International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 04 | Apr 2022 www.irjet.net p-ISSN: 2395-0072

COLD FORMED CORRUGATED STEEL PLATE SHEAR WALL: A REVIEW

Aneetta Varghese[1], Jinta John[2]

[1]PG Scholar, Dept. Of Civil Engineering, St. Josephs College of Engineering & Technology, Kerala, India
[2]Assistant Professor, Dept. Of civil Engineering, St. Josephs College of Engineering & Technology, Kerala, India

***

Abstract - *Shear walls are used in high rise framed structures to resist monotonic load in high rise framed structures. Here this study focuses on cold formed steel plate shear wall with different corrugations such as trapezoidal and rectangular. These two types that is corrugated steel plate shear wall and simple steel plate shear wall construction method is widely used to resist the lateral forces. Steel plate shear wall have large initial stiffness, high level of energy absorption and ability to openings. Here conducted a rare approach of analysis that is analysis of corrugated steel plate shear wall with openings. Parametric study includes plate thickness, angle of corrugation, opening size, and effect of dimensions. On completing this project, a detailed comparative study on seismic analysis of cold formed corrugated steel plate shear wall and simple steel plate shear wall can be determined.*

Key Words: *Steel plate shear wall, Corrugated steel plate shear walls, seismic analysis*

1.INTRODUCTION

[1] Shear walls are the most important structural component in construction. When compared with other lateral force resisting structures, steel plate shear wall has high stiffness, energy absorption capacity and attractive stiffness and when compared to standard reinforced concrete shear wall, steel plate shear wall have better ductility and superior seismic stability, light weight and also reusable.

Due to lack of knowledge about the response of corrugated steel plate shear wall, elastic and inelastic behaviour, and design requirements of corrugated steel plate shear walls construction industry was stuck on the standard shear walls and later a new construction based on the steel plate shear wall is made that is corrugated steel plate shear wall. Corrugated steel plates have the same properties of flat steel plates, in addition to their superior in-plane stiffness and out-of-plane stiffness[2].

Fig -1: Cold formed steel

Today cold formed steels are getting popularized all over the world because it introduces a better solution to demand for low-cost high-performance houses. Cold formed members are produced by cold rolling, pressing, bending steel sheets and stamping. Cold rolling process helps to provide lightness of systems, high quality of final products, helps to limit the production environment and flexibility[3]. and [4] also cold formed structures are more beneficial under seismic actions. channels like simple, hat, zeds are mainly used in roofs and walls and other residential applications and now these sections are commonly used in portal frames and floor systems. By using more complex stiffeners, more different shapes are being constructed if the sections become thinner in greater strength [5].Different experiments have been conducted on thin Steel plate shear wall. Steel Plate Shear Walls (SPSWs) have high stiffness, excellent energy absorption capacity and attractive stiffness when compared with other lateral force resistance structures. In areas with significant earthquakes, Steel Plate Shear Walls (SPSW) are known to be effective monotonic load resistance systems [6]. In comparison with the standard reinforced concrete shear wall, the SPSW has better ductility, superior seismic stability, light weight, and high construction quality, as well as quick repair, fast demolition, and reusability.

