3. RECENT NEW APPROACHES FOR SEISMIC RETROFIT IN JAPAN

As described before, the rapid increase of buildings to retrofit has caused wider variety of their structural or architectural types in Japan. In some cases, conventional seismic retrofit schemes can not be applied since one or more of the following conditions may often have higher priority in determining available retrofit scheme.

- Limit of construction spaces, period and time
- Noise, vibration, dust during work
- Preservation of architectural and/or structural design
- Functional performance as well as structural performance
- Serviceability during construction

Recently both communities of researchers and practitioners in Japan are trying to develop new but reliable and cost-effective techniques which include innovative technologies such as the use of seismic isolation, supplemental energy dissipation, active control, high performance materials etc. to improve the safety of existing seismically vulnerable buildings. In this chapter, the author will focus on introducing seismic retrofit techniques which were recently developed and applied, or will be applied in the near future.*

Latticed shear wall with concrete-encased steel unit members

Installation of new shear walls in existing frames is one of the most conventional and convinced retrofit schemes to increase the lateral strength of existing building. However, this scheme has disadvantage such as increase in weight, less flexibility in architectural design/planning, difficulties in providing natural lighting and ventilation. The latticed shear wall consists of precast concrete unit members which are bolted each other, and post-installed anchors connects the new wall with existing beams and columns through reinforced concrete boundary frame. Figure 5 shows general view of the wall and Figure 6 shows a typical subassemblage consisting of four unit members.

The latticed wall can provide the lateral resistance as much as conventional retrofit schemes such as new shear wall or steel framed brace. Furthermore, the latticed wall has a major advantage over conventional schemes since it can provide higher quality, facilitate assembling and reduce construction period due to precast fabrication of the unit members. In addition, it has higher flexibility in architectural design which can provide openings for natural lighting and ventilation.

Figure 7 shows the load-deflection relationship of the latticed wall which was installed in an RC frame specimen with 6.75 m span length and 4.0 m story height, and was tested under load reversals. The specimen

* Most of original figures and photos presented in this chapter can be found in Ref 4.

exhibited the maximumlateralresistance of 700 tonfwhichcorresponds to the average shear stress of approximately 50 kgf/cm^2 in an equivalent monolithic RC wall with 20 cm thickness.

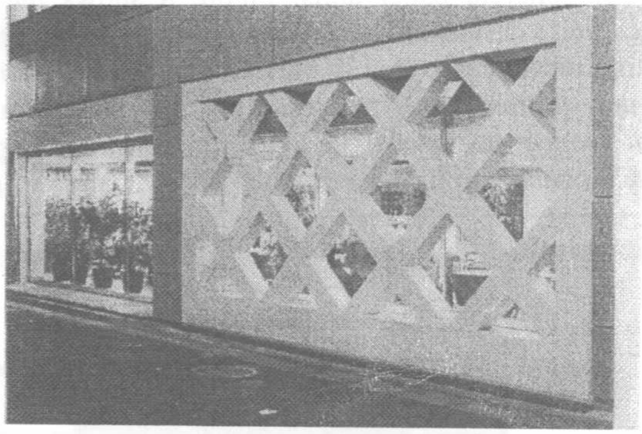


Figure 5. General view of latticed shear wall [4)]

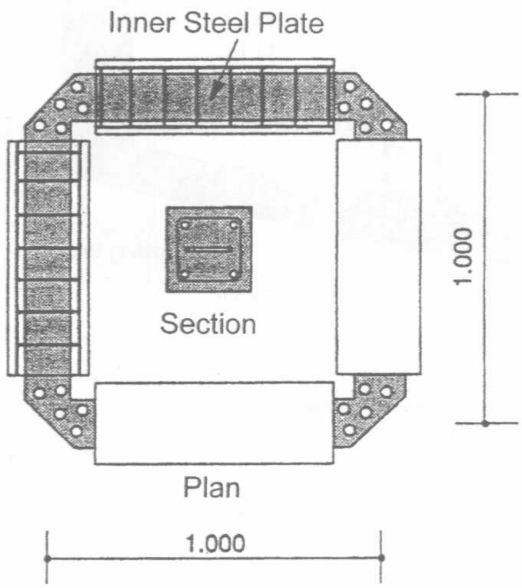


Figure 6. Typical □-shaped subassemblage consisting of four unit members [4)]

