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Analyzing Behavior of Multi Story Steel Building with Steel Plate Shear Wall

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Abstract: Steel Plate Shear Walls (SPSW) have been introduced as one of the most efficient type of lateral load resisting system in last few decades. A steel shear wall frame consists of beams and column having steel plate connected in between them. The steel plate shear walls are very much similar to plate girders. They are cantilevered vertically and fixed from base. In SPSW system columns act as flanges and beams as stiffeners. The webs in SPSW system are very slender and these webs develop diagonal tension field action responsible for resisting lateral load. Surrounding beams and columns also resist the lateral loads. SPSWs show high initial stiffness, behave in very ductile manner and dissipate high amounts of energy when subjected to cyclic loading. In this paper, the behavior of steel plate shear wall (SPSW) in the multi-story steel building frame has been studied. Analysis is carried out for steel moment resisting building frame having (G+5) stores situated in low and high seismic zone. The analysis of steel plate shear wall and the building are carried out using Software SAAP2000 V20. The main parameters consider in this paper is to compare the seismic performance of buildings such as story drift, bending moment, shear force and lateral deflection. This paper also focused on behavior the steel structure with and without shear wall.
Keywords: Steel plate shear walls (SPSW), SAAP 2000 v20, steel building, Seismic behavior.

I. INTRODUCTION

Steel Plate Shear Walls (SPSW) are one of the innovative types of lateral load resisting systems having capability to resist earthquake and wind loads. They have gained much attention in recent years because of its efficiency over other lateral load resisting systems. Since 1970's, steel plate shear walls have been used in many structures in United States, Japan, Canada. Because of its high ductility and excellent energy dissipation capacity, they are used as primary lateral load resisting system in high rise buildings. The structural elements of SPSW have vertical steel plates also known as web or infill plates connected to the surrounding columns and beams and continued along full height of the structure. It can be installed in frames having simple or moment resisting beam-to-column connection. SPSW can be used in new construction and to retrofit the older structure or repair the damaged structure. As compared to other lateral load resisting systems, steel plate shear walls have unique performance benefits. Its resilient post buckling strength, high initial stiffness, superior ductility, high energy dissipation capacity makes them stand out performer among other lateral load resisting systems. The light weight structure, increased floor area, better quality control make them better than conventional reinforced concrete shear wall. Their light weight ultimately reduces the gravity loads and seismic loads transmitted to the foundation resulting into economical structure. Steel plate shear walls are manufactured in shops which reduces the construction time, field fabrication.