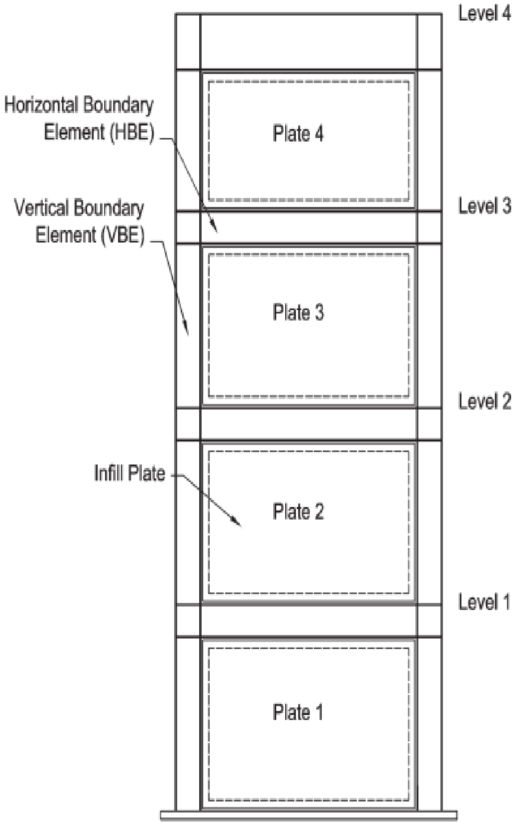

Fig-2 Steel plate shear wall

Most of the research findings shows that certain shortcomings in thin Steel Plate Shear Wall's performance characteristics, such as the out-of-plane buckling deformation of the steel plate wall under cyclic and monotonic loads, the excessive noise of the phase change, affect the structure's usefulness productivity and the tension field's appearance will carry the vertical edge portion with additional bending moment [7]. There must be a practical technological solution to prevent SPSW from bending out-of-plane in order to improve the poor seismic response caused by extreme out-of-plane deflections of the steel plate. Since structural engineers discovered the advantages of steel plate shear walls (SPSWs), the selection of SPSWs as the predominant monotonic force resistance device in structures has dramatically increased. In the design of the shear wall, stiffeners are introduced around openings to minimize shear buckling and preserve plate shear capacity. The fabrication and installation of stiffeners increases material and labour costs significantly, in addition to requiring additional inspections [8]. Two types of steel shear walls are used, stiffened and unstiffened. The stiffened type has greater stiffness and strength and the stiffening the panel can heavily increase the amount of energy dissipated under cyclic loading.

2. CORRUGATED STEEL PLATE SHEAR WALL

In contrast to traditional steel shear walls, CSSWs are relatively new, untested, and innovative. In fact, the early buckling of steel shear walls can be minimized through their use. A new construction based on the steel plate shear wall is the corrugated steel plate shear wall. Corrugated steel plates have all the properties of flat steel plates, in addition to their superior in-plane stiffness and out-of-plane stiffness [9].

As of now, corrugated steel has been successfully applied in practical engineering, such as bridge engineering, composite floor systems integrated container structures, and tunnel engineering. Over the past decade, research conducted on the performance of corrugated steel plate shear walls has been conducted, comparing the stiffness of unstiffened, vertical corrugated, and horizontal corrugated steel plate walls. Although the limit load of unstiffened samples was superior to others, its energy-dissipating capacity, ductility, and initial stiffness were all lower than those of corrugated samples [10].

3.EFFECTS OF CORRUGATED SHEAR WALLS

3.1 Effect of opening in Corrugated Steel plate Shear Wall

A thicker infill plate increases the ultimate strength for both CSSW and SSW; however, the SSW has slightly better performance for a given thickness. The overall performance of the shear wall is influenced by the thickness of the plate and the opening size. Since each panel thickness performs differently, a comparison between CSSW and SSW is only accurate when panel thickness and opening size are taken into consideration and the initial stiffness of CSSW is generally 20% higher than that of the corresponding SSW, leading to a lower level of non-structural damage. Further, the CSSW is 80% more ductile than the simple SSW under the procedures [11]. Particularly when there is a smaller opening. It is also cleared that the opening size has considerable influence on the CSSW ductility. From the corner of the opening, the yielding behaviour of the SSW with an opening begins. Adding an opening to SSW results in a greater than 50% stiffness degradation, whereas the CSSW with opening has a negligible stiffness degradation. The inclusion of an opening in SSW results in a greater than 50% stiffness degradation; however, CSSW with the opening has negligible stiffness degradation [12]. The degradation point - the point at which shear force begins to decrease - is delayed in CSSW in comparison with an unstiffened SSW. The CSSW geometry prevents yielding at the opening, resulting in smaller plastic strains at that displacement. When the load is increased, the stiffness in the SSW system without an opening may be as much as 50% higher than the stiffness in a system with an opening; however, in some situations, the stiffness becomes zero. The CSSW ultimate shear strength can be achieved at displacements five times greater than the

SSW ultimate shear strength, which may provide an advantage if seismic performance of the structural system is important.