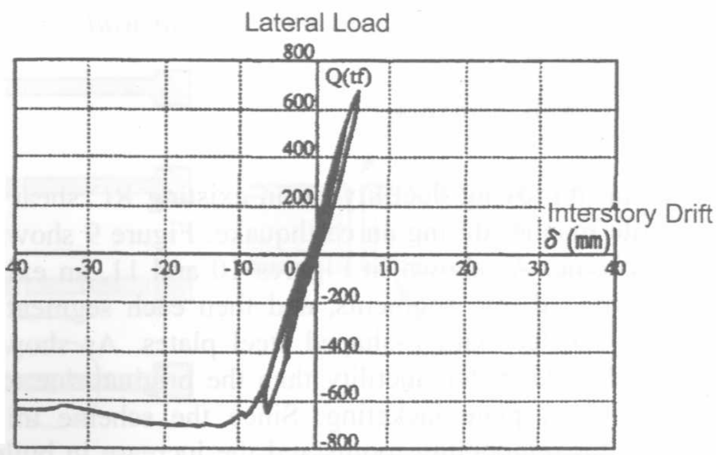


Figure 7. Load-deflection relationship of latticed shear wall specimen [4)]

Precast concrete shear wall

This scheme aims at infilling a new shear wall through assembling light-weight precast concrete panel units. Figure 8 shows the outline of the scheme. Each unit consists of two precast concrete panels glued each other, and connecting rebars embedded in the unit and bonded anchors are used to fasten the unit with existing beams. This technique can minimize the disruption of users or occupants due to shorter construction period resulting from dry-wall construction and reduction in size and weight of infilling units.

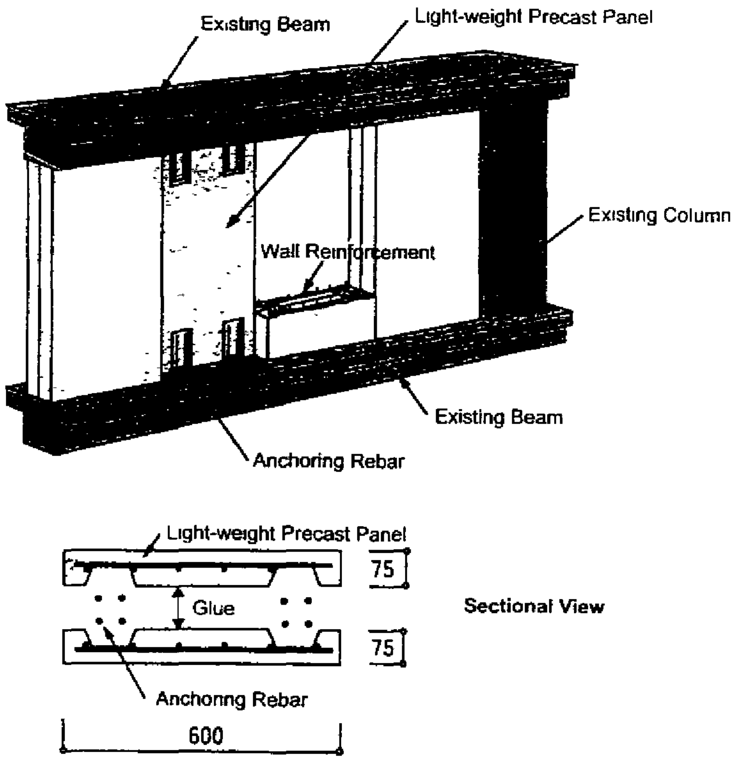


Figure 8. General view of precast concrete shear wall

Steel jacketing of slit RC wall elements

This scheme aims at improving ductility of an existing RC shear wall which may fail in brittle manner during an earthquake. Figure 9 shows the basic concept of the scheme. As shown in Figures 10 and 11, an existing wall panel is slit and divided into segments, and then each segment and boundary columns are jacketed with L-shaped steel plates. As shown in Figure 12, test results showed better ductility than the original due to the confinement effects by steel plate jacketing. Since the scheme utilizes existing walls, the need for remodeling rooms and the increase in building weight can be minimized.

