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Review of Structural Analysis of Steel Plate Shear Wall

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Abstract- For construction activity normally we use materials as concrete and steel to build up tall buildings. In concrete there are different constituents like aggregate, cement, sand, admixtures, water and plasticizers from which we can achieve the characteristic strength according to our structure. We also use various grades of steel like MS, TOR, TMT, depending on the type of structure. We can construct building by using these two main components up to the limit that means the deign limits according specified by the IS 456:2000 'Plain and Reinforced Concrete'. But for the high rise structures we cannot go only by using these two components i.e. concrete and steel. We have to choose some different alternatives or different systems to construct the high rising structures therefore we can see system like Steel plate Shear Wall (SPSW) suggested by different scientist that we are going to study in this paper. We are going to study the Performance of Steel Plate Shear Wall during Past Earthquakes events. In this paper we will also study the testing on steel plate and also the different case study of SPSW system.

Keywords- SPSW, deformation, stress.

I. INTRODUCTION

The main function of steel plate shear wall is to resist horizontal story shear and overturning moment due to lateral loads. Steel plate shear walls (SPSW) can be use as a lateral load resisting system for buildings. A typical SPSW (Fig. 1) consists of stiff horizontal and vertical boundary elements (HBE and VBE) and infill plates. The resulting system is a stiff cantilever wall which resembles a vertical plate girder.

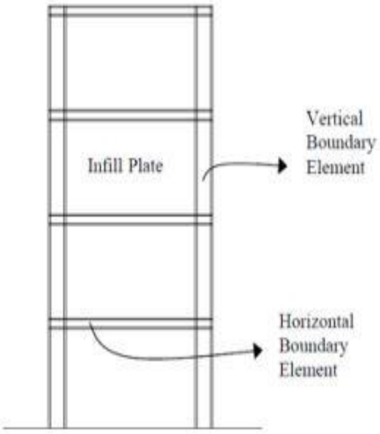

Fig 1. Typical Steel Plate Shear Wall.

There are two types of SPSW systems, which are the standard system and the dual system. (Fig.2). In the standard system SPSW is used as the sole lateral load resisting system and pin type beam to column connections are used in the rest of the steel framing. In the latter system, SPSW is a part of a lateral load resisting system and installed in a moment resisting frame. In this case forces are resisted by the frame and SPSW. SPSW can have stiffened or unstiffened infill plates depending on the design philosophy. Earlier designs used stiffeners to prevent buckling of infill plates under shear stresses. On the other hand, more recent approaches rely on post buckling strength. Based on the work of Wagner, it has been known that buckling does not necessarily represent the limit of structural usefulness and there is considerable post buckling strength possessed by restrained unstiffened thin plates.

At the onset of buckling, this occurs at very low lateral loads, the load carrying mechanism changes from in-plane shear to an inclined tension field. The additional post buckling strength due to the formation of tension field can be utilized to resist lateral forces. Due to the cost associated with stiffeners most new designs employ unstiffened infill plates.

Design recommendations for SPSW systems are newly introduced into the AISC Seismic Provisions for Structural Steel Building. These provisions basically present guidelines on the calculation of lateral load capacity of SPSW as well as recommendations on the seismic characteristics. Lateral load resisting capacity of SPSW systems has been studied experimentally and numerically in the past and procedures for computing the nominal capacity are developed. These experimental and analytical studies led to the development of code provisions. [1].

The high rise buildings mostly fail due to bucking therefore we have use to SPSW system for the lateral force resisting system. In this paper we will study the behaviour of SPSW. [5]

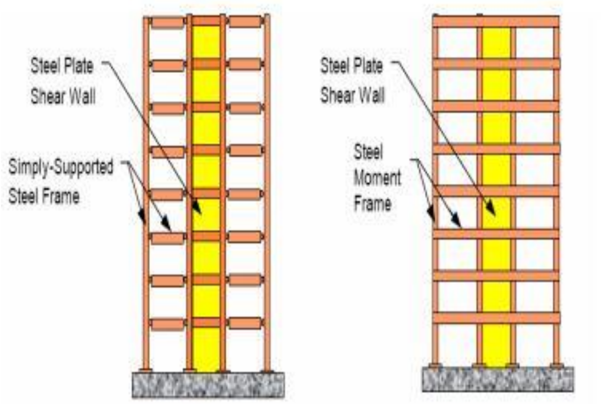

Fig 2. (a) Standard SPSW system (b) Dual SPSW system.