3.2 Effect of corrugation angle

Angle of corrugation has no any significant effect on the ultimate strength capacity of Corrugated Steel Shear Wall with opening. When compared with other dimensions, corrugation of 45^0 shows slightly better performance, because the corrugation dimension parallel to the tension fields and the behavior of model will converge to the behavior of frame by increasing the dimension of opening. Here it indicates that the angle of corrugation would have only a less influence on openings have larger sizes. CSSW stiffness increases as the wall thickness increases, while it decreases as opening sizes grow. Generally, CSSWs respond in this manner. Because of the higher out-of-plane shear buckling stiffness observed for a 90° corrugation angle, CSSW has a higher stiffness than that of the other angles. There is a significant relationship between opening size and CSSW ductility, including the ductility of walls with smaller openings [13]. According to these figures, corrugation has no substantial effect on the ultimate strength of the shear wall system. CSSW, on the other hand, is 30% to 50% stiffer and ductile at the beginning than SSW, particularly when thinner plates are used. A simulated, monotonic load does not significantly affect the ultimate strength or stiffness of the corrugated plate.

3.3 Effect of different aspect ratio

It has been found that high aspect ratios increase initial stiffness as well as ultimate shear strength. We normalized the results for all considered wall aspect ratios to the corresponding CSSW with an aspect ratio of 1.5. The effects of aspect ratio become more pronounced as opening sizes increase. Due to an increase in steel plate dimensions, the tension field effect increases, allowing the CSSW to produce tension field more efficiently, leading to an increase in ultimate shear strength and stiffness. Shear walls with large openings have high aspect ratio and in corrugated steel plate shear walls, Corrugated Steel Shear Walls with opening having greater impact effect when compared with corrugated steel shear wall without opening. . According to research, increasing the thickness of the infill results in higher ultimate strength and stiffness [14].Then evaluated the ratio of ultimate shear strength and initial stiffness for each configuration compared with that of a wall without openings to better understand the effect of openings. The stiffness ratio K(Opening)/K (initial stiffness of single opening to no opening) as well as the ultimate strength FU(Opening)/FU (ultimate shear strength of single opening to no opening) are plotted as functions of d/D, where d represents the opening diameter and D represents the opening diameter of a shear wall.

3.4 Effect of plate thickness

The thickness of an infill plate influences the elastic and inelastic behavior of systems. The SPSW system is better in elastic and inelastic zones than the SPSW system. Increasing the Length/Height ratio increases the ultimate strength, stiffness, and energy absorption of systems [15]. All systems have improved elastic and inelastic behavior. Consequently, Length/Height ratio does not significantly affect the inelastic stiffness and the elastic stiffness is significantly affected by Length/Height ratio.

4. BEHAVIOUR OF CORRUGATEDSTEEL PLATE SHEAR WALL

A number of studies have been conducted to investigate the lateral resistance, stiffness, and buckling behavior of shear wall systems and to propose prediction models. In shear wall designs, stiffeners around openings are typically introduced to inhibit shear buckling and preserve shear capacity. Stiffener fabrication and installation, however, significantly increases material and labour costs, as well as inspection requirements. Specimens are loaded cyclically according to estimated yield displacements. It is studied the nonlinear behavior of steel plate shear walls (SPSWs) incorporating stiffened rectangular openings used as windows or doors in buildings [16] .The mathematical analysis of a number of SPSWs with and without openings is used to characterize the behavior of SPSWs with openings, to investigate the effects of various opening features on the system as well as the size of local boundary elements (LBE) around the opening and the thickness of infill plates on opposite sides, and to investigate the changes in system strength, stiffness, and ductility caused by the openings. During the test, the displacement-controlled quasi-static cyclic loading program will be used. Studies have indicated that Low yield Steel Plate Shear Wall has a relatively small yield displacement. In order to estimate yield displacement values, the pushover analysis was conducted on the specimen's using information gained from the coupon test results and the as-built geometric information. In the pushover curve, the yield displacement was determined using the Park R method. Cyclic load analysis is depended upon the estimated yield displacements and here the behavior of unstiffened corrugated steel plate shear walls with opening and without opening have been determined and studied Corrugated panels postpone the ultimate strength and degradation point leading to better performance under seismic loads. hysteresis curve is an important index to evaluate the seismic behavior of the structure [17]. The corrugations of trapezoidal corrugated infill plates are stiff out-of-plane, which results in significant initial stiffness, as a consequence of the corrugated geometry of the plate infill, plastic strain around openings is limited cause each corrugation supports adjacent corrugations in the out-of-plane direction.

