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# Repair and Reinforcement of Concrete Structures by Steel Shear Walls

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**Abstract**: Steel shear walls have been given special attention by structural engineers for the reinforcement of steel buildings in the last 51 years.Its unique features have attracted more attention; its features include its economy, easy execution, low weight compared to similar systems, high ductility, fast installation, high-energyabsorption, and significant reduction of residual stress in the structure.All the reasons led us to study its use in the restoration of concrete buildings, because this system is lightweight, it does not add extra load to the structure and even strengthens the beams and columns around it with its connections.In addition, this system does not require special equipment and can be connected to other structural components without draining the building and destroying structural members.Of course, the design of this system in concrete buildings does not seem to be economical without restoration.

In this paper, initial explanations of the steel shear wall for further familiarity are presented, and in the following sections, the study in strengthening and repairing concrete structures will be studied. The difference with LYP is that the behavior of steel shear panels will be considered in the same bracing system, and finally the test results will be examined.

**Keywords:** Concrete structures, Steel shear wall, Strengthening

## 1. Introduction

In recent years, SSW steel shear walls have been proposed and considered in order to capture the lateral forces of earthquake and wind in tall buildings.This new phenomenon, which is spreading rapidly in the world, has been used in the construction of new buildings as well as the strengthening of existing buildings, especially in earthquake-prone countries such as the United States and Japan.Their use, compared to moment frames, saves up to 2% on steel consumption in buildings.

Steel shear walls are a very simple system in terms of performance and there is no special complexity in it.Therefore, engineers, technicians, and technical workers with the existing technical knowledge can implement it without the need to acquire new skills.The accuracy of the work is at the normal level in the execution of steel structures and by observing it, the executive reliability coefficient is much higher than other types of systems.Due to the simplicity and possibility of its construction in the factory and its installation in place, the speed of system implementation is high and the executive costs are reduced to a high level.In terms of shear stiffness, the system is more difficult than the most rigid X-shaped bracing systems, and due to the possibility of opening in any part of it, it has the efficiency of all bracing systems in this regard.

In addition, the behavior of the system in the plastic environment and its energy absorption rate is better than the bracing systems.In the steel shear wall system, due to the wide range of materials and connections, the adjustment of stresses is much better than other systems resistant to lateral loads such as frames and restraints, in which the materials are usually grouped and concentrated, and the behavior of the system is more appropriate, especially in a plastic environment.

Preliminary reports from research conducted in 2000 at the Davis Hall Structures Laboratory at the University of California, Berkeley show that the capacity of steel shear walls to withstand hazards such as earthquakes, storms, and explosions is at least 25% higher than that of other systems such as special moment frames.It has been used in research laboratories with a capacity of about 6670 KN.The experiments show that steel shear walls have a very high ductility.Given the importance of the budget, this research funded by the National Science Foundation and the Office of Public Services of America to provide a reliable system for building federal buildings to withstand hazards such as earthquakes, storms, and bombs.

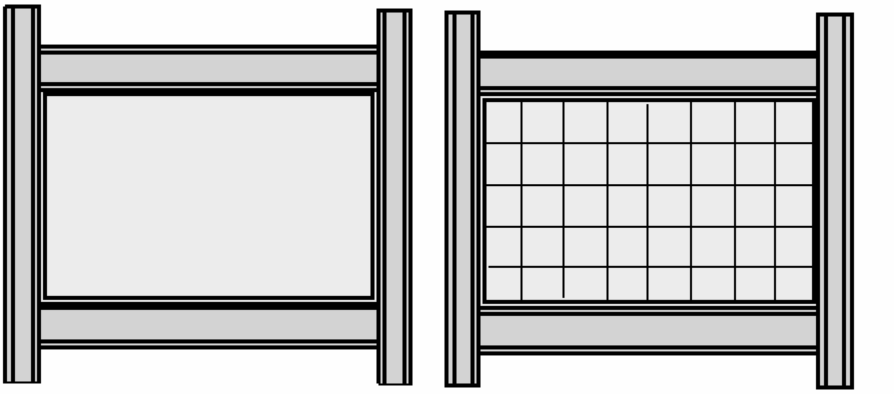


Figure 1. Steel shear wall in steel structures with hardener and without hardener

## 2. Buildings made of steel shear wall:

The first building to use this method was a hospital in Los Angeles called Sylmar Hospital.

One of the largest structures built with the steel shear wall system is the Shinjuku Nomura building in Tokyo, which has 51 floors and its height is 211 meters.The 5 floors are located in the basement and are 2 meters below ground level. To avoid the use of concrete shear walls, a steel shear wall system was used in the central core of the building, which is around elevators, stairs, and installation risers.