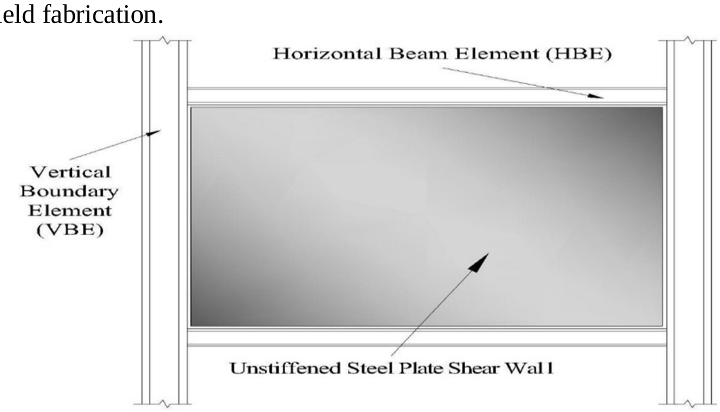

Figure 1. Unstiffened Steel Plate Shear Wall System

II. PREVIOUS RESEARCH

SAAP 2000 has been used by civil engineers because of its advantage and facilities of analysis than other design software. Ms Deepika C. Hiwrale, [2] in her research work she analysis steel moment resisting building frame having (G+6) storey situated in zone III, the analysis of steel plate shear wall and the building are carried out using software STAAD PRO V8i SELECT series II. Pundkar R. S, [4] in his work he analysis high-rise steel building with and without Steel Plate Shear Wall (SPSW) of building frame having (G+19) storey situated in zone III, the analysis of steel plate shear wall building is carried out using Software SAP2000 V15. Prashant Topalakatti [5] in his work he analysis of high-rise steel buildings frames with and without Steel plate shearwall (SPSW) by using STAAD PRO V8i FEA, he focus on thickness of plate. S. D. Ambadkar [7], in her work she analysis cost comparison of industrial steel building with steel plate shear wall by considering I-section & encased I-section as column sections the analysis of sections are carried out using STAAD PRO. Vijay Vadgama, Girish Joshi [9], in this work they analysis G+12 structure and compare result of reinforced wall with steel plate shear wall for weight of structure and economy of structure, they used SAAP 2000 V17 software for their analysis. Dr.J.Premalatha, R. Shanthi Vengadeshwari, Abhijith B, [11] in their work they analysis multi story building using ETAB software. Deepna U, Arjun S Menon, S.Balamurugan, [12] in their work they analysis compare the seismic performance of high rise buildings and optimizing the thickness of RCC shear wall, Steel Plate Shear Wall (SPSW) and composite shear wall for (G+20) stories, suing ETAB software. Many researchers of steel plate shear wall have examined multistory building in their research for various parameters, some of them used STAAD PRO software, some of them used SAAP 2000 software, some of them used ETAB software for structural analysis. However, the analysis of steel plate shear wall using SAAP 2000 V20 for different earthquake zone has not been studied.

III. MODELLING TECHNIQUES

1) *Strip Model Method:* Thorburn et al (1983) developed strip model (Figure 2.1) in which infill plates are represented by a series of pin-ended, the tension only strips and subsequently refined by Timler and Kulak (1983). Later Driver et al (1998) indicated that steel shear wall can be modelled as truss members by using a series of diagonal tension struts positioned at almost 45-degree angles. By replacing the shear wall with these struts, the resulting steel structure can be analysed using currently available computer analysis software, such as SAP2000 Nonlinear and inelastic pushover programs.
2) *Finite Element Model:* Elgaaly et al. (1993) used finite element models and models based on revised multi- strip model proposed by Timler and Kulak (1983), to replicate results achieved by Caccese et al. (1993). Using multi-strip model, they found results in reasonable agreement with the experimental results with respect to initial stiffness, ultimate strength and displacement at ultimate strength.

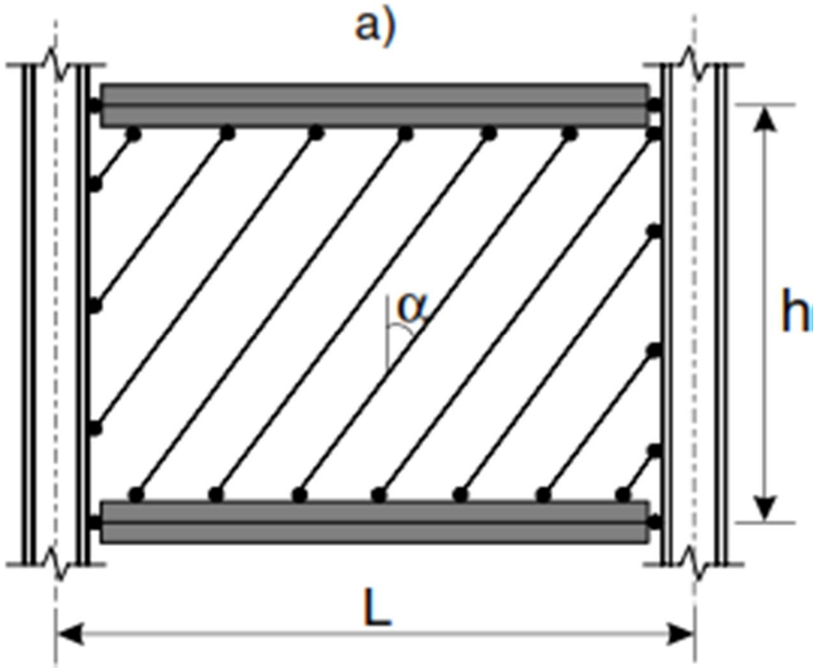

Figure 2. Strip model representation of a typical steel panel developed by Thorburn et al. (1983)

IV. ANALYSIS OF SPSW

A. For Low Seismic Zone

Data of Example: Total seismic weight of building= 29983 KN, Storey height= 5 m, G.F.= 4.1 m, Floors= G+5 floors,Type of soil: Medium, Zone factor, Z=0.16 for zone III, I=1.5 and R= 4, Main girder: D= 650 mm, width of flange= 350 mm, thick of web = 12mm, thick of top flange= 20mm, thick of bottom flange= 12mm, Secondary beams= ISMB 500, Column Section= 600x700 mm, thick = 20 mm. Plan of a building is shown in figure 3.