4.1 Lateral stiffness

By measuring the lateral resistance of infill plates, we can determine their contribution to supporting lateral loads. Curves of stiffness for SPSWs with Length/Height is 1.0, 1.8, and 2.6 and different infill thicknesses. When compared with open frames, infill walls improve lateral stiffness considerably. It has been reported that walls with thicker walls have a higher initial lateral stiffness. After the appearance of diagonal yield zones, which occur at similar drift angles, the curves tend to converge. Also, with the increase of plate thickness, the plateau between the first yield zone and the diagonal yield zone of the walls fades away and the system experiences a sharper loss of stiffness. As a result of the occurrence of the first yield points in frame members and between the drift angles of 0.5% and 1%, infills become less effective and all stiffness curves merge into an open frame curve [18]. In other words, after a drift angle of 1%, it is only the frame that bears lateral loads. With early buckling of their infill plates at very early stages of loading, SPSWs with no openings experience significant loss of stiffness.

4.2 Ultimate shear strength

An increase in ultimate strength is achieved when the infill plate stress is the same on the SPSW. Increasing the Length/Height ratio as well as infill plate thickness will result in higher ultimate strength. In fact, increasing the Length/Height ratio has a greater impact than increasing the infill plate thickness. In a model with Length/Height is 1, by increasing plate thickness from t to 2t that is 2 times, the ultimate strength is increased by 5%, whereas in the model with an infill plate thickness of t, by increasing Length/Height ratio from 1 t to 2t that is 2 times, the ultimate strength is increased by 11%. The Length/Height ratio is therefore more effective than the thickness of the infill plate [8].

4.3 Energy absorption

An approximate definition of energy absorption capacity is the load–displacement region between onset of inelastic behavior and a half cycle load with 30% drift ratio. CSSW and SSW under lateral shear loading, with an opening, and their energy absorption capacity. Based on the size of the opening, the average shear wall energy absorption of walls with central openings. For both CSSW and SSW, the absorption energy decreases as the opening size increases. There has been a consistent difference between the energy absorption capacity of SSW and CSSW and Furthermore, the CSSW energy absorption capacity for all plate thicknesses is greater than the SSW capacity. For different thicknesses and opening sizes, the CSSW absorbs more energy than a corresponding SSW and for each thickness, the CSSW with central opening configuration exhibits considerable absorbed energy when compared with the corresponding SSW [6].

5. CYCLIC PERFORMANCE

It has been studied extensively to investigate the cyclic behavior of CSW in high-rise buildings and nuclear plants under seismic or imposed forces, since adequate security must be guaranteed. When subjected to in-plane cyclic shear loading, CSW displays adequate power dissipation capacity, shear strength, and deformation capacity. The failure mode for composite walls is similar to that of monotonic shear. There is a slight reduction in the shear load capacity for the cyclic case of composite walls with shear studs only under cyclic shear, which provides a fundamental principle for other types of connectors. The steel plate reinforcement ratio is found to be the most important factor influencing the cyclic shear behavior of composite walls in parametric studies [9]. For example, the in-plane shear resistance of CSW increases linearly with the steel plate reinforcement ratio, while the influence on other parameters is almost insignificant, such as wall aspect ratio. Meanwhile, extensive research has been conducted on composite walls under combined axial compression and in-plane cyclic shear loads in order to simulate the lower storey loading conditions. The experimental and numerical results demonstrate that CSW is capable of dissipating energy and deforming to an appropriate extent, which makes it an excellent candidate for use within a shear resistance framework. A higher axial load ratio also increases the initial stiffness of the skeletal curve, which can be effectively implemented in shear resistance frameworks. Experimental and numerical results demonstrate that CSW has a high energy dissipation capacity and an adequate deformation capacity. Additionally, it decreases energy dissipation capacity and ductility. Several equations have been developed to calculate load-carrying capacity and stiffness. A boundary element may also increase the energy dissipation and deformation capacities of composite walls when combined with axial compression and cyclic shear loads [2].