One of the applications of these panels is in the reinforcement of concrete structures in the Charleston Medical Center building, which was damaged by the 1963 earthquake.The building consists of several buildings from 1 to 5 floors, the foundation of which is about 32500 m$^2$.The best design and research team was used to strengthen this structure.After many studies, this system was considered appropriate for the following reasons:

- Prevent daily disruption and reduce problems for patients due to the speed of its installation
- Prevent the reduction of useful infrastructure and waste of space
- Predicting the possibility of future changes, because in the steel shear wall, the desired changes can be easily made, either by moving the architecture or by creating an opening due to the passage of the facility.
- Prevent structural weight gain

In addition to the above buildings, many structures such as:

Van Mellon Bank's five-story central building in Pittsburgh, Pennsylvania, USA
51-story residential building in San Francisco
25 story building in Edmonton, Canada
32 story building of Byer-Hochhaus in Leverkusen, Germany
20 story federal courthouse in Seattle, USA

To strengthen the concrete building, the state library of Oregon can be named in which a steel shear wall has been used for reinforcement.

## 3. Introducing a steel shear wall system for reinforcing concrete structures

A 1995 earthquake in Hugoken-Nanbu, a devastating earthquake, killed and injured many people.Many buildings were severely damaged, and buildings built before 1981, and especially before 1971, were severely damaged and some even collapsed.

This indicates that the old regulations for building design did not properly consider earthquake forces and structural ductility.

In 1999, an earthquake in Taiwan's Chi-Chi also caused extensive damage and destroyed many structures.These buildings, which were designed and built before 1983, were demolished again, and after the 1999 earthquake, all the rules and regulations of the earthquake were revised and all the previous regulations were repealed.Regional seismic coefficients were generated and generated in each Taiwan region.For example, the magnitude of the earthquake in the Taichung region increased from 0.23 g to 0.33 g.As a result, almost all buildings in Taichung need to be rehabilitated in accordance with the new design regulations.The aim of this project is to increase and improve the seismic strength of reinforced concrete buildings.This project includes three sub-categories, which include:

Finding and realizing the lack of seismic strength of existing reinforced concrete buildings according to the new regulations

The problem of the forces acting on the adjacent structures due to their excessive lateral displacement

Research on two methods for absorbing energy by steel shear panels and steel braces to improve seismic strength of existing structures.

## 4. Seismic characteristics of steel shear panels with low yieldpoint (LYP):

The use of steel shear walls improves the seismic strength of the system in the design of new buildings and strengthens the constructed buildings.Thin steel plates tend to buckle, so the energy absorption capacity of these plates is limited.

Recently, new methods and technologies in the field of metals have made new steel plates available to us.These types of steel have lower yield stress and high length, and show the ability to deform and absorb more energy before breaking.Another feature is the low yield point, which increases the plastic area and absorbs more stress.

LYP steel shear panels are capable of absorbing and wasting a lot of energy and can be used in new buildings.These types of panels, like the steel shear wall, are designed and manufactured relative to earthquake forces.Because these panels have high-energy absorption and loss characteristics, they can be used as dampers to dampen seismic energy.These types of metal dampers have sufficient strength when absorbing energy and do not require maintenance and repair compared to the dampers currently in use.

Yield point and the end of the LYP plates are both affected by the strain rate.In this study, the effect of strain rate and loading method on the seismic strength characteristics of the plate panel has been tested.The experimental set is a study of the behavior of shear panels made of LYP steel under different loading speeds and developmental displacements.

### Experimental studies on steel shear panel of LYP

Shear steel panel, made of steel with low yield point, is an effective factor for high-energy absorption.With proper design and construction of steel shear panels, large amounts of seismic energy can be used to absorb and dissipate.However, the structural behavior of this type of shear panel is affected by the strain intensity.

In 9 samples tested in the experiment, their behavior was evaluated in each of the different loading modes.Figures 2 and 3 show how the samples were designed and the experiments were performed, respectively.In these examples, the width-to-thickness ratio of panel is taken 50.The outer edges of the members are shaved to prevent cracks between the edge, the panel and the column foot plate.This is due to avoiding the focus of stress and diverting the plate to the plastic area we discussed earlier.In this study, the loading history of steel shear panel has been tested and examined.Three loading speeds of 2.5, 5 and 100 mm.s$^{-1}$ are selected.

