International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-8, June 2020

Determination of Lateral Force on Steel Plate Shear Wall by using American Code

Sudarshan R. Vhatkar, Pradip D. Jadhao

***Abstract:** For seismic design requirements, the major stress dispersing components for steel plate shear walls (SPSWs) that be resistant against lateral forces are un-hardened plates infilled (webs) that bend for shear then shape the sequence with diagonal tension field actions (TFAs). The tensile load of an infill plate must be resisted through the horizontal boundary elements (HBEs) and the vertical boundary elements (VBEs) surrounding every plates by means with its capacity design point of view. If rigid connections were established for both the HBEs and the VBEs as well as among VBEs even its base (when stated with other SPSW cases), the SPSWs often gain along with moment of resistance from another boundary element with that of its lateral horizontal forces deployed.*

Appreciating every usefulness by their boundary frame with their overall strength in that model, through their interest as can also occur in any form of optimizing the design of the SPSW, so instead of based for their appearance to this process for the over strength with which this can supply for withstand a defined lateral forces.

About the lateral design, many aspects control its reaction to light – frame shear wall: rank the encasing elements, fastener style, fastener position, keep on low tightening system, size as well as the classification with the connected structural boards, existence frame connections, aspect ratio in the wall (height of the wall and length of the wall ratio), with wall attached components. While framing products and fastener forms vary throughout Cold – Formed Steel (CFS) as well as wood – frame shear wall mechanisms, a whole responds for those mechanisms also seem to be relatively equal when they are sufficiently comprehensive to resolve the material centric limit states.

The steel plate shear wall (SPSW) arrangement seems to be recognized just like most among any simplest efficient ways for resistance of the lateral forces, specifically through seismic activity, the loads are adapted on the model.

This comprises along with one steel plate infilled attached through an enclosed system throughout horizontal beams and vertical columns for the movement of lateral forces to the base of the foundation. Steel plate shear walls (SPSWs) column in mid – rise along with high – rise constructions typically needs an outsized compression capability, because it bear either an axial forces with gravitational forces of lateral forces and imposed by the moment of overturning.

In order to ensure the effective usage with steel inward the plate infilled, and even will attain goodness as a whole earthquake output on that wall, that formed tension field need to have relatively consistent, requiring suitable anchoring by effective accompanying members of the frame. The lateral fore on the steel plate shear wall (SPSW) is determined by using American code.

***Keywords:** Cold – Formed Steel, Horizontal Boundary Element, Steel Plate Shear Wall, and Vertical Boundary Element.*

I. INTRODUCTION

A steel plate shear wall (SPSW) model will be recognized is being among a very powerful the way with resistance to lateral forces, in particular loads apply in the system since the earthquakes occurrence.

This comprises along with their steel plate infilled fixed under an enclosure system around columns with beams for the shift of lateral forces with its base of the footing.

Steel plate shear walls columns across mid – rise and high – rise constructions typically need the strong compression ability, being it is bear all those of them gravitational forces and axial forces imposed because of lateral forces by a overturning moment.

In order to ensure the appropriate utilization with steel infilled plate, but also thereby ensure reasonable overarching earthquake performance either wall, the formed tensile zone might remain relatively homogenous, requiring appropriate anchoring by supporting enclosure elements.

In order for attain these; members of its edge would have ample stiffness then according to American Standard for Steel Construction (AISC) seismic provisions for structural steel buildings, ANSI / AISC 341 – 10.

Classic Steel Plate Shear Wall (SPSW) comprises along with steel infilled panels enclosed alongside vertical columns, known as a Vertical Boundary Elements (VBEs), supports either direction are horizontal beams, known as a Horizontal Boundary Elements (HBEs), upward with beneath.

Shear wall mechanisms which uses steel plates become popular seismic engineering regardless for that ductility, stiffness, and lightness.

This Steel Plate Shear Wall seems agreed more in North America so it's incorporated throughout the American steel design standards (AISC 2010).

This opposes distortion in shear through tension field action at that start about the buckle also exhibits a significant griping activity of the process of hysteresis.

