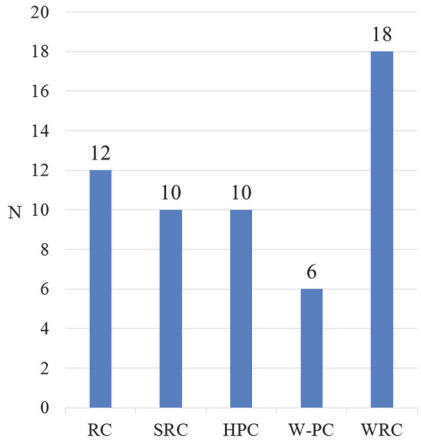


Fig. 3 Structure type classification of non-reinforcement condos, Is ≧0.6.

3. Analysis of Reinforcement Plans in Condos

3-1. The Outline of Reinforcement Target Condos. The targets of the reinforcement are 104 condos, completed from 1966 to 1981 fiscal year. That is why there are no condos designed by new aseismic design law, and 20 condos were designed before 1971, those hoop-pitch of columns are beyond 100 mm.

The structure classification in reinforcement target condos is shown in *Fig.4.* 43 condos, 41.8% of total, are RC construction and average number of stories is 5.8 stories. 33 condos are SRC, and average number of stories is 11.5 stories. Mixed structure is defined as lower part of building is SRC, and upper part of building is RC. 27 condos are mixed structure, and average number of stories is 9.9stories. So, the

average number of its stories are a little shorter compared with the number of that whole stories are built with SRC.

The number of stories above ground on the reinforcement target condos is shown in *Fig.5*. 7 storied condos are 16 that are the most in number, 15.5% of total. Middle-high-rise condos, more than 10th floor, built with SRC or mixed structure are the second one, there are 44 condos, 42.7% of total.

The structural feature of the reinforcement condos are shown in *Fig.6.* The rhamen structures with shear wall are predominant in RC, SRC and mixed structure. The ridge direction, the condos built with rhamen system has wing walls, some kind of non-structural walls and something. Therefore the wall volume is insufficient. On the other hand, the span direction, condo has lots of shear walls of residents border use. And there are a lot of setbacks to use up the ratio of building volume. Unexpectedly, there are only 4 condos with piloti on the 1st floor.

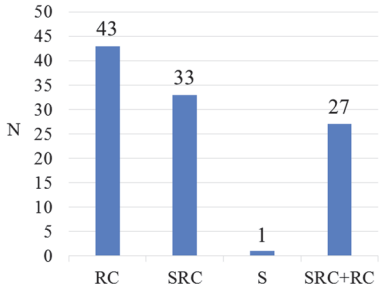


Fig. 4 Structure classification in reinforce condos.

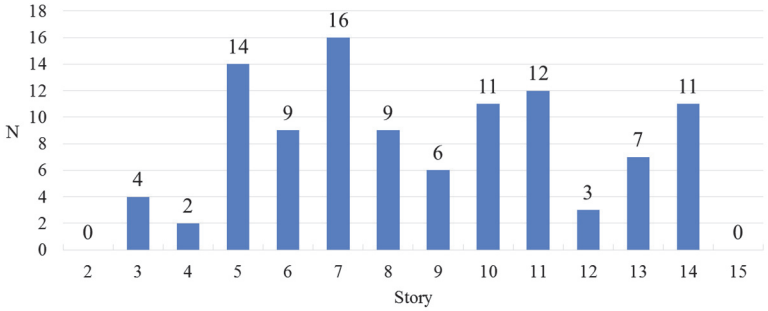


Fig. 5 The number of stories above ground in reinforce condos.