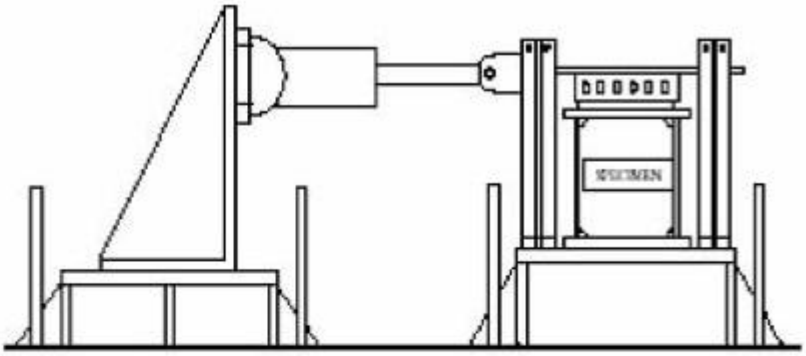


Figure 2. How to test

To achieve the strain velocity of these samples, gradual loading is applied instead of seismic load.For all three different modes, we accept δy, 2δy, and 3dy displacements in each loading period of the experiment.Testing on the structure is stopped until the strength reaches below 3% of the final strength. Table 1 shows the test results.

**Review of test results:**

Figure 4 shows the hysteresis ring behavior of shear panels.Studies show that their relative rotation is more than 5%, which is more than the lateral displacement angle required by the structure, which usually considers the relative rotation of the structures to be 2.5%, which further destroys the structure. By deformation the element and expected deformation the angle of the lateral displacement of 5%, it seems that it is enough for the shear panel.It is obvious that all the tested samples of their lateral displacement angle will be more than 5% as shown in Table 1.It can be seen that the fast and slow loading has made a difference of about 16%.

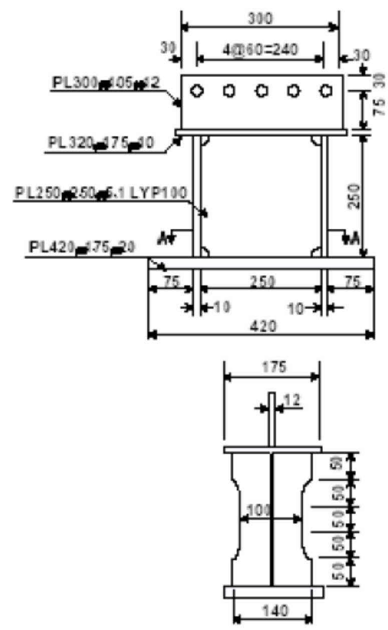


Figure 3. Sample longitudinal and transverse shear

The difference in the final strength of the LYP shear steel panel with the increase in uniform loading, the effect of the loading ratio on the total energy dissipation capacity can be neglected.Figure 4 shows that the tested steel panel has significant strength and energy absorption and is indifferent to the range of displacement in load or change in range of motion.

The amount of energy lost in the shear panels remains constant under any seismic loading conditions.The load-displacement curves of the shear panel are strongly influenced by the shear buckling of the thin steel plates.Usually the final strength gradually decreases after the shear buckling has occurred.

The final deformation capacity of the shear panel is affected by the ratio of width to thickness of the panel.In this study, the ratio of the width to the thickness of the tested sample was taken 50, and the onset of shear buckling occurs when its lateral deformation angle reaches 4%.Delay in shear buckling alone does not indicate an increase in the ductility capacity of the shear panel, but the reduction in damage to the non-structural elements depends on the shear panel.Figure 5 shows the amount of energy stored in all tested panels.