Revised Manuscript Received on June 30, 2020.
* Correspondence Author

Sudarshan R. Vhatkar*, Research Scholar, Civil Engineering Department, K. K. Wagh Institute of Engineering Education and Research, Nashik, Affiliated to Savitribai Phule Pune University, Pune, Maharashtra State, India. E-mail: srvhatkar@kkwagh.edu.in

Dr. Pradip D. Jadhao, Professor and Head, Civil Engineering Department, K. K. Wagh Institute of Engineering Education and Research, Nashik, Affiliated to Savitribai Phule Pune University, Pune, Maharashtra State, India. E-mail: pdjadhao@kkwagh.edu.in

II. PREVIOUS WORK DONE FOR THE STUDY OF STEEL PLATE SHEAR WALL

A. Review of Researchers

Rafael Sabelli, *et al*, a Steel Plate Shear Wall (SPSW) have studied on the point of lateral load resistant arrangement comprising with vertical steel plate in filled attached with each accompanying columns and beams so mounted across one or several bays at that entire height through that building can create cantilevered wall.

Steel Plate Shear Wall (SPSW) accustomed to cyclic – inelastic pertubations evokes large initial stiffness, is somewhat ductile and disperses significant quantities of energy. Such features make it ideal for resistance to earthquake loading. Steel Plate Shear Wall (SPSW) might be used not just for the design and construction of new structures along with retrofit current structures.

Beam – to – column interfaces of its own steel plate shear wall may, in principle, be either of the simple type or moment – resisting type [17].

Bing Qu, *et al*, worked for the traditional design for the Steel Plate Shear Walls (SPSWs) and guesses such hundred percentages in that storey shear has always been prevented through every panel of infills. Ensuing the present path, the stability received respectively boundaries frame moment resistive behavior, that generated effective Steel Plate Shear Wall with over strength will be ignored.

Although these concept presumptions seems to have a beneficial effect toward the earthquake efficiency from Steel Plate Shear Walls, none of the empirical research was performed which measure their significance from these over strength generally details. Based on plastic evaluation for the Steel Plate Shear Walls, that study investigates directly proportional also respective contributions containing boundary frame moment resistant activity as well as panel infilled tension field action on that entire plastic capacity throughout Steel Plate Shear Walls (SPSWs) [4].

M. Nava, *et al*, have taken some available qualifying / verification summary for substitutes to the code – acceptable construction of light gauge Cold – Formed Steel (CFS) shear wall and pre – requirements for research samples with a aspect ratios of 1:1 and the vertical panel joints have been established.

Information including three discrete developmental research studies was examined in order will release some focus at joint board including aspect ratio influences toward Cold – Formed Steel Frame Shear Wall (CFSFSW) execution. This recent study found such effective output data based on walls beyond the panel intersection including among aspect ratios being elevated to $2\frac{1}{4}$ providing fair lower bound success metrics [16].

X. Wang, *et al*, presents the study for the earthquake accomplishment belonging to twice group based on Cold – Formed Steel wall elements classified on a true kind five – storied structure shake table testing activities: (1) the external architectural exterior, covering its bottom three floors with that structure, (2) an internal curtain wall framework covering entire floors with that structure.

Any sample structure would have been susceptible with the series with earthquake contributions movements in rising magnitude, primarily when a structure has been detached in there foundation bottom, along with then when it's been attached from that shake table. The research work discusses the harm measures for Cold – Formed Steel (CFS) wall devices if architectural façades are used and demonstrates fields that will be discussed in specific throughout earthquake design [21].

Anju Sreekumar, *et al*, a significant number of buildings in Los Angeles were destroyed by the Northridge earthquake of January 1994. The most frequent form of structural failure has been its brittle collapse of the beam – column connection across Moment – Resisting Frames (MRFs) of steel. One of that activity demonstrated the requirement for progressively strengthen that Moment – Resistant Frames as well as particular attachments.

That original Moment – Resisting Frames (MRF) framework popularly referred being Self – Centering Moment Resisting Frames (SC – MRF) has been formulated. Such studies were strong enough to resist the seismic forces without causing much harm.

The study subjected to cyclic loading shows that the behavior based on Self – Centering Moment Resisting Frames (SC – MRF) both either or not Steel Plate Shear Walls (SPSWs) [2].