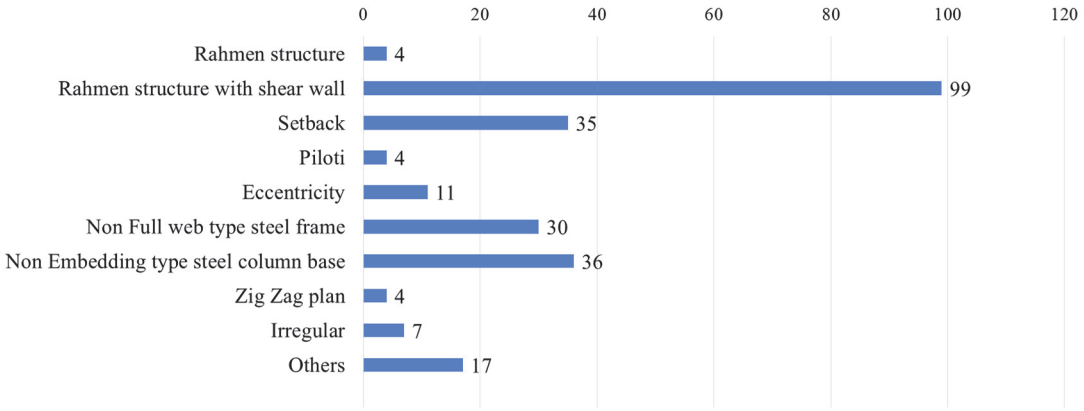


Fig. 6 The structural feature of the reinforcement condos.

The distribution of the smallest concrete strength by concrete coring in condos is shown in *Fig.7*. The average concrete coring strength is below design standard strength Fc=20.6 N/mm^2 in most condos. Still more, low strength concrete defined by its strength is less than 13.5 N/mm^2 was detected. In regard, there is concern to use the anchor-bolt to that low strength concrete. The average carbonation depth is indicated in *Fig.8*. This shows the carbonation depth of 62 condos, 59.6% of total, is below1.0cm. The carbonation depth of condos isn't deep considering almost condos have been passing 50 years after completion.

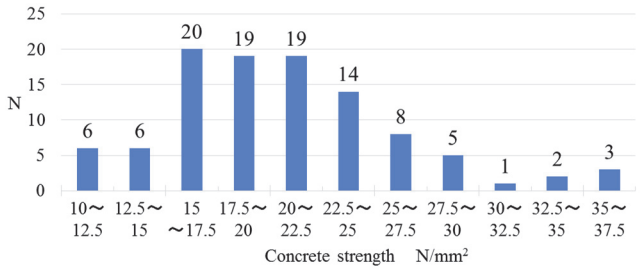


Fig. 7 Average depth of carbonation in condos

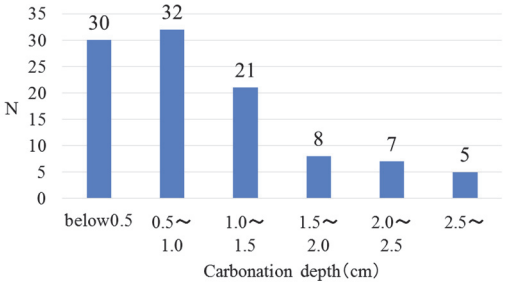


Fig. 8 Distribution of min. concrete strength in condos

3-2. Is value and ΔIs. The number of condos and the smallest Is by seismic evaluation on each condos is shown in *Fig.9.* The Is is smallest Is in floors and both directions. For most condos, Is value indicates more than 0.4 and less than 0.6, but there are serious ones i.e. Is value is less than 0.3. The number of condos and increased Is value, ΔIs, by the reinforcement is shown in *Fig.10.*

80 condos, 77.7% of total, Δ Is less than 0.3, are the most common. And there are 22 condos, 22.3 % of total, Δ Is were increased more than 0.3.

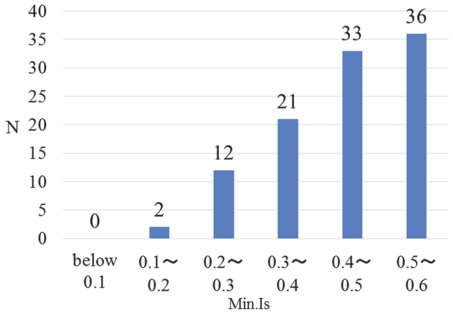


Fig. 9 Smallest Is value by seismic evaluation

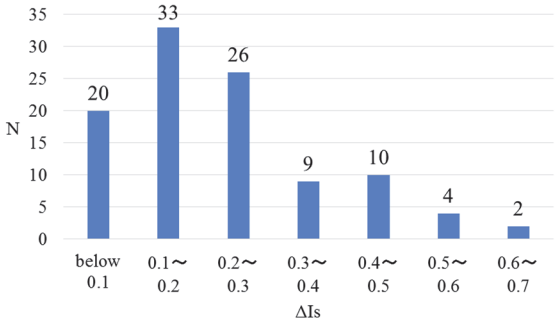


Fig. 10 Increased Is value Δ Is by reinforcement

The most common reasons which Is by seismic evaluation is small, is lack of strength by uneven distribution of shear wall. The second ones are that ductility index is small by existence of extremely brittle columns and large eccentricity, lower floor column without wall.
Because of the difference in the shear wall volume of the ridge direction and span direction, Is values of both directions are different and it is particular to condo. Various small opening like fanlight opening, door opening and equipment opening in the ridge direction make columns easily brittle. (*Fig.11*)