1. SPSW's Benefits

- Steel shear walls are particularly effective and cost-effective methods for lateral load resistance.
- Because of its high initial stiffness, the steel shear wall system is highly good in limiting drift.
- The steel shear wall is substantially lighter than reinforced concrete shear walls, which may result in less weight being carried by the columns and foundations, as well as less seismic stress owing to the structure's lower mass.
- By adopting shop-welded, field-bolted steel shear walls, the erection process may be sped up and the cost of construction, field inspection, and quality control can be reduced, resulting in even more efficient systems.
- From an architectural standpoint, steel plate shear walls take up much less area than similar reinforced concrete shear walls due to their comparatively thin thickness. If reinforced concrete shear walls are utilised in high-rises, the walls on lower levels grow exceedingly thick and take up a lot of space.
- When utilised in seismic retrofit of existing buildings, steel plate shear walls may be significantly simpler and quicker to install than reinforced concrete shear walls.
- Steel plate shear wall systems that can be built using shop welded-field bolted parts may be more efficient than typical steel plate shear wall systems. [1].

II. REVIEW OF THE LITERATURE

Yamaguchi and colleagues (1), For wood framed shear walls, we conducted monotonic, cyclic tests with varying loading rates, pseudo dynamic testing, and El Centro shaking table tests. The tests with greater load cycling and large amplitudes correlated together post peak strength decrease. The findings of the rapid reversed cyclic test are comparable to shaking table testing.

Similar amplitudes load cycles were detected in pseudo dynamic testing and shaking table tests, but the results were different.

Mc mullin and Merrick (2) performed force-controlled cycle testing on walls clad on both sides with OSB, 3 ply plywood, 4 ply plywood, and gypsum wall board (GWB). GWB was discovered to have more rigidity than OSB and ply wood.

Salenikovich and Dolan (3) used statically and cyclically to evaluate walls with varied aspect ratios and overturning restrictions. The ductility and stiffness of the walls were the same in both procedures. For walls with aspect ratios less than or equal to 2:1, capacity and associated displacement were found to be 13 percent and higher than 30 percent, respectively.

Shear walls anchored with hold downs, without hold downs, and with dead loads and no hold downs were researched by Ni and Karacabeyli (4). We utilised ISO (1998) standards for static and reverse cyclic loading. There was a comparison of wall displacement without hold downs versus wall displacement with hold downs and no vertical load. Walls without hold downs or vertical loads had a 50 percent comparable displacement to walls with hold downs and no vertical load.

Venkatasai ram kumar.N et al. (5) investigated the impact of lateral loads on reinforced concrete shear walls in multistory structures in flat terrain with varied seismic zones according to IS: 1893: 2002 and wind loads according to IS: 875: 1987. (Part : 3). The base moment changed in a power equation pattern in all of the G + 2, G + 4, G + 6, building frames studied, while the graphs for base shear varied linearly. The stability of the structure grew as the base area expanded, and the minimal thickness to avoid buckling of the shear wall dropped as the stability increased.

Venkata Sai Ram Kumar N et al. (6) investigated the behaviour of reinforced concrete shear4 walls by assuming a 3.5m rise in building height from ground level to G+7. The analysis involved developing capacity curves that relate wind drift, shear wall length, wind drift, wind shear, wind moment, seismic drift, seismic shear, seismic moment, base moment, and base shear with increasing height. The base shear of medium and soft soils does not change and varies linearly, but the base shear of rocky soils decreases slightly after 20 metres of building height.
The behaviour of steel plate shear walls was evaluated using STAAD PRO software, both with and without shear walls, for a building frame of (G+6) storeys located in seismic zone III as per Indian code 1893:2002.

The rigidity of the construction is improved by the presence of a found steel plate shear wall. Buildings using SPSW have much less deflection, bending moment, shear force, and deflection than buildings without SPSW, and the amount of steel used is also decreased. SPSW takes up less area than RC shear wall, which has both economic and architectural benefits.
Steel shear walls have been employed as the major lateral load resisting method in a number of contemporary and

significant constructions since the 1970s. Stiffened steel shear walls were first utilised in Japan in new construction and in the United States for seismic retrofit of existing structures as well as new construction during the 1970s. Unstiffened steel plate shear walls were utilised in structures in the United States and Canada in the 1980s and 1990s. In other situations, concrete was used to cover the steel plate shear walls, resulting in a composite shear wall. A short overview of the uses of steel plate shear walls, both stiffened and unstiffened, is presented below.

According to Thorburn (1983), this structure, known as the Nippon Steel Building, was the first big structure to use steel plate shear walls. It was finished in 1970 and is located in Tokyo. The lateral load resisting system comprised of steel plate shear walls in the longitudinal direction and a mix of moment frame and steel plate shear wall units in the transverse direction. Steel plate wall panels with horizontal and vertical steel channel stiffeners were 9' by 12'-2" in size. Steel wall plates were available in thicknesses ranging from 3/16" to 12". The gravity force was not applied to steel shear walls during design, and the walls were built to withstand design lateral stresses without buckling. Shear walls made of reinforced concrete were originally used to construct the building.