Weifeng Tian, *et al*, observed thin Steel Plate Shear Walls (SPSWs) became the important lateral load obstruction mechanism and is commonly used in structures. Engineers include the capability to reliably forecast both elastic and inelastic structural reactions in Steel Plate Shear Walls (SPSWs) by means of the simplified system that is easy using. Depending on the strip concept, the study suggests a new simplistic system for Steel Plate Shear Walls (SPSWs), called that three – strip method, where across the infill plates within Steel Plate Shear Walls (SPSWs) such that substituted by only three tension strips.

Distinctions of experimentally received pushover responses of Steel Plate Shear Walls (SPSWs) also which estimated by proposed system are provided and fair agreement is reached [20].

Liusheng He, *et al*, A Steel – Slit – Shear Wall received a great deal of consideration in the process of the lateral load resistance device. Although, problems including fragmentation produced as of it's terminates of slit together with compress hysteresis limit strength distraction.

Through resolving the particular problems, researchers had established steel – slit – shear wall prepared of less yield phase steel with less yield stress along with high ductile also setting of the strain.

Steel shear walls with slit developed of less yield phase steel absorbed strength in the vicinity of low shear deformation, lateral movement, has been uniformly spread over total series, fracturing would be avoided, along with heavy hysteresis was possible except its need including the away from area restraints. Proposed design process was given to ensure successful energy dissipation [15].

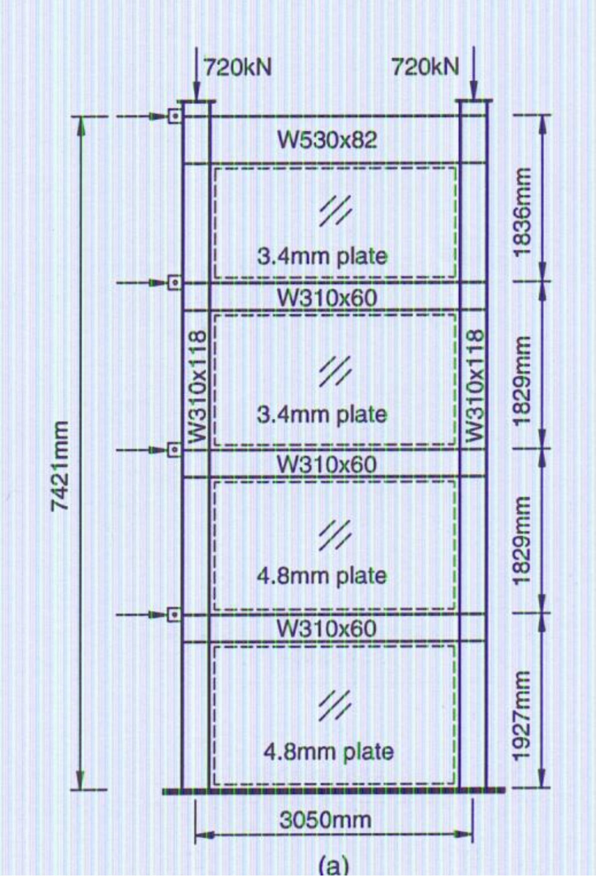

Fig. 1. Steel Frame Associated with Steel Plate Shear Wall [20]

B. Determination of Lateral Forces:

Step 1: Preliminary Data:

1. Type of Structure: Steel Framed Structure
2. Material Used: Steel
3. Site Location: Nashik
4. Occupancy Category: II (As per Table 1 – 1, Page 3, ASCE 7 – 05)
5. Seismic Zone: III (As per Annex E, Page 37, I.S. 1893 (Part 1) : 2016)
6. Importance Factor, I = 1.0 (As per Table 8, Page 19, I.S. 1893 (Part 1): 2016).
7. Response Reduction Factor, (R): 5 (As per Table 9, Page 20, I.S. 1893 (Part 1): 2016).
8. Type of Soil: Hard Rock.
9. Site Class: Site Class A (As per Table 20.3 – 1, Page 205, ASCE 7 – 05)
10. Response Spectra (As per I.S. I.S. 1893 (Part 1): 2016).
11. Method of Analysis: Equivalent static method (As per Clause 6.4.3, Page 10, I.S. 1893 (Part 1): 2016).