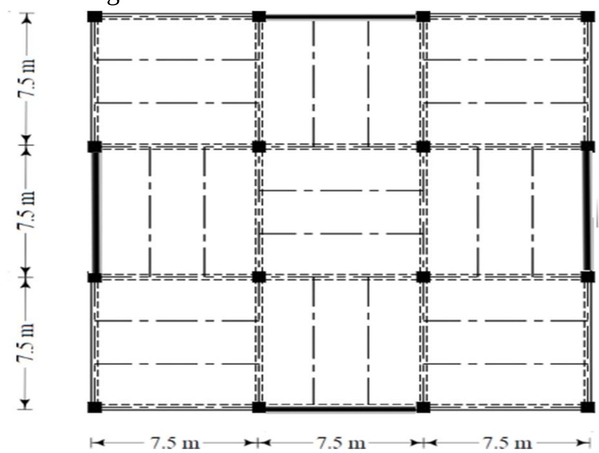

Figure 3. PLAN OF BUILDING

Table 1 Shears in Each Steel Plate Shear Wall

Shears in each SPSW	
Level	Frame Shear (KN)
Roof	210
Sixth Floor	365
Fifth Floor	465
Fourth Floor	525
Third Floor	550
Second Floor	555

1) Shears in each storey is divided two parts as each storey has two numbers of SPSW.
2) Shears in each SPSW are shown in Table 1.
3) The design strength of web plates can be calculated as,

$\phi V_n = 0.9(0.42) F_y \; t_w \, L_{cf} \sin(2\square)$ (10.1)

Fy= yield stress (MPa) tw= thickness of web plate

Lcf= clear length of web panel between VBE flanges

α = angle of tension stress

Table 2 Strength of Web Plates

Strength of Web Plates			
Level	Web plate thickness (mm)	Required Shear Strength (KN)	Design Shear Strength (KN)
Sixth floor	1	210	640
Fifth Floor	1	365	640
Fourth Floor	1	465	640
Third Floor	1	525	640
Second Floor	1	550	640
First Floor	1	555	640

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4) Required M.I. of VBE

$Ic \geq 0.003(t_w h^4/L)$ (10.2)

t_w= thickness of plate

h= distance between HBE centerlines

L= distance between VBE centerlines.

5) Required M.I. of columns are shown in Table 3.

Table 3 Required Moment of Inertia of Column

Required Moment of Inertia of Column				
Level	Web plate thickness (mm)	h (mm)	L (mm)	Moment of Inertia of Column Ic (mm^4)
Sixth Floor	1	5000	7500	2.5×10^8
Fifth Floor	1	5000	7500	2.5×10^8
Fourth Floor	1	5000	7500	2.5×10^8
Third Floor	1	5000	7500	2.5×10^8
Second Floor	1	5000	7500	2.5×10^8
First Floor	1	4100	7500	1.13×10^8

6) Minimum M.I. required for HBE,

$I_{HBE} \geq 0.003(\Delta tw\ L^4/h)$ (10.3)

Δtw = difference between the web plate thickness above and below the HBE.

L= distance between VBE centerlines

h= distance between HBE centerlines

B. For High Seismic Zone

Data of Example: Total seismic weight of building= 29983 KN, Zone factor, Z=0.36 for zone V, I=1.5 and R= 4, Shears in each SPSW are shown in Table 4 and Table 5 shows strength of web plates.

Table 4 Shears in each SPSW

Shears in each SPSW	
Level	Frame Shear (KN)
Roof	466
Sixth Floor	820
Fifth Floor	1050
Fourth Floor	1175
Third Floor	1233
Second Floor	1250

Table 5 Strength of Web Plates

Strength of Web Plates			
Level	Web plate thickness (mm)	Required Shear Strength (KN)	Design Shear Strength (KN)
Sixth floor	1.5	466	965
Fifth Floor	1.5	820	965
Fourth Floor	2	1050	1285
Third Floor	2	1175	1285
Second Floor	2.5	1233	1605
First Floor	2.5	1250	1605

Table 6 Required Moment of Inertia of Column

Required Moment of Inertia of Column				
Level	Web plate thickness (mm)	h (mm)	L (mm)	Moment of Inertia of Column Ic (mm^4)
Sixth Floor	1.5	5000	7500	3.75×10^8
Fifth Floor	1.5	5000	7500	3.75×10^8
Fourth Floor	2	5000	7500	5×10^8
Third Floor	2	5000	7500	5×10^8
Second Floor	2.5	5000	7500	6.25×10^8
First Floor	2.5	4100	7500	6.25×10^8

V. COMPARISON OF RESULTS

The figures showing comparison of steel building with and without SPSW are shown in the following figures.