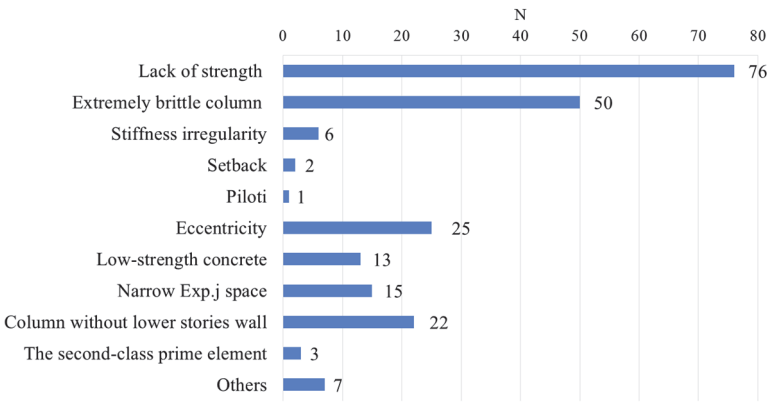
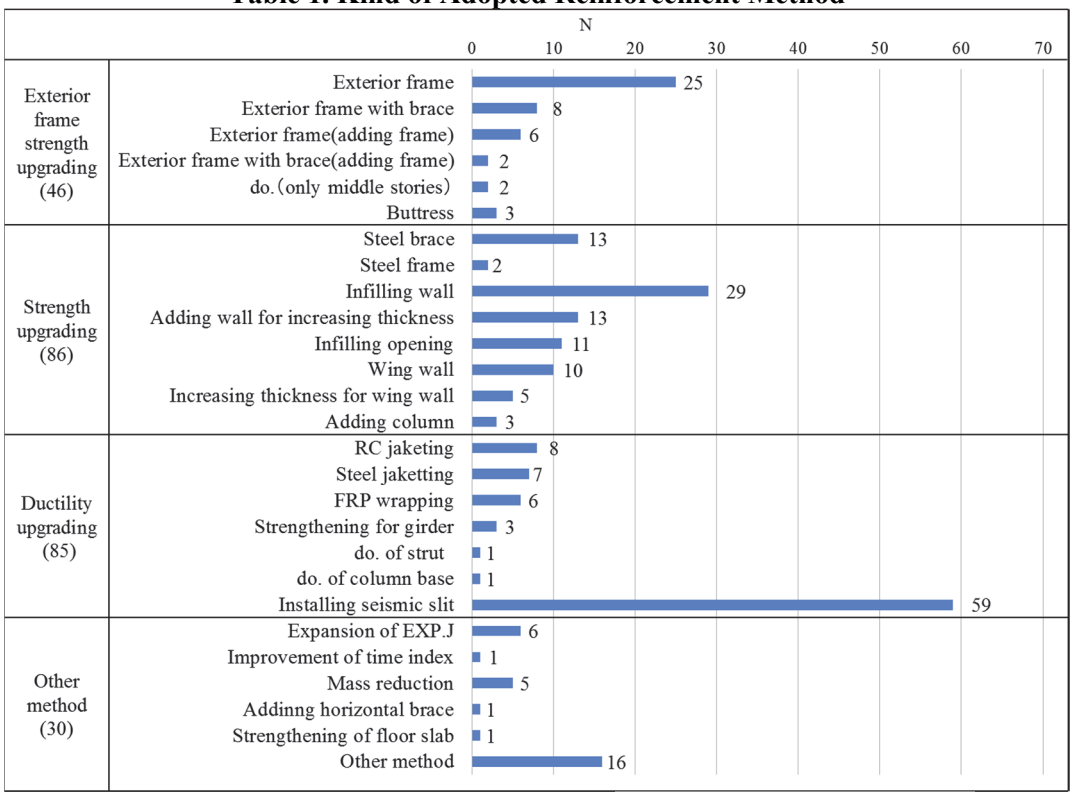