Step 2: Peak Ground Acceleration (PGA) Calculation:

As per ASCE 7 – 05, Peak Ground Acceleration for the Maximum Considered Earthquake (MCE) = 0.0810 g,

Where g = acceleration due to gravity.

Spectral accelerations for MCE are 0.1618 g at a period of 0.2 seconds, and 0.0592 g at a period of 1.0 second respectively. These values are expressed as S_s and S_1 respectively:

S_s = 0.1618 g and;

S_1 = 0.0592 g

The spectral values are modified as per site class. As per Table 11.4 – 1 and 11.4 – 2, page 115, ASCE 7 – 05, site coefficients are taken as:

F_a = 0.8 and;

F_v = 0.8

Modified values (As per clause 11.4.3, page 115, ASCE 7 – 05) are:

$S_{MS} = F_a \times S_s$

$S_{M1} = F_v \times S_1$

S_{MS} = 0.8 × 0.1618 g

S_{M1} = 0.8 × 0.0592 g

Now, value becomes:

$S_{MS} = 0.129\ g$

$S_{M1} = 0.047\ g$

The design spectral acceleration parameters are given below as per clause 11.4.4, page 115, ASCE 7 – 05

$$S_{DS} = \frac{2}{3} S_{MS}$$

$S_{DS} = 0.086\ g$

$$S_{D1} = \frac{2}{3} S_{M1}$$

$S_{D1} = 0.031\ g$

Step 3: Load Calculation:

1. Total Dead Load (TDL) = 3327.511 kN
2. Factored TDL = 1.5 × 3327.511 = kN
3. Total Live Load (TLL) = 3.0 kN
4. Factored TLL = 1.5 × 3.0 = kN
5. TDL + TLL on Storey 1, Storey 2, Storey 3
   = 5011.517 kN
6. TDL + TLL on Storey 4 (Roof Floor) = 4991.267 kN
7. Seismic Weight at all floors = $M_1 + M_2 + M_3 + M_4$
   = 5011.517 + 5011.517 + 5011. 517 + 4991.267
   = 20025.818 kN
8. Seismic Weight of the Building = 20025.818 kN

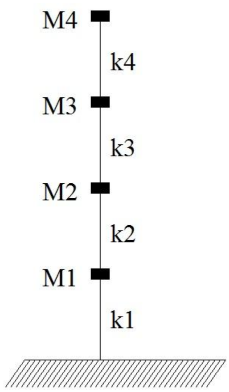

Fig. 2. Typical Lumped Mass Model Diagram

Step 4: Location of Co ordinates for Centre of Stiffness:

1. In X Direction = 7.5 m.
2. In Y Direction = 7.5 m.

Step 5: Estimation of Fundamental Period: As per clause 12.8.2.1, page 129, ASCE 7 – 05

$$T_a = C_t h_n^x$$

Where, C_t = 0.02 (As per table 12.8 – 2, page 129, ASCE 7 – 05)

$x = 0.75$ (As per table 12.8 – 2, page 129, ASCE 7 – 05)
h_n= structure height in feet = 40 ft.

$$T_a = 0.02 \times 40^{0.75}$$

T_a = 0.318 seconds

Step 6: Calculation of Design Seismic Base Shear:

1. As per ASCE 7 – 05, page 129, clause 12.8.1.1 seismic response coefficient = C_S

$$C_S = \frac{S_{D1}}{T_a\left(\frac{R}{I}\right)}$$

$$C_S = \frac{0.031g}{0.318\left(\frac{5}{1}\right)}$$

C_s = 0.0195 g

By using equivalent lateral force procedure,
The seismic base shear = $V = C_s \times W$
V = 0.0195 × 20025.818 kN
V = 390.503 kN

This base shear is distributed vertically along the height of the building as per ASCE 7 – 05, clause 12.8.3, page 130.