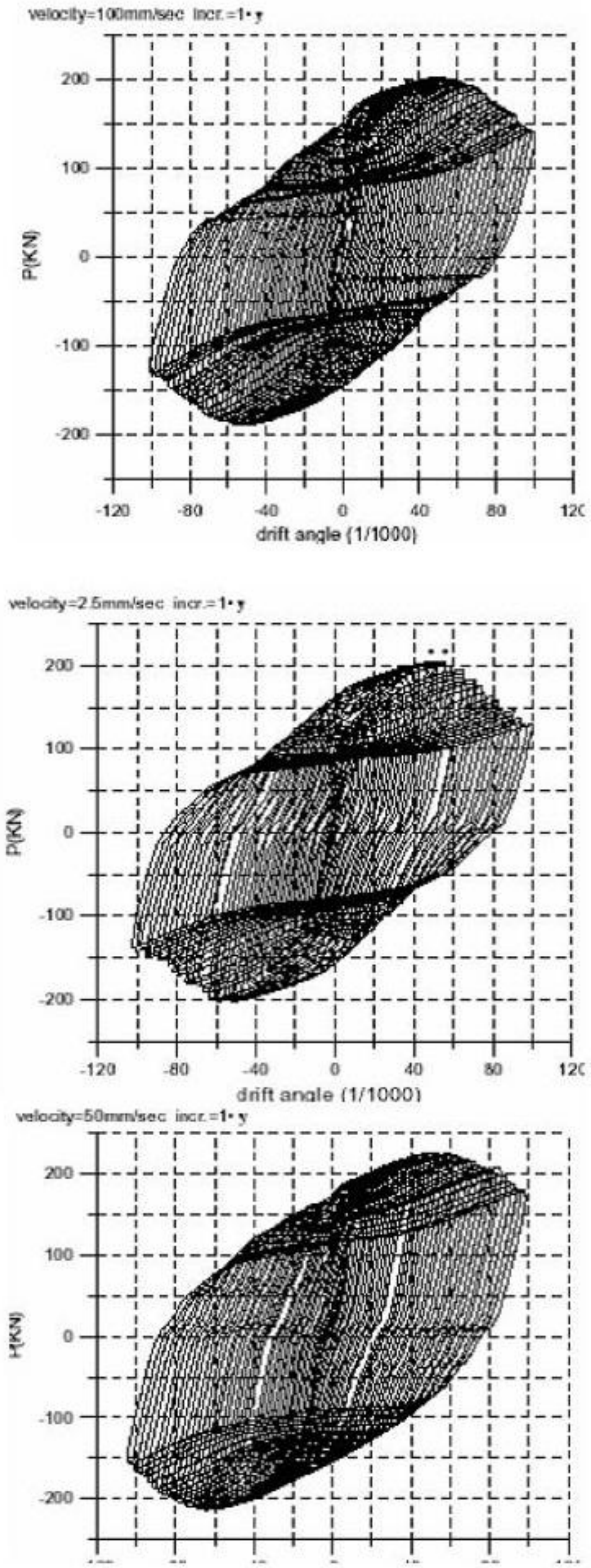


Figure 4.Hysteresis ring behaviorof steel shear panels

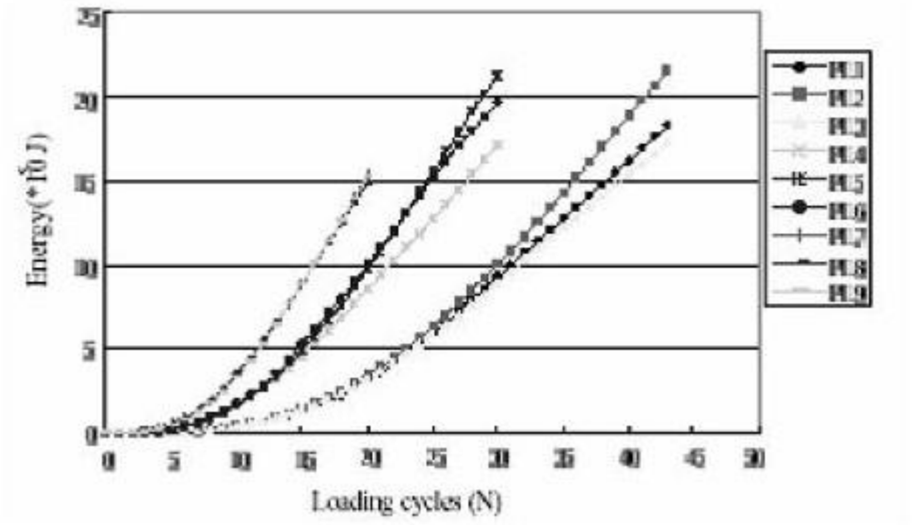


Figure 5. Collective energy in samples

In Figure 5, the total energy lost does not depend on loading and displacement, because vibrational periods are random in nature, these studies show that energy is indifferent to the loading history, and this is one of the advantages of a shear panel like seismic dampers.In shear panels, the energy dissipation remains constant under a random loading cycle.Steel panels can be effective for strengthening existing buildings.Experimental studies to strengthen concrete frames by steel shear dampers are described in the next section.

## 5. Seismic strength of structures using low final strength in bracing frames and shear panels:

### Braced frame (Cross brace)

Previous experience has shown that buildings that are not designed and constructed in accordance with today's regulations cannot withstand the force of an earthquake and suffer damage.