Fig. 11 The structural weak points of condos by seismic evaluation

3-3. Adopted reinforcement method. Adopted reinforcement method and its adoption number are shown in *Table.1*. The number of condos adopted seismic slit are 59. It is 57.3% of total condos. Installing seismic slit is basic method to improve ductility index in extremely brittle columns and extremely brittle wing walls. For upgrading strength, infilling wall and adding wall for increasing thickness method are adopted in 42 condos and steel braces method are used in 13 condos. It is particular to condo to adopt exterior frame method and frame adding outside existing condos in *Fig.12*. In this case, 46 condos, 44.7% of total, adopted those methods. There are also 3 condos adopted buttress reinforcement, and if having enough room for site, it's effective. 21 condos are adopted RC jacketing column method and steel jacketing column method as ductility upgrading. But there is just 3 condos adopted beam reinforcement. As other reinforcement, weight reduction is in 6 condos, EXP.J expansion is in 5 condos. Nowadays, adopted reinforcement methods are quite various.

Table 1. Kind of Adopted Reinforcement Method



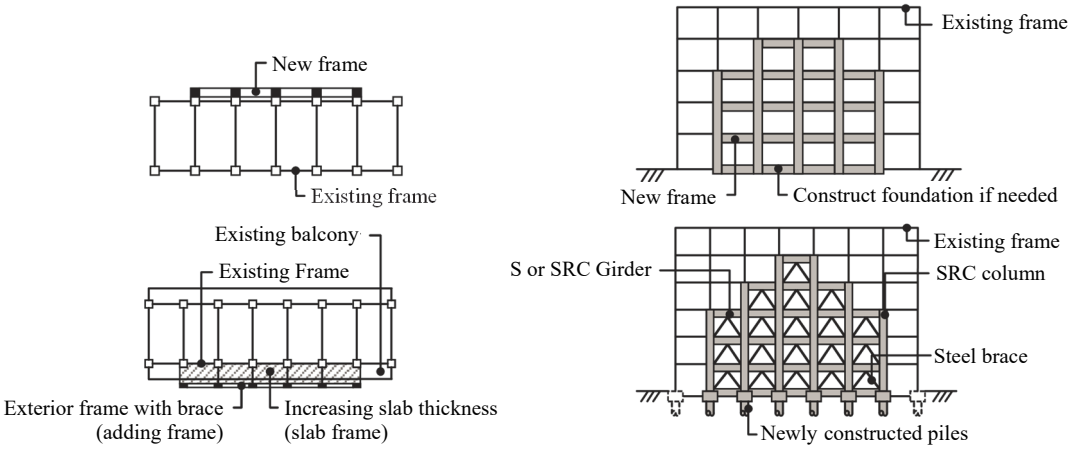


Fig. 12 Exterior Frame and Exterior Frame with Brace (adding frame) (reference 2)).

The number of adopted reinforcement method in one condo and number of these case condos are shown in *Fig.13*. The condos reinforced with only one method are 31, 29.8% of total, and that with less than 3 kinds of reinforcement method are 84, 80.8% of total, and it occupies the most. The reinforcement method of among 104 condos ,49 condos which Δ Is ≧0.2 are investigated.

The reinforcement methods is consist of three, i.e. exterior frame strength upgrading method, strength upgrading method and ductility upgrading method. The result is shown in *Fig.14*. The exterior frame upgrading method is adopted much more than conventional method except for the case Δ Is is large extremely.

The exterior frame upgrading method come to popular because it makes construction work possible to be conducted while people are staying in condos.

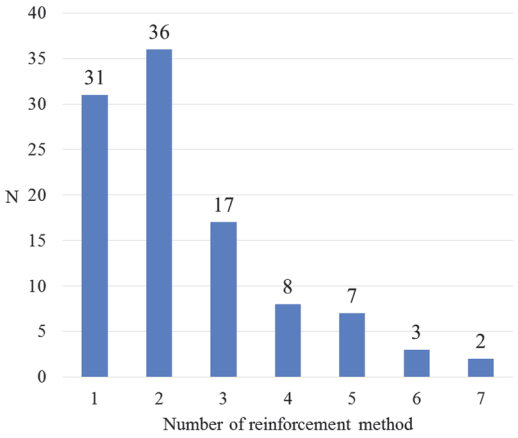


Fig. 13 The number of adopted reinforcement method in one condo.