According to Engineering News Record (1978), the R/C walls were modified to steel shear walls because of a patent issue. "The contractor rejected a steel braced building core as too costly" compared to steel shear wall, according to an ENR article (ENR, 1978). The construction was made out of a moment perimeter frame and strengthened steel shear walls in the form of a "T." Vertical stiffeners on one side and horizontal stiffeners on the opposite side of the wall panels, which were roughly 10 feet high and 16.5 feet long. Bolts were used to attach the panels to the boundary box and H steel columns. "The next high-rise building we do won't likely be constructed with bolted steel seismic walls," said the construction contractor in this scenario (ENR, 1978). According to an ENR story, after failing to attain the needed accuracy, the contractor of another Tokyo high-rise shifted from bolted steel panels to welded panels.

This construction, detailed in Reference (Troy and Richard, 1988), is an excellent illustration of how steel shear walls may be used effectively in places with minimal seismicity but significant wind loads. In the longitudinal direction, the 30-story building features a steel braced frame and steel plate shear walls in the transverse direction. In this construction, the shear walls absorb around 60% of the tributary gravity force, while the broad flange columns at the shear wall's edge withstand the remaining 40%. The designers conserved a large quantity of steel in beams and columns by employing steel plate shear walls as gravity load bearing components, and the steel shear wall system utilised 1/3 less steel than an equal steel moment resisting frame (Troy and Richard, 1988). The controlling lateral loads were wind loads, which were located in Dallas.

Maximum drift was just 0.0025 under the design wind load. Steel plate shear walls have a relatively high in-plane stiffness, which accounts for the minimal drift. This construction is an excellent example of the utilisation of steel shear walls in a "critical" structure such as a hospital in a seismically active location like California. The hospital replaces the reinforced concrete Olive View Hospital, which was largely destroyed in the 1971 San Fernando earthquake and had to be dismantled. The gravity load is totally resisted by a steel space frame in the new Sylmar Hospital, while the lateral load is resisted by reinforced concrete shear walls in the first two floors and steel plate shear walls in the top four stories. This building's steel shear wall panels are 25 feet wide and 15.5 feet high, with wall plate thicknesses of 5/8" and 3/4".

There are window apertures and stiffeners in the walls. The fin plates on the columns are fastened to the steel plate panels. To make a box shape, the horizontal beams and stiffeners are double channels welded to the steel plate. The double channel box sections were utilised to generate torsionally stiff parts at the borders of steel plates and to boost the plate panels' buckling capability, according to the designers.

The stiffened walls were developed for global buckling capacity as well as local buckling capacity of the stiffener-bounded panels. Although the designers recognise the availability of tension field action and evaluate its strength as a "second line of defence" mechanism in the case of a maximum credible earthquake, it was not utilised. The Sylmar hospital has been instrumented by the California Strong Motion Instrumentation Program (CSMIP). The building was shaken by the earthquakes in Whittier in 1987 and Northridge in 1994, and significant data on the structure's reaction were gathered.

The accelerations above roof level were over 2.3g, whereas the acceleration on the ground was at 0.66g. According to the author's examination of damage to this building during the 1994 Northridge earthquake, there was considerable damage to various non-structural features such as suspended ceilings and sprinkler system, resulting in sprinkler breakage and flooding of some levels. Furthermore, most of the TV sets that had been attached to the walls of the patients' rooms had broken their connections to the wall and were hurled to the floor.

The non-structural damage was obviously an evidence of the structure's very high rigidity, which was also the source of rather considerable acceleration amplification from ground to roof level. [1] The 35-story high-rise in Kobe, Japan, is one of the most significant structures with steel plate shear walls in a seismically active location. The building was built in 1988 and was damaged by the Kobe earthquake in 1995. The building's structural structure is made up of a steel moment frame and shear wall system.

The shear walls in the three basement levels are reinforced concrete, composite walls in the first and second floors, and stiffened steel shear walls above the second story. Two weeks after the 1995 Kobe earthquake, the author visited this building and noticed no evident damage. The damage to this building was moderate, with local buckling of stiffening steel plate shear walls on the 26th level and a permanent roof drift of 225mm in northerly and 35mm in westerly directions, according to studies. Soft stories may have developed between the 24th and 28th floors of the building, according to the findings of post-earthquake inelastic investigations mentioned in the above sources.