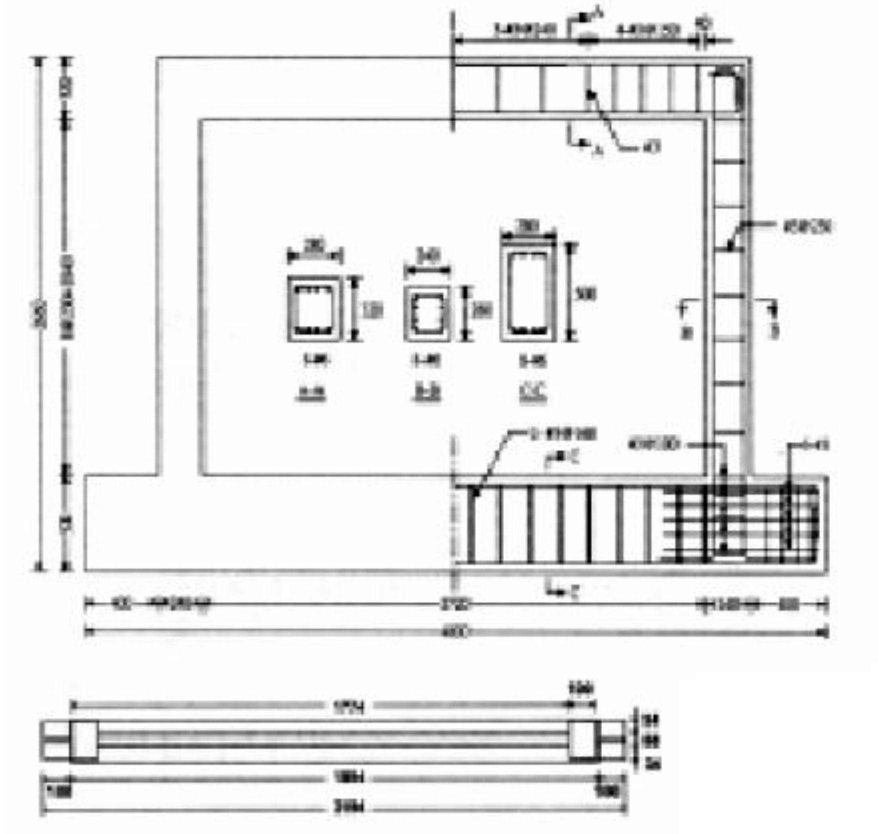
In Taiwan, these buildings are mostly reinforced concrete structures and need to be repaired to improve seismic strength.Moment frames (BIB) and fixed steel shear panels have high strength and high ductility and stable hysteresis rings.The braced frame includes loading elements and bracing elements for lateral loads.

Axial loads are controlled by the loading elements (beams) and the lateral supports of the element are responsible for preventing the buckling of the element.LYP steel shear walls, like a well-designed shear-loading element, can perform well against seismic forces.In this study, moment frames and steel shear walls have been used to strengthen concrete frames and the efficiency of each of them is investigated.

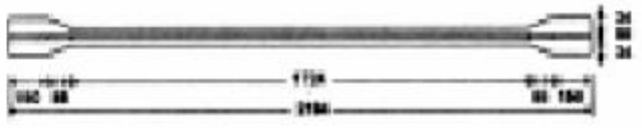
**Methods**:

The concrete frame is made with a scale of 0.8.Figure 6 shows the details of the concrete frame.One of the concrete frames is tested without reinforcement, which is designed according to MRF.The second example is a cross brace made of LYP100 steel designed according to BIBLYP.The third cross brace is made of A36 steel and is designed according to A36 BIB. The fourth sample is inhibited by a steel shear wall made of LYP100 steel.

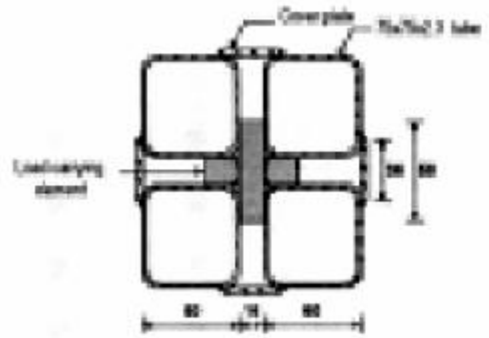
Figure 7 shows the details of the cross brace made of LYP 100.The yield point of the A36 steel cross brace is equal to the LYP cross brace.Details of the steel shear wall can be seen in Figure 3. The yield point of the shear wall is approximately equal to the LYP cross brace.



(a) Overall view



(b) Load-carrying element



(c) Cross section

Figure 6. Reinforced concrete frame details&Cross brace details with LYP steel

Each reinforcing element, such as a cross brace and a steel shear wall linked to a steel frame that is attached to the concrete and made from four to H 200*200*8*12 and shown in Figure 8 that the smaller H axis is sunk into the concrete frame.

Shear stud weldingare welded to H-shaped web pages.The cross braces and the steel shear wall are connected to the concrete frame along the steel frame, which is placed inside the steel and concrete frame.

The mechanical specifications of the used steel are shown in Table 2.Concrete compressive strength was obtained 21.8, 20.7, 25, and 23.7 MPa for MRF, BIB-LYP, BIB-A36, and SSW-LYP, respectively.The cyclic loading is interred non-stop through the jack, which is fully attached to the beam (Fig. 10), and the beam is always pressurized.