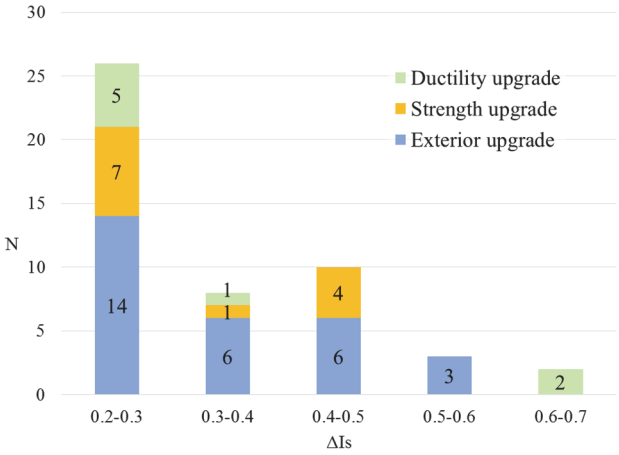


Fig. 14 Reinforcement method used for Δ Is ≧0.2 condos.

3-4 The examination of SRC and Mixed structure. As shown in *Fig15,* the ratio of the floor including steel frames is 43% (7 story) to 64% (14 story) to all floors in mixed structures. And it seems natural for the ratio of steel frame become increasing according to the condos height.

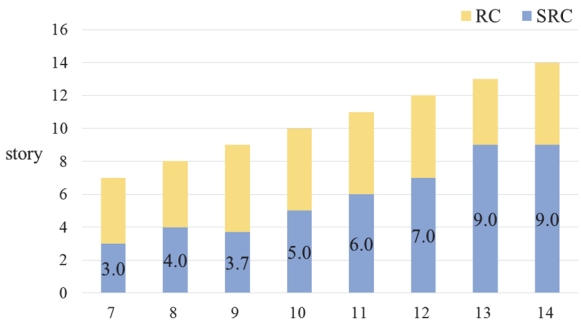


Fig. 15 The number of floors including steel frames in mixed structures.

The mean Is in ridge direction and span direction of each floor about 10 storied (8 condos) and 11 storied (5condos) is indicated in *Fig.*16. Is value in span direction where shear wall exists is much larger than Is in ridge direction. Is value along height direction in mixed structure condos are low in middle floors as shown in *Fig.16.* Because Is value can be found below 0.6, middle floors reinforcement become necessary. This would happen in accordance with the influence of the change of the structure in the middle floors from SRC to RC.
It's also supposed to link with the middle floor collapses observed in Hyogo-ken Nanbu Earthquake.