The highest inter-story drift in the NS frame is roughly 1.7 percent on the 29th level. A 52-story structure in San Francisco is now the highest building with steel plate shear walls in a seismically active location of the United States. The structure will be a residential skyscraper with 48 floors above ground and four basement parking levels when finished. The building's gravity load-bearing system comprises of four enormous concrete-filled steel tubes in the centre and sixteen smaller concrete-filled steel tube columns around the periphery.

Outside the core, post-tensioned flat slabs are used, whereas within the core and on the lower levels, composite steel deck-concrete slabs are used. A single reinforced concrete mat foundation serves as the foundation. The structure's primary lateral load resisting system is made up of a core made up of four massive concrete field steel tubes, one at each corner, as well as steel shear walls and connection beams. Between the two corner pipe columns are built-up H columns. Coupling beams link the steel shear walls to concrete-filled steel tubes. At each floor's mid-height, the shear wall modules are predominantly shop-welded and bolt spliced.

The connecting of the girders and steel plate shear wall to the massive concrete-filled steel tube columns is the sole field welding. The steel plate shear wall system in this building is mostly shop-welded, field bolted, with only steel plates and girders welded to the round columns in the field, similar to the 52-story construction detailed in the preceding section. The majority of gravity in the inside of the structure is carried by four spherical concrete-filled tubes. The I-shaped columns inside the steel box core do not transmit gravity; instead, they are principally part of the lateral load resisting system, which is a dual system of steel shear wall and unique moment-resisting frames. [1]

Some of the initial testing of steel shear walls were undertaken by Takanashi et al. (1973) and Mimura and Akiyama (1977). Takanashi et al. put 12 one-story and two two-story specimens through cyclic testing. The 12 single-story examples were about 6'-11" (2.1 m) wide and 2'-11" (0.9 m) tall. Steel plates with thicknesses of 3/32", 1/8", and 3/16" (2.3mm, 3.2mm, and 4.5mm) were utilised. The examples might be deemed 14 – size of prototype walls when compared to regular construction proportions. All specimens had vertical or vertical and horizontal stiffeners welded on one or both sides of the steel plate, with the exception of one. The boundary frames were pin-connected frames with a lot of stiffness. The specimens were put diagonally in the panels to achieve practically pure shear. The behaviour of the specimens was very ductile, with drift angles exceeding 0.10 radians in several situations.

Torii et al. (1996) investigated the use of "low-yield" steel walls in high-rise buildings. In Japan, major research and development efforts have been made in recent years to employ low yield steel in shear walls to limit seismic reaction. As a result of these efforts, a number of structures employing this technology have been designed and built (Yamaguchi et al, 1998). According to the provided statistics, this method looks to be highly promising, and additional study and development in this subject is required.

Nakashima et al. (1994 and 1995) investigated the cyclic behaviour of steel shear wall panels composed of "low yield" steel and published their findings. These characteristics result in this kind of steel's early yielding and its capacity to dissipate energy over a long period of time. In cyclic load tests, low-yield steel showed highly stable hysteresis loops and a reasonably substantial energy dissipation capacity. Figure depicts typical specimen hysteresis behaviour. The specimens consisted of one-story un-stiffened and stiffened walls that were fastened to the set-up at the top and bottom and subjected to cyclic shear stresses.

The panels were about 3'-11" by 3'-11" in size (1.2mx 1.2m). All of the panels were roughly 15/64" thick (6mm). During the exam, a panel is also shown in the figure. Testing of low yield steel shear walls in Japan has resulted in a substantial advancement in steel's ability to withstand dynamic lateral stresses. Low yield shear panels have been used in structures by Japanese designers. [1] The United Kingdom's 16 tests of diagonally loaded steel shear panels were reported by Sabouri-Ghomi and Roberts (1992) and Roberts (1995). Steel plates were used as specimens in these tests, which were put inside a four-hinged frame and bolted to it.

Figure was either 12"x12" or 12"x18" and featured holes on some of the panels. Steel plate thickness was either 1/32" or 3/64". The cyclic force was applied along the diagonal axis, causing pure shear in the steel plate. The testing revealed that all panels were ductile enough to withstand four major inelastic cycles.

III. OBJECTIVES

The goal of this study is to use Finite Element Analysis to evaluate the influence of circular opening on the lateral load resisting behaviour of SPSW. The ANSYS simulation programme is used for modelling and structural FEA analysis. Stress and deformation are used to assess the strength of SPSW with and without opening.

IV. CONCLUSION

After analysing the preceding studies, we can infer that steel plates may be utilised to dynamically evaluate lateral force resisting systems in high-rise buildings. The steel plate shear wall system is dependent on the kind of steel used and the building's design specifications. The rigidity of the building is also improved by adopting the SPSW technology. Then we can use this system to construct multistory buildings.

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