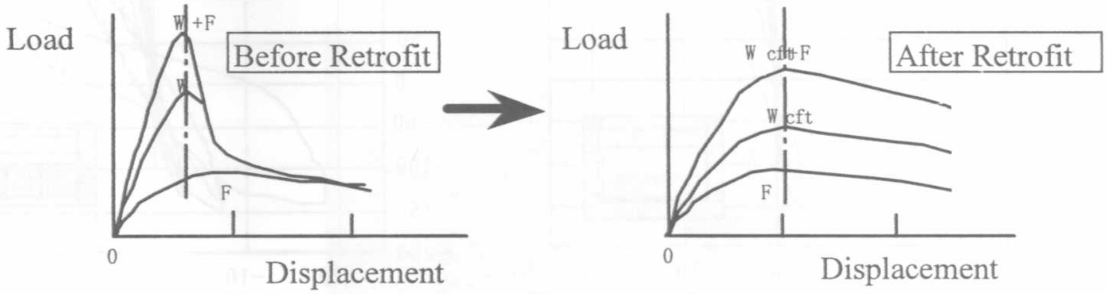


Figure 9. Basic concept of steel jacketed slit wall [4)]

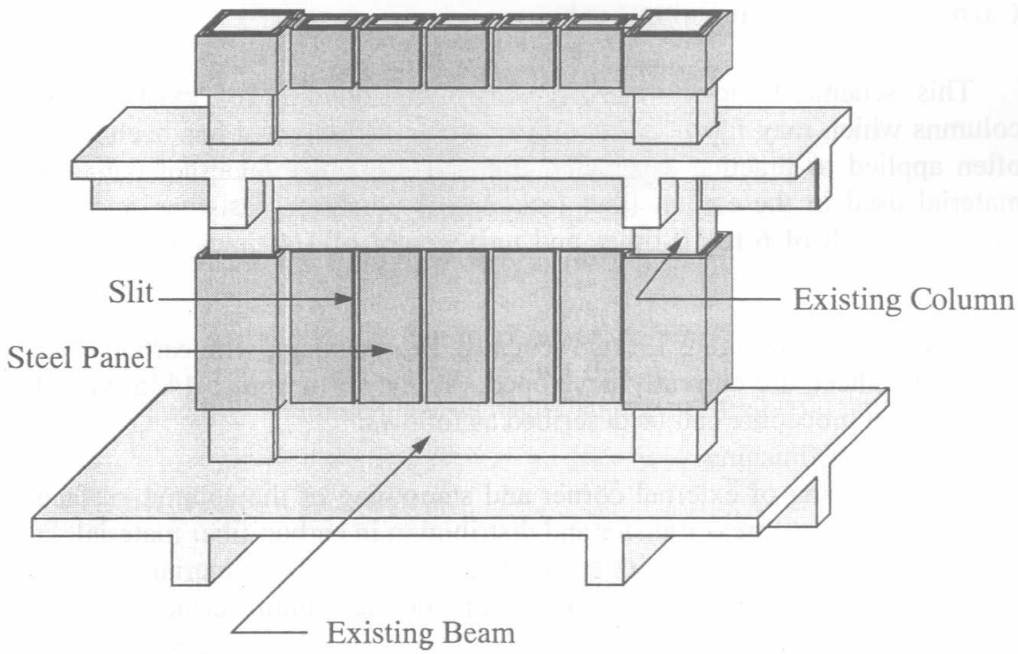


Figure 10. General view of steel jacketed slit wall [4)]