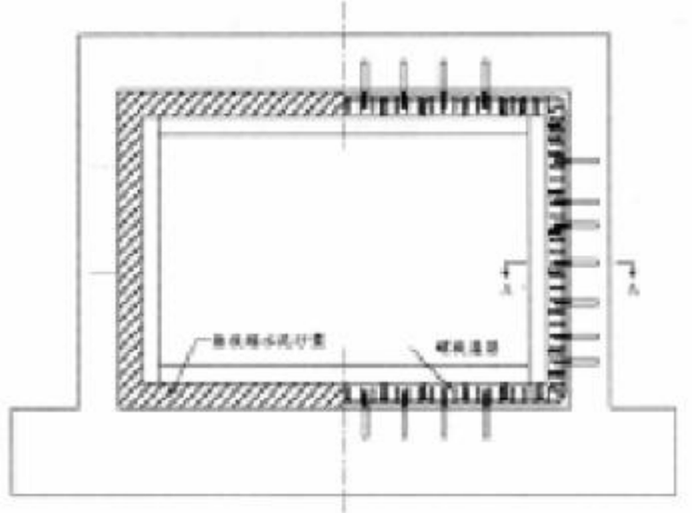


Figure 7. How to connect a steel frame to a frame

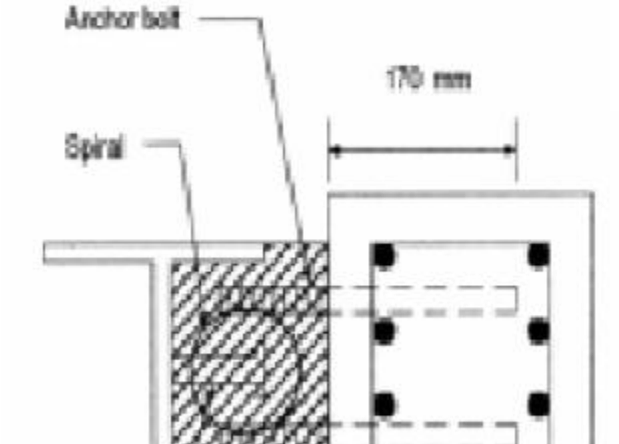


Figure 8. Details of connections

Table 1. Features of consumable steel

| Type of steel | Final strength | Tensile strength | Increase in length (%) | Application |
|---|---|---|---|---|
| LYP-16MM | 98.6 | 247 | 48.6 | Steel shear wall |
| LYP-1.5MM | 95.7 | 275 | 45.2 | |
| Rebar 6 | 321 | 665 | 28 | Concrete frame |
| Rebar 3 | 433 | 601 | 22 | Concrete frame |
| Rebar 4 mm | 418 | 358 | 23 | Ring steel |

## Results

Figures 11 and 12 show the cracks in the LYP cross brace and cross brace samples with A36 steel and the steel shear wall, respectively, at approximately a lateral angle of 2.5%.Diagonal shrinkage of LYP and A36 cross braces, both of which are under pressure and tension, cause extensive cracks in the column.The LYP steel shear wall is asymmetrically deformed.When the load is applied from the right side, the steel frame is separated from the concrete frame by a flexural anchor at the point shown in Figure 1.