$F_x = C_{vx} \times V$

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

Where, C_{vx} = Vertical distribution factor
V = Seismic base shear
w_i and w_x = the portion of the total effective seismic weight of the structure (W) located or assigned to the level of i or x
h_i and h_x = the height from the base of level i or level x
k = constant related to the structure period as for structures having a period of 0.5 seconds or less, then take k = 1

Table- I: Vertical Distribution Factors (C_{vx}) and Storey Forces (F_x)

Storey Level	W_i	h_i	$W_i \times h_i$	$C_{vx} = W_i h_i / \sum w_i h_i$	$F_x = C_{vx} \times V$
4	4991.267	40’	199650.68	0.399	155.811
3	5011.517	30’	150345.51	0.301	117.541
2	5011.517	20’	100230.34	0.200	78.101
1	5011.517	10’	50115.17	0.100	39.050
Sum = ∑ =	20025.818		500341.7	1.000	390.503

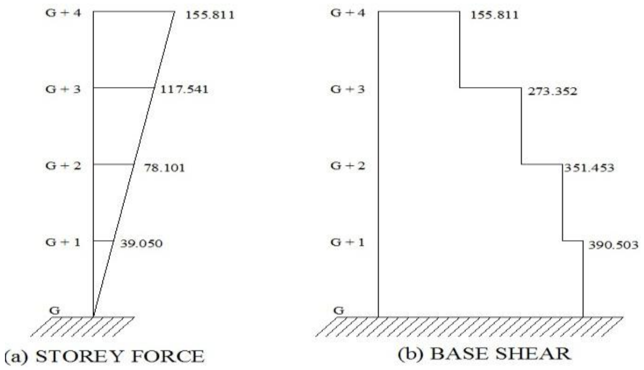

Fig. 3.Storey Force and Base Shear for G + 4

III. RESULT AND DISCUSSION

1) The maximum lateral force is at top floor (roof level) at the G + 3 and it is 155.811 kN as per American code.
2) The minimum lateral force is at ground level at base and it is 0 kN as per American code.

IV. CONCLUSION

The lateral force at free end i.e. at top floor is maximum and at the fixed end it is zero. By using American code the lateral fore on the steel plate shear wall (SPSW) is determined.

REFERENCES

1. A.I.S.C. 341s1 – 05, (2005). “Seismic Provisions for Structural Steel Buildings.” Including Supplement No. 1, American Institute of Steel Construction, Chicago, IL, pp. 1 – 334.
2. A. Sreekumar, A. K. Asraff, and J. Ramanujan, “Finite Element Analysis of Self – Centering Moment Resistant Frames with and without Steel Plate Shear Walls.” Procedia Technology, International Conference on Emerging Trends in Engineering, Science and Technology, Science Direct, vol. 24, pp. 161 – 168, 2016.
3. A.S.C.E. 7 – 05, (2005). “Minimum Design Loads for Buildings and Other Structures.” American Society of Civil Engineers, Reston, VA, pp. 1 – 419.
4. B. Qu, and M. Bruneau, “Design of Steel Plate Shear Walls Considering Boundary Frame Moment Resisting Action.” Journal of Structural Engineering, ASCE, vol. 135 no. 12, pp. 1511 – 1521, 2009.
5. I.S. 800: 2007, “Indian Standard, General Construction in Steel – Code of Practice,” Bureau of Indian Standards, 2007.
6. I.S. 801: 1975 (Reaffirmed 1995), “Indian Standard, Code of Practice for Use of Cold – Formed Light Gauge Steel Structural Members in General Building Construction,” Bureau of Indian Standards, 1995.
7. I.S. 811: 1987 (Reaffirmed 1995), “Indian Standard, Specification for Cold – Formed Light Gauge Steel Structural Steel Sections,” Bureau of Indian Standards, 1995.
8. I.S. 875 (Part 1): 1987 (Reaffirmed 1997), “Indian Standard, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Part 1: Dead Loads – Unit Weights of Building Materials and Stored Materials,” Bureau of Indian Standards, 1997.
9. I.S. 875 (Part 2): 1987 (Reaffirmed 1997), “Indian Standard, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Part 2: Imposed Loads,” Bureau of Indian Standards, 1997.
10. I.S. 875 (Part 3): 2015, “Indian Standard, Design Loads (Other than Earthquake) for Buildings and Structures – Code of Practice, Part 3: Wind Loads,” Bureau of Indian Standards, 2015.
11. I.S. 875 (Part 4): 1987 (Reaffirmed 1997), “Indian Standard, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Part 4: Snow Loads,” Bureau of Indian Standards, 1997.
12. I.S. 875 (Part 5): 1987 (Reaffirmed 1997), “Indian Standard, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures, Part 5: Special Loads and Combinations,” Bureau of Indian Standards, 1997.
13. I.S. 1893 (Part 1): 2016, “Indian Standard, Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings,” Bureau of Indian Standards, 2016.
14. I.S. 4326: 2013, “Indian Standard, Earthquake Resistant Design and Construction of Buildings – Code of Practice,” Bureau of Indian Standards, 2013.
15. L. He, T. Togo, K. Hayashi, M. Kurata, and M. Nakashima, “Cyclic Behavior of Multirow Slit Shear Walls Made from Low – Yield – Point Steel.” Journal of Structural Engineering, ASCE, vol. 142, no. 11, pp. 04016094 – 1 – 9, 2016.
16. M. Nava, and R. Serrette, “Effect of Panel Joints on the Performance of Cold – Formed – Steel Light – Frame Shear Walls.” Journal of Structural Engineering, ASCE, vol. 142, no. 2, pp. 06014007 – 1 – 7, 2015.
17. R. Sabelli, and M. Bruneau, “Steel Design: Steel Plate Shear Walls.” American Institute of Steel Construction, 2007.
18. S. R. Vhatkar, Dr. P. D. Jadhao, “Steel Plate Shear Wall – A 20th Century Review”, *International Conference on Recent Trends in Engineering and Sciences* (ICRTES) – 2018, Paper code: 732, 2018.