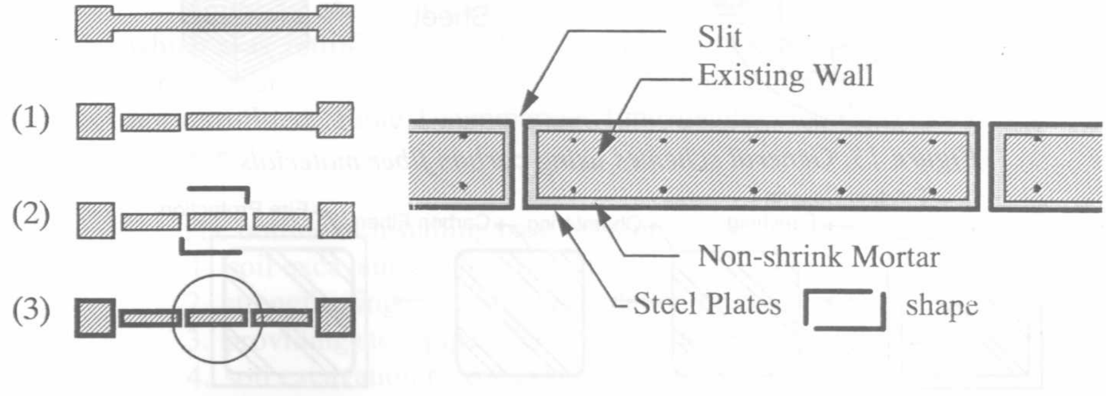


Figure 11. Construction procedures of steel jacketed slit wall [4)]

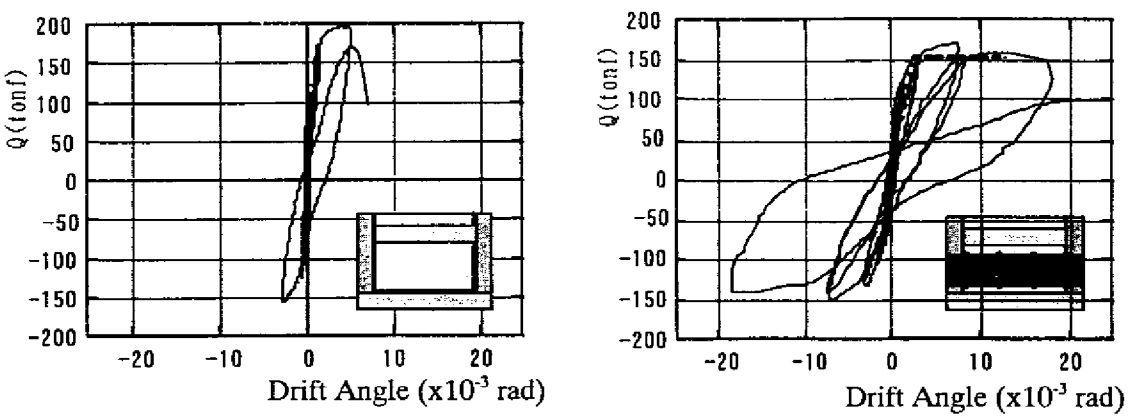


Figure 12. Test results of steel jacketed slit wall [4]

Carbon fiber jacketing of RC columns

This scheme basically aims at improving ductility of existing RC columns which may fail in shear during an earthquake, and has been more often applied to practice especially after the 1995 Kobe earthquake. The material used in the carbon fiber jacketing is corrosion resistive, and has tensile strength of 6 to 10 times and unit weight of 1/4 times as much as steel.

As illustrated in Figure 13, two schemes, i.e., jacketing with carbon fiber strand and sheet, are currently developed. As shown in Figure 14, a typical construction procedure can be described as follows:

1. removal of finishing
2. chamfering of external corner and smoothing of the column surface for uniform stress transfer and distribution in carbon fiber material
3. jacketing of column with epoxy dipped carbon fiber material
4. providing fire protection and finishing on the column surface

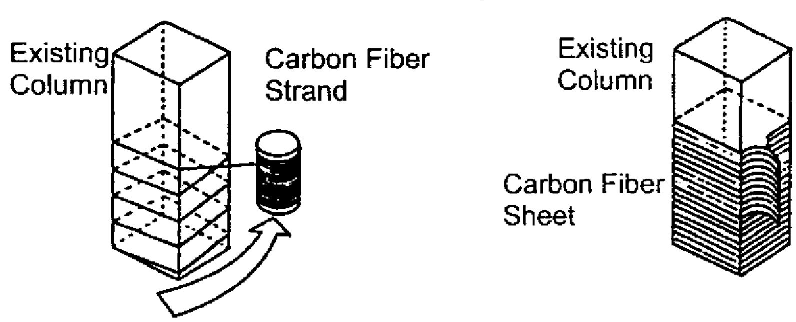


Figure 13. General schemes using carbon fiber materials [4]