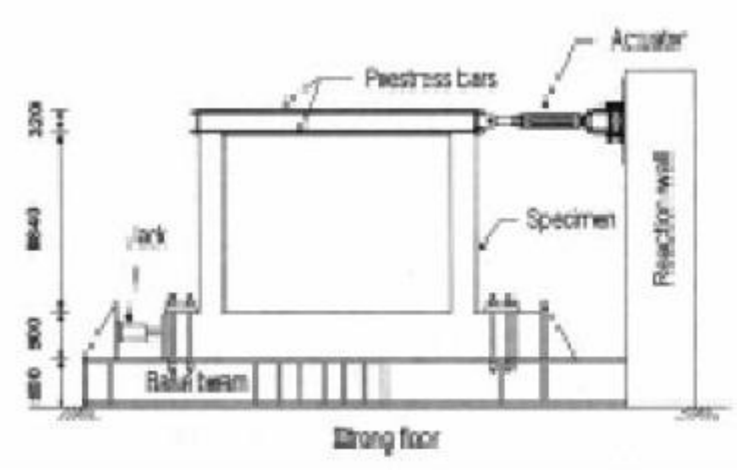


Figure 9. How to test LYP

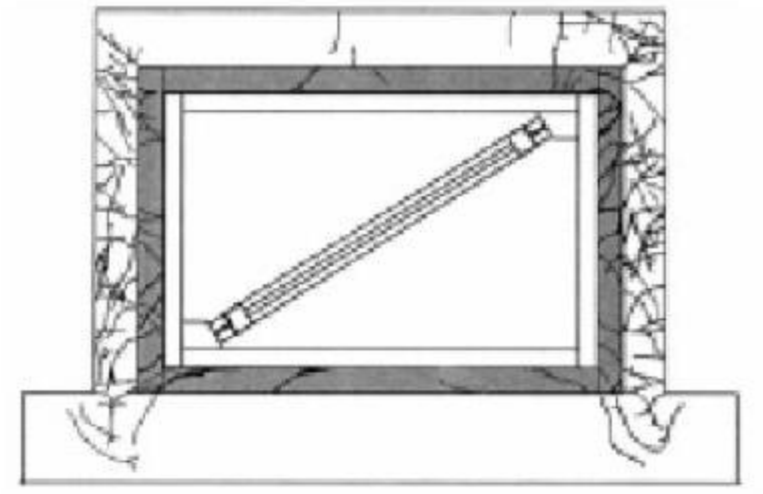


Figure 10. Cracking in reinforced concrete frame with cross brace with a relative rotation of 2.7%

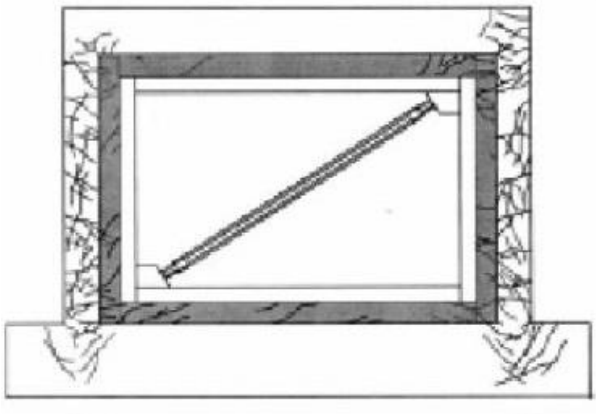


Figure 11. Cracking in reinforced concrete frame with A36 cross brace with a relative rotation of 2.7%

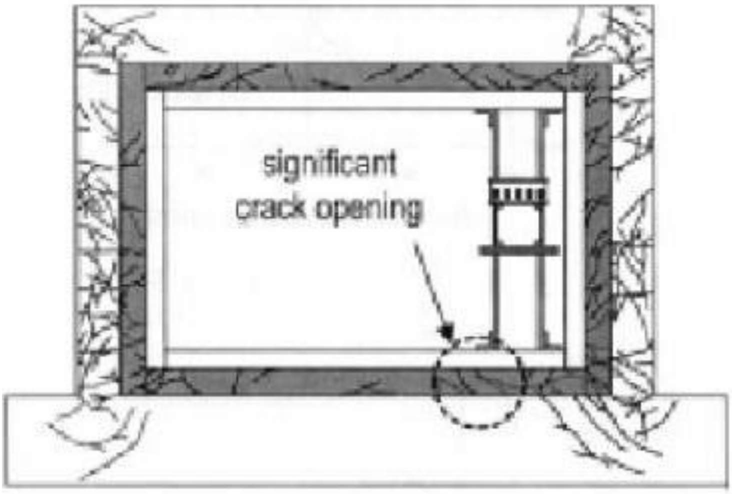


Figure 12. Cracking in reinforced concrete frame with shear steel wall with a relative rotation of 2.4%

Figure 13 shows the load-displacements hysterical ring of the test frame.By comparing the frame without restraint, the hardeners and strength of all the frame reinforces give interesting results.Figure 15 shows the axial force against deformation in the form of hysterical rings drawn for cross brace with LYP and A36 steel.Figure 16 shows the hysteresis rings of shear force versus horizontal displacement.The steel shear wall test shows an asymmetric result and reaction, which is summarized in Table 3.

Experimental results show that preventing cross brace buckling and steel shear wall is effective in strengthening the frames.The hardness and strength and ductility of the frames after strengthening them as details of the connection between the concrete frame and the steel frame cross brace is an effective factor and is easy to build.Cross braces improve strength and ductility.However, the details of the frame reinforcements for the steel shear wall require much study.