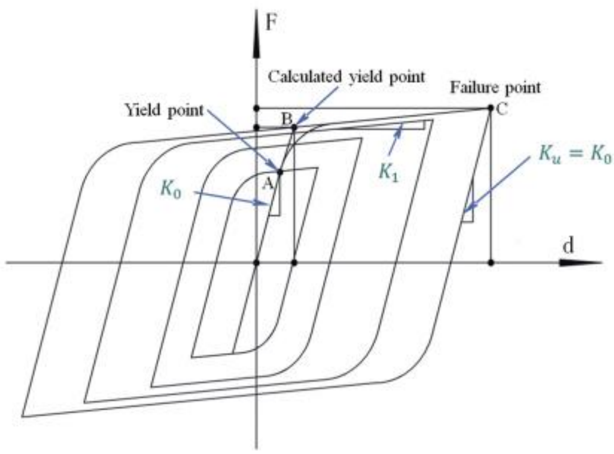

Fig 3-Hysteretic model recommended by the Code for Building Isolation and Energy Dissipation Design

6. CONCLUSION

We have studied the behaviour of unstiffened and corrugated steel plate shear walls with and without openings and in this computational study, the effect of opening dimensions on the behaviour of steel plate shear walls, boundary element stiffness, and steel infill plate interconnection is investigate and A discussion was conducted on seismic behaviours such as ductility, stiffness degradation, and cumulative energy dissipation [19]. Due to their corrugated construction, corrugated panels postpone the decay point and have better seismic performance and a number of single and multi-storey Steel Plate Shear Walls with and without stiffened large rectangular openings which are used as doors and windows in all buildings were analysed clearly and the results were utilized

- to evaluate the behaviour of SPSWs with stiffened rectangular openings,
- To study the effect of opening as well as size and thickness
- To determine the effects in the system behaviour due to the introduction of the openings in shear wall [11].

And from the analysis conducted, the following observations and conclusions are obtained,

- In case of shear walls with openings, initial stiffness and ductility of Corrugated Steel Shear Walls higher than Simple Steel Shear Walls.
- In most of the cases, ultimate shear strength of Steel Shear Wall is higher than that of Corrugated Steel Shear Wall [20].
- Ductility and initial stiffness of corrugated steel shear wall without opening is greater when compared with unstiffened shear walls
- Larger aspect ratio shear walls exhibit an increased performance of ultimate shear strength and initial stiffness, particularly for walls having large openings.
- Installation of openings improves the performance, Increase of approximately 10% under monotonic loads.
- The energy absorption capacity is higher for Corrugated Steel Shear Wall than the Steel Shear Walls.
- It indicates the suitability of Corrugated Steel Shear Walls with an opening under cyclic loadings in different opening sizes.

REFERENCES

[1] M. Wang, Y. C. Guo a, Lu Yang, "Damage indices and fragility assessment of coupled low-yield-point steel plate shear walls", Journal of Building Engineering vol 42 (2021)

[2] F. Emami, M. Mofid, A. Vafai, "Experimental study on cyclic behavior of trapezoidally corrugated steel shear walls" Engineering Structures vol 48 (2013) pp 750-762

[3] Y. Wanga, C. Gua, b, Q. Tanga, Y. Shia, L. Xua, J. Tana, W. Luod "Experimental study on cyclic pure shear behaviour of hat-section coldformed steel member buckling-restrained steel plate shear walls without effect of frame" Engineering structures vol 201 (2019)