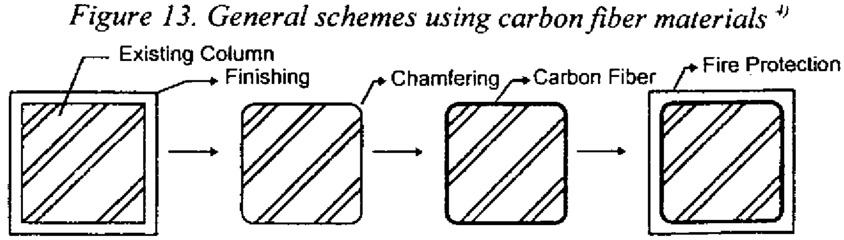


Figure 14. Construction process of carbon fiber jacketing [4]

In the case of carbon fiber strand, a special device is often used to facilitate jacketing works as shown in Figure 15.

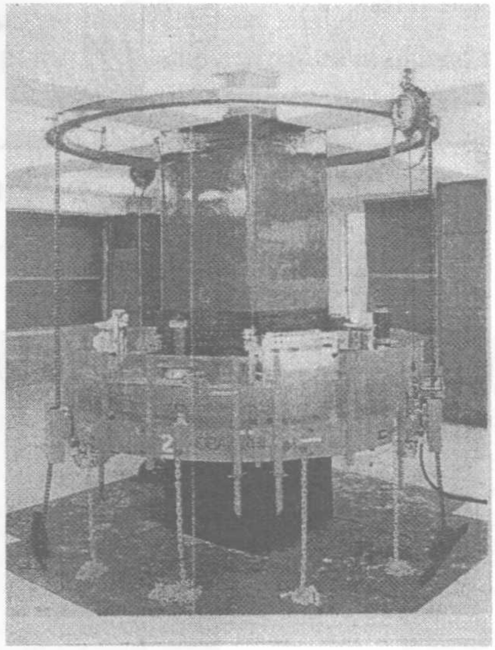


Figure 15. Jacketing device of column with carbon fiber strand [4)]

Figure 16 shows the comparison of responses between existing and retrofitted columns. It is clearly shown that the jacketed column had much larger ductility and much less damage than the existing column.