19. S. R. Vhatkar, P. D. Jadhao, "Determination of Lateral Load on Steel Plate Shear Wall by Indian Standard Code", International Journal of Innovative Technology and Exploring Engineering, vol. 8 no. 7C2, pp. 379 – 383, 2019, *Retrieval Number: G10820587C219/19©BEIESP*.
20. W. Tian, J. Hao, and C. Fan, "Analysis of Thin Steel Plate Shear Walls Using the Three – Strip Model." Journal of Structural Engineering, ASCE, vol. 142, no. 5, pp. 04015169 – 1 – 11, 2016.
21. X. Wang, E. Pantoli, T. C. Hutchinson, J. I. Restrepo, R. L. Wood, M. S. Hoehler, P. Grzesik, and F. H. Sesma, "Seismic Performance of Cold – Formed Steel Wall Systems in a Full – Scale Building." Journal of Structural Engineering, ASCE, vol. 141, no. 10, pp. 04015014 – 1 – 11, 2015.

AUTHORS PROFILE

Sudarshan R. Vhatkar completed D.C.E. from Government Polytechnic, Kolhapur, B.E. Civil from Tatyasaheb Kore Institute of Engineering and Technology, Warnanagar, Dist. Kolhapur, affiliated to Shivaji University, Kolhapur, M.E. (Structures) from K. K. Wagh Institute of Engineering Education and Research, Nashik, affiliated to Savitribai Phule Pune University, Pune. He has published various papers in national and international conferences. Area of research work is engineering mechanics, steel structures, etc; He is having a membership of Institution of Engineers, India. IE (I) AM 1322632.

Dr. Pradip D. Jadhao completed B.E. Civil from Sant Gadge Baba Amravati University, Amravati, M.E. (Geotechnical Engineering) from University of Pune, Pune, completed Ph.D. from Sant Gadge Baba Amravati University, Amravati. He has published various papers in national and international journals and conferences. Area of research work is geotechnical engineering, concrete technology, etc; He is having a membership of Institution of Engineers, India. IE (I) AM 086214 – 5, Chartered Engineer (India) AM 086214 – 5, Life member of Indian Geotechnical Society (IGS) LM 1982, Life Member of Indian Society of Technical Education (ISTE) LM 26164, Life Member of Indian Society of Rock Mechanics and Tunneling ISRMT.