[4] J. Tan, C. Gu, M. Su, Y. Wang a, K. Wang, Y. Shi, Y. Lan, W. Luo, X. Deng, Y. Bai, Q. Chen, "Finite element modelling and design of steel plate shear wall buckling-restrained by hat-section cold-formed steel members" Journal of Constructional Steel Research vol 174 (2020)

[5] J. Cui, J. Xu, Z. Xu, T. Hou, "Cyclic behavior study of high load-bearing capacity steel plate shear wall" Journal of Constructional Steel Research vol 172 (2020)

[6] S.A. Aghazadeh, A. Farrukhabad Gh. Langata, E. Pedramc, H. Malekinejada, S. Farahani Mohammadi a, H. Ahmadia "Characterization of compressive behavior of PVC foam infilled composite sandwich panels with different corrugated core shapes" Thin-walled structures vol 135 (2019) pp 160-172

[7] Wei Wang, Qirui Luo, Zhuangzhuang Sun, Benjie Wang, Shawne Xu "Relation analysis between out-of-plane and in-plane failure of corrugated steel plate shear wall" structures vol 29 (2021) pp 1522-1536

[8] Maryam Bypour, Mahdi Kioumarsi, Mohammad Yekrangnia c "Shear capacity prediction of stiffened steel plate shear walls (SSPSW) with openings using response surface method" Engineering structures vol 226 (2021)

[9] Sajjad Sayyar Roudsari, Sayed M. Soleimani, Sameer A. Hamoush "Analytical study of the effects of opening characteristics and plate thickness on the performance of sinusoidal and trapezoidal corrugated steel plate shear walls" Journal of Constructional Steel Research vol 182 (2021)

[10] Meng Wang a, ∗, Yongjiu Shi b, Jian Xu c, Weiguo Yang a, Yixin Li b "Experimental and numerical study of unstiffened steel plate shear wall structures" Journal of Constructional Steel Research vol 112 (2015) pp 373-386

[11] Nasar Ahmad Khan, Gaurav Srivastava "Models for strength and stiffness of steel plate shear walls with openings" Structures vol 27 (2020)

[12] S.A.A. Hosseinzadeh, Mohsen Tehranizadeh "Introduction of stiffened large rectangular openings in steel plate shear walls" Journal of Constructional Steel Research vol 77 (2012) pp 180-192

[13] Alireza Farzampour, Jeffrey A. Laman "Behaviour prediction of corrugated steel plate shear walls with openings" Journal of Constructional Steel Research vol 114 (2015) pp 258-268

[14] Elsayed B. Machaly, Sherif S. Safar n, Mostafa A. Amer "Numerical investigation on ultimate shear strength of steel plate shear walls" Thin-Walled Structures vol 84 (2014) pp 78-90

[15] H.R. Habashi, M.M. Alinia "Characteristics of the wall–frame interaction in steel plate shear walls" Journal of Constructional Steel Research vol 66 (2010) pp 150-158

[16] Jongwon Yia, Heungbae Glib, Kwangsoo Youmc, Hakeun Leed, "Interactive shear buckling behavior of trapezoidally corrugated steel webs" Engineering Structures vol 30 (2008) pp 1659-1666

[17] Jia-Chun Cui, Ji-Dong Xu, Zi-Ran Xu, Tao Huo "Cyclic behaviour study of high load-bearing capacity steel plate shear wall" Journal of Constructional Steel Research vol 172 (2020)

[18] Nima Paslara, Alireza Farzampourb, Farzad Hatamic Investigation of the infill plate boundary condition effects on the overall performance of the steel plate shear walls with circular openings structures vol 27 (2020) pp 824-836

[19] Jinju Lu a, b, Haiyang Zhang b, Shunji Yu b "Study on seismic behaviours of self-centering steel plate shear walls with slits" Journal of Constructional Steel Research vol 185 (2021)

[20] Life Feng, Tianshu Sun, Jinping Ou "Elastic buckling analysis of steel-strip-stiffened trapezoidal corrugated steel plate shear walls" Journal of Constructional Steel Research vol 184 (2021)