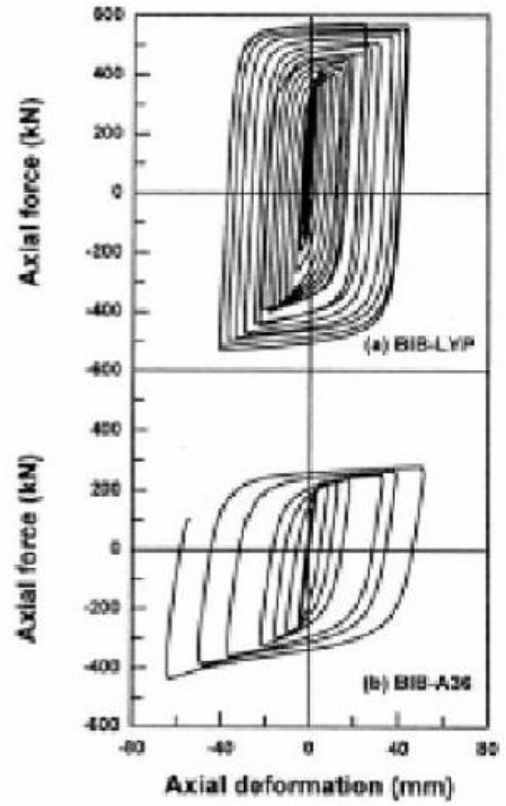


Figure 13. Hysterical ring of concrete frames

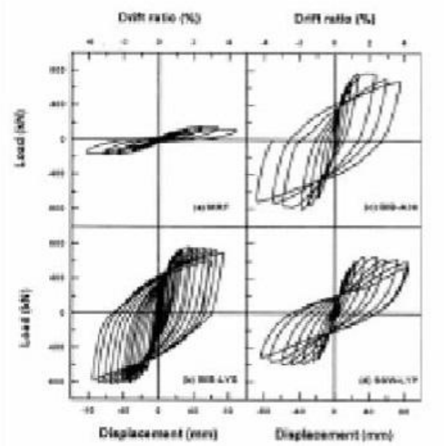


Figure 14. Hysterical rings of cross braces

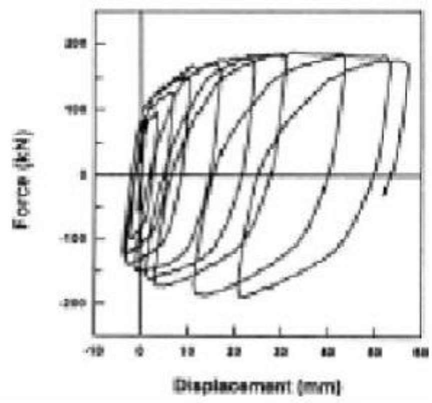
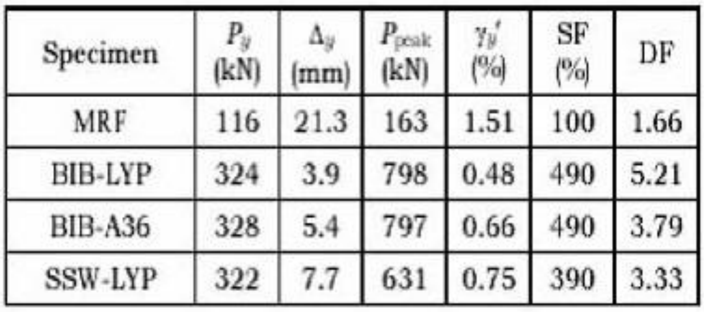


Figure 15. Hysterical rings of steel shear wall



| Specimen | $P_y$ (kN) | $\Delta_y$ (mm) | $P_{peak}$ (kN) | $\gamma_y'$ (%) | SF (%) | DF |
|---|---|---|---|---|---|---|
| MRF | 116 | 21.3 | 163 | 1.51 | 100 | 1.66 |
| BIB-LYP | 324 | 3.9 | 798 | 0.48 | 490 | 5.21 |
| BIB-A36 | 328 | 5.4 | 797 | 0.66 | 490 | 3.79 |
| SSW-LYP | 322 | 7.7 | 631 | 0.75 | 390 | 3.33 |

Figure 16. Test results

## Conclusion

1. The yield strength and ultimate strength of LYP steel are affected by the strain ratio.The ultimate strength of the shear panels made of LYP steel depends on its loading speed.In this study, the ultimate strength difference with high and low speeds is about 16%.This means that if the loading speed is fast, it is 16% higher than slow loading.
2. Proper construction and design of shear panels made of LYP steel has reached a relative rotation of 5%, which requires a high-energy loss.
3. Under the load of the shear panel, first, the lateral yield occurs and with increasing the buckling load of the panel, as a result, the panel bends outwards and causes the cross section to stretch.After the panel is completely yielded, the outer strips of the screen absorb energy from the very end.This means that first, the middle of the screen absorbs energy and gradually reaches the yield point, and this energy absorption is transferred to the panel, which eventually reaches the yield point, which causes a lot of loss and absorbs a lot of energy.

## References:

[1]. An Introduction to Steel Shear Wall by Dr. Saeed Sabouri

[2]. Astaneh-Asl, A. (2000). “Steel plate shear walls,”U. S.-Japan Workshop on Seismic Fracture Issues in Steel Structure, San Francisco.

[3]. Seismic Assessment and Strengthening Method of Existing RC Buildings in Response to Code Revision

[4]. Shun-Tyan Chen -Van Jeng- Sheng-Jin Chen-Cheng-Cheng Chen