Seismic isolation techniques

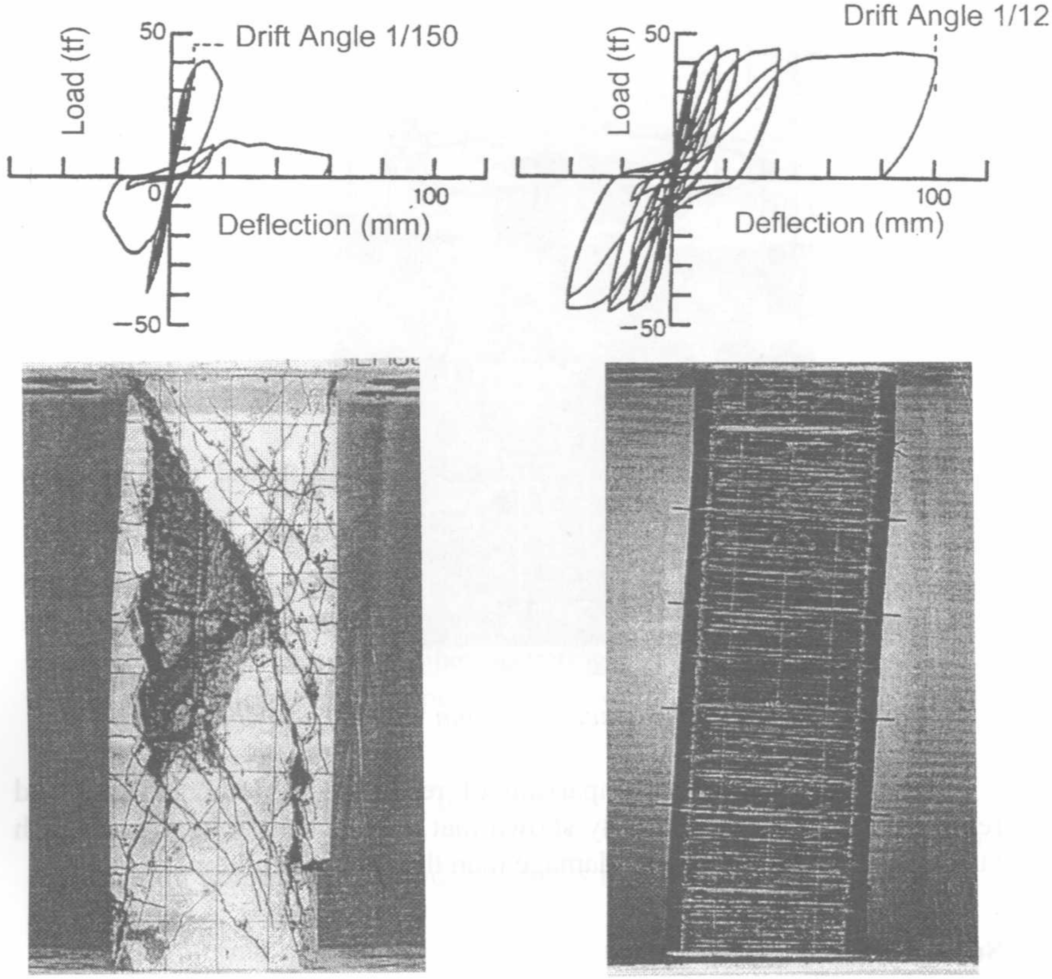
Retrofit schemes other than conventional technique are often desired especially in the case of buildings which need to preserve original structural system, architectural planning or design etc. This is especially so when the building has historical or architectural importance, and such buildings are often retrofitted with seismic isolation technique instead of retrofitting superstructure.

Figure 17 shows a three story art museum designed by Le Corbusier which was retrofitted with base isolation technique. Forty-nine laminated rubber bearings were installed below columns while the superstructure was not retrofitted. Table 1 summarizes fundamental characteristics of the base isolators.

The outline of installing base isolator can be summarized as follows:

1. soil excavation below the building
2. strengthening of existing foundation beams
3. providing steel pipe piles to temporarily support the superstructure
4. soil excavation below existing footings
5. providing mat foundation below footings

6. installation of base isolators
7. cut-off of temporary steel pipe piles



(a) Before retrofit (b) After retrofit

Figure 16. Comparison of performances [4)]

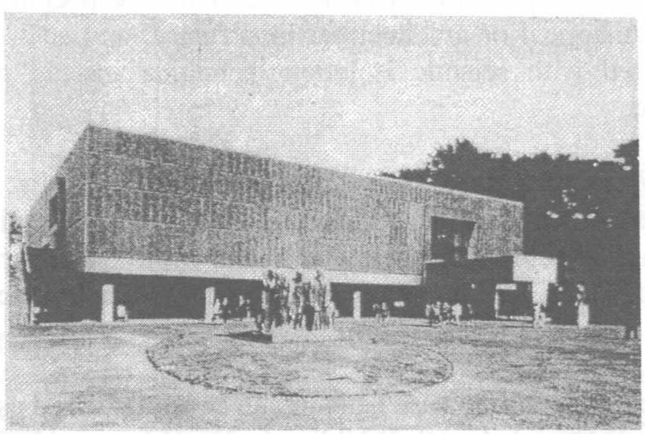


Figure 17. General view of art museum (before retrofit) [4)]

TABLE 1. FUNDAMENTAL CHARACTERISTICS OF BASE ISOLATORS

Bearing type	high damping laminated rubber
Diameter	650 mm or 600 mm
Max. allowable drift	40 cm