A. Figure 5.1 shows storey drift comparison of steel buildings (with and without SPSW).
B. Figure 5.2 shows bending moment comparison of steel buildings (with and without SPSW).
C. Figure 5.3 shows shear force comparison of steel buildings (with and without SPSW).
D. Figure 5.4 shows lateral deflection comparison of steel buildings (with and without SPSW).

Comparison of Steel Building (With and Without SPSW)

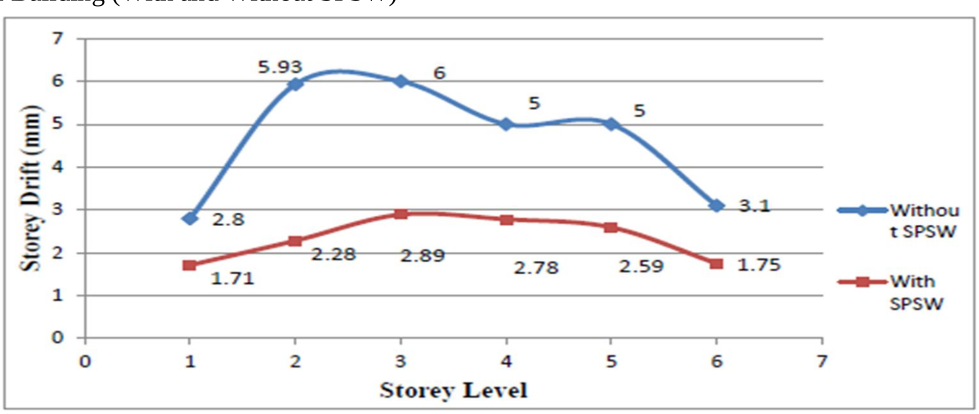

Figure 5.1 Storey Drift

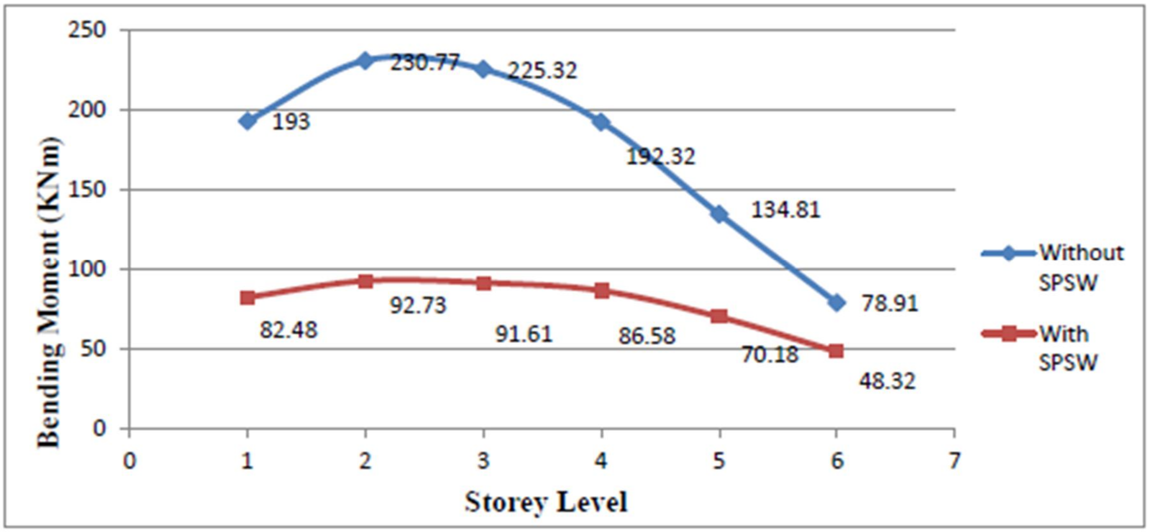

Figure 5.2 Bending Moment

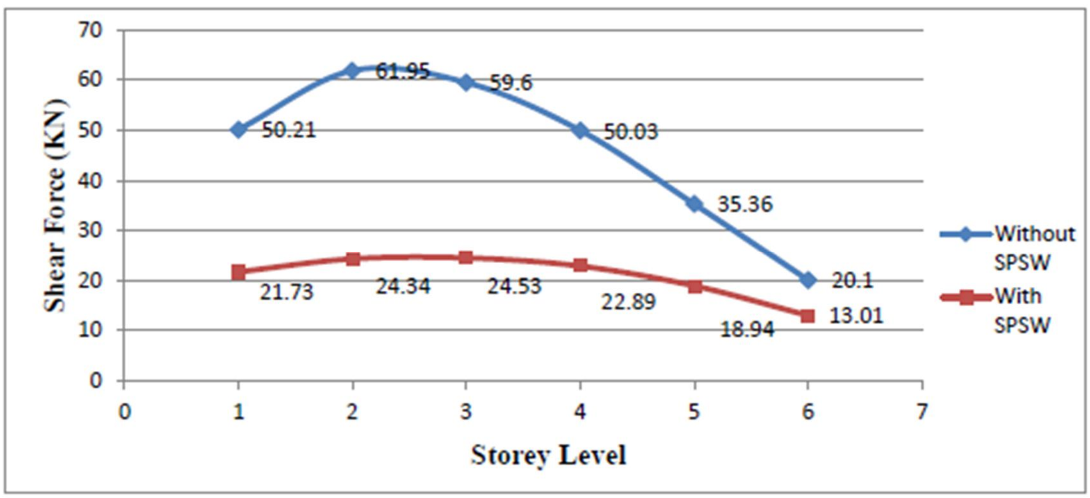

Figure 5.3 Shear Force

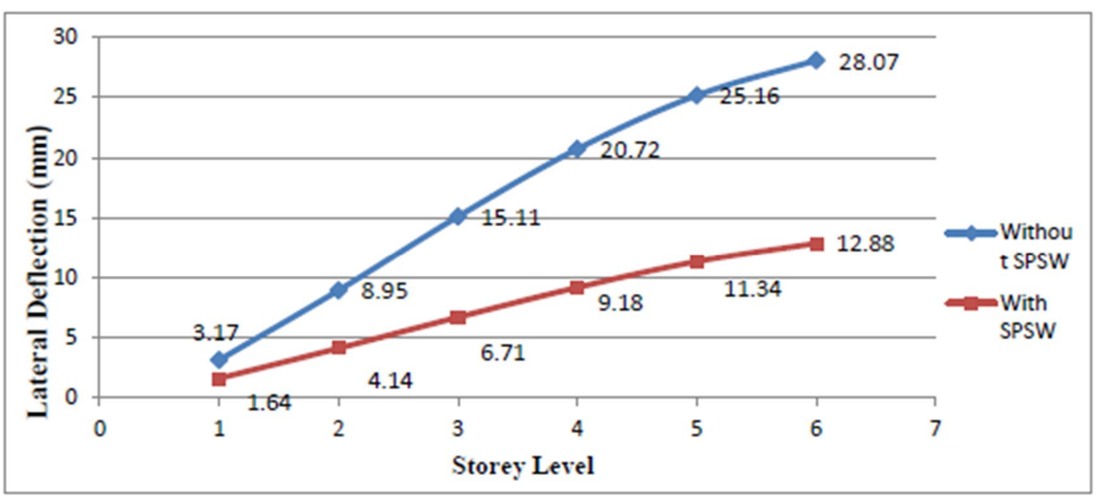

Figure 5.4 Lateral Deflection

VI. CONCLUSIONS

Based on the analyses of multi-story steel building models, the following conclusions are drawn.

A. Steel plate shear wall system is very effective tool in both low and high seismic zone as compared to steel frame building without SPSW.
B. .From the system analysis it is concluded that multi-story steel frame building with SPSW has lesser story drift, bending moment, shear force and lateral deflection values as compared to steel frame building without SPSW.
C. Steel plate shear wall occupy much less space due to relatively small thickness and also reduce aver all weight of building as compare to reinforced concrete structure.
D. Steel plate shear wall aesthetic good from architectural point of view.
E. Result shows that steel plate shear wall proves to be very useful and provide quick construction option in case of structure rehabilitations and disaster situations.

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