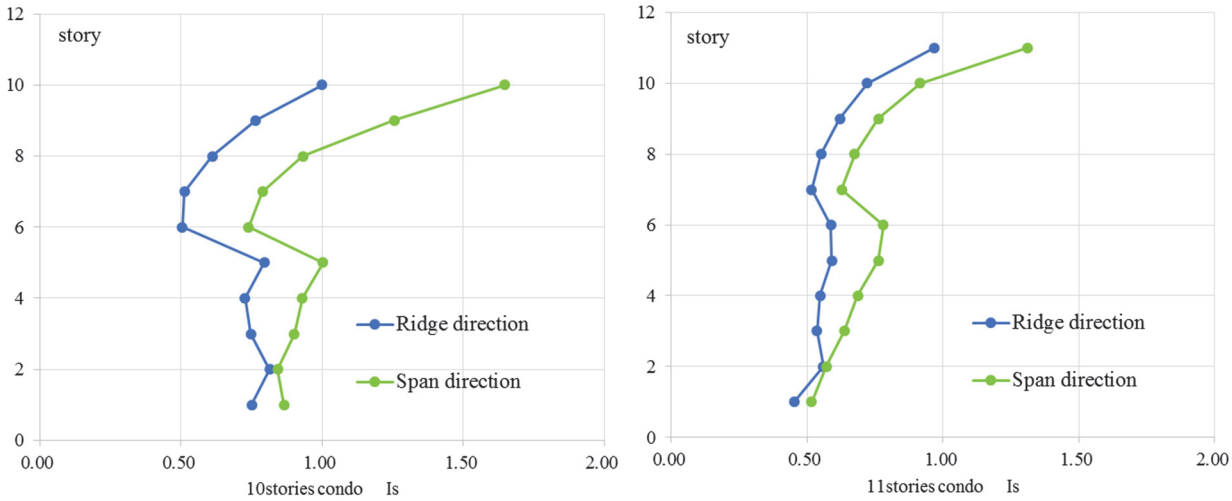


Fig. 16 Mean Is value distribution of the condo along height direction in mixed structure.

The investigation results of 33 condos columns in all SRC structure and 27 SRC columns in mixed structure are shown in *Fig.17*. From these results, non-full web steel frame (grid-shaped, see *Fig.18*) are 30 condos, 50% of all, and non-embedding type column base are 36 condos, 60 % of all.

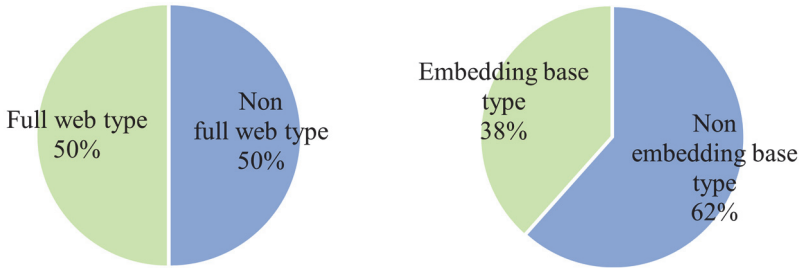


Fig. 17 The ratio of non-full web steel frame and non-embedded column base in SRC and mixed structure.

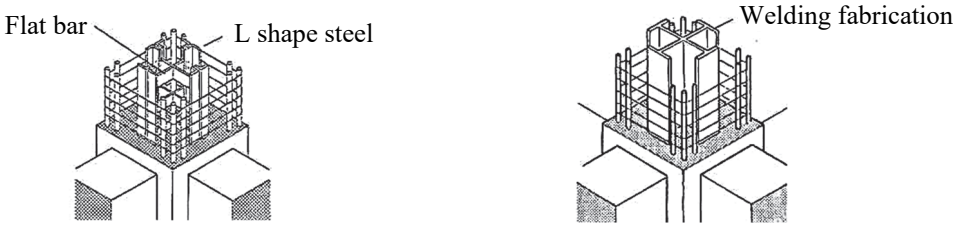


Fig. 18 non-full web steel frame (grid-shaped) and full web steel frame

4. The cause and the Measure, Why the Seismic Retrofit in Japanese Condos Doesn't Make Progress

The several causes are considered as follows.

1. Aging of the resident and the building is progressing, the resident can’t afford to pay expensive retrofit cost.
2. To form a consensus in condo management society is quite difficult, because it's a condominium.

The next measures are taken by public administration and structural engineers association, because there is a fear that the next big earthquake would happen soon without aseismic reinforcement in the current state of affairs.

Public administration measure

3. The expansion of support by local government on seismic retrofit cost.
4. The proposition of gradual method on retrofit cost and retrofit method
5. The Provision new system to give a continual advice like adviser delegation.

Structural engineer's association proposal

1. Minimum reinforcement should be done to the part that would bring about fatal damage during earthquake, like collapse.
2. The proposition of reinforcement method that is handy and low in cost.

5. Conclusion

1. Major condos are necessary to conduct seismic retrofit, as a result of the seismic evaluation on condos, however seismic retrofit haven't made progress yet.
2. The proposed seismic retrofit method are a lot of exterior frame upgrading method because of construction work while staying in residents. But some attention shoud to be pay to anchor strength in low strength concrete. When Is value of middle floors is small in mixed structure, it's also necessary to conduct middle floors reinforcement.
3. To promote seismic retrofit of condos, the expansion of public support funds and the gradual method of reinforcement are necessary. The most important thing is providing new system to encourage resident to make seismic retrofit and give continuous advice to the condos residents all the time.
4. Lastly, structural engineers have to make effort to reduce the burden i.e. dangerous condo buildings i.e. social negative legacy, for the next generation.

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