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ANALYSIS OF STIFFENED AND UNSTIFFENED LOW YIELD POINT STEEL PLATE SHEAR WALL WITH DIFFERENT TYPES OF PERFORATIONS

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***Abstract**:* The use of steel structures in seismic –prone areas is a well-established effective approach due to their strength and ductility, which enables them to withstand the forces generated during earthquakes. Steel shear walls, in particular, are considered one of the best options for seismic resistance. However, recent advancements in steel production have introduced a new material called Low-Yield Point Steel (LYP Steel), Characterised by extremely low yield strength and high elongation properties. This new steel material has the potential to offer unique benefits in seismic design.

In the current study, we delve into the seismic performance of a wide spectrum of low yield point steel plate shear walls, encompassing various stiffness configurations and perforation types, including square, circular, and elliptical. The research accounts for shear walls that are unstiffened, horizontally and vertically stiffened, diagonally stiffened, and combinations thereof. Additionally, the impact of varying perforation sizes is considered. This comprehensive investigation seeks to shed light on the diverse structural behaviours exhibited by these shear wall configurations when subjected to seismic forces. The outcomes aim to provide valuable insights into optimizing the use of low yield point steel plate shear walls, guiding engineers and architects in the pursuit of resilient and efficient building designs that meet the evolving demands of seismic-prone regions.

Index Terms **- Low Yield Point (LYP) Steel, Seismic, Steel plate shear wall.**

I. INTRODUCTION

Shear walls are vertical structural elements in structural engineering, designed to withstand lateral forces, such as wind and seismic loads. Steel plate shear wall (SPSW) systems, often incorporating low yield point (LYP) steel infill plates, are widely employed for their strength and resilience. Stiffeners and perforations play crucial roles in optimizing the performance of shear walls, influencing factors like strength and ductility. In this context, we explore the behaviour of stiffened and unstiffened LYP steel plate shear walls with different types of perforations. A literature study in this area was carried out.

Ali Ghamari et. al (2021) determined the High-Performance Steel Plate Shear Wall (HPSPSW) using numerical and paramedical approaches. The properties of HPSPSW and LYP (Low Yield Point) steel (LHPSPSW) were measured. In this paper, the improvement of HPSPSW behaviour for achieving higher ultimate strength and stiffness, and lower energy absorption properties are investigated. The results showed that the L/H ratio improves the behaviour of SPSW, HPSPSW, and LHPSPSW in the case of elastic stiffness, ultimate strength and energy absorption. The LHPSPSW system significantly improves the elastic stiffness of SPSW. The numerical results indicated that the SPSW has a higher stiffness, ultimate strength, and energy absorption than HPSPSW. Also, it was shown that LHPSPSW exhibits higher properties compared to SPSW and HPSPSW in both elastic and inelastic zones. It was also concluded that using LYP in HPSPSW enhances the seismic parameters of the system.

Jia-Chun Cui et.al (2020) developed a kind of high load-bearing capacity steel plate shear wall with yield load not less than 3000kN to be applied in the frame-steel plate shear wall structural system which has been utilized in the design and construction of high-rise buildings. Low-Yield Point (LYP) steel was adopted as the shear web plate of the steel plate shear wall. In this research, two specimens of the LSPSW including LYP shear web plate, flange plate, connection plate, vertical stiffener and horizontal stiffeners were designed. The main difference between the specimen LSPSW1 and specimen LSPSW2 was the cyclic loading history. The stiffness degradation, ductility and energy dissipation characteristics of the LYP steel plate shear wall (LSPSW) were investigated. Based on the test study, the finite element package ABAQUS is also utilized to further investigate the plastic behaviour of the specimens proposed in this study. Comparative studies of the cyclic test and FEM analysis were carried out to verify the accuracy of the FE model of the LSPSW. The test results indicated that the newly developed LSPSW has superior ductility and energy dissipation capacity, which confirm that it can be used as an effective lateral force resisting structure system in the future.

Tadeh Zirakian et.al (2015) assessed the structural behaviour as well as plate–frame interaction characteristics of unstiffened low yield point steel plate shear wall systems via finite element and analytical approaches. In this paper, the structural performance of code designed and unstiffened LYP steel shear wall systems was examined primarily through finite element analysis. The advantages of using LYP steel material in SPSW systems as compared to the conventional steel material were demonstrated through comparison studies. In addition, the performance of the SPSW models with slender, moderate, and stocky LYP steel infill plates under monotonic and cyclic loads were investigated as well. SPSWs were designed according to capacity-design principles, in which boundary elements were designed to permit the web plates to develop significant diagonal tension. After experimental validation of the numerical modelling, advantages of use of low yield point steel as compared to the conventional steel are demonstrated. The PFI model was introduced and demonstrated that this modelling technique is able to predict the behaviour of different SPSW configurations with thin or thick infill plates, and with or without stiffeners and openings. It was concluded that application of LYP steel not only facilitates the design of SPSW systems, but also may enable upgrading the structural performance through seismic retrofit of existing buildings. It was demonstrated that application of LYP steel infill plates results in reduced forces imposed on the boundary frame members as compared to the conventional steel infill plates. Application of unstiffened steel shear wall systems with relatively high buckling and low yielding capacities, enhanced serviceability as well as energy dissipation capacity is made possible in the light of use of LYP steel material.

2. NEED OF THE STUDY

This study on LYP steel shear walls with varying perforation shapes and stiffener configurations serves critical engineering needs by optimizing structural design. It enhances safety and reliability, particularly in earthquake or high-wind-prone regions, ensuring the protection of occupants and property. Additionally, it promotes cost-efficient designs by identifying effective configurations, reducing material waste. Architects benefit from the design flexibility to accommodate aesthetic and functional requirements. The study's insights can inform building codes, aligning construction practices with the latest research. It also contributes to sustainability goals by minimizing material use. Ultimately, this research helps mitigate risks and advances structural engineering practices in the construction industry.

3. OBJECTIVES OF THE STUDY

- ❖ To study numerically the performance of diagonally stiffened Low Yield Point (LYP) Steel plate shear wall with different types of perforations (circular, rectangular and square perforations) under lateral load.
- ❖ To study the improvements in performance of LYP steel shear wall by providing diagonal stiffeners, combination of diagonal and horizontal, combination of horizontal and vertical, 3 combination of diagonal, vertical and horizontal stiffeners.
- ❖ To investigate the performance of LYP steel shear wall with increase in size of central perforation.
- ❖ To assess the improvements in performance of LYP steel plate shear wall with perforations due to stiffening, compared to unstiffened shear wall

4. ANALYSIS OF STIFFENED AND UNSTIFFENED LYP STEEL SHEAR WALL WITH DIFFERENT SHAPES OF PERFORATIONS

The analysis of stiffened and unstiffened LYP steel shear wall with three different shapes of perforation. The shapes of perforation are circular, square and elliptical. For stiffened models, diagonal stiffeners, combination of horizontal and vertical stiffeners, combination of diagonal and horizontal stiffeners, combination of diagonal, horizontal and vertical stiffeners are used for analysis. Thirty models of LYP steel shear walls are created using ANSYS with stiffened and unstiffened perforated models.

4.1 Circular Perforations

Ten models of LYP steel shear wall with circular perforation are created using ANSYS. Out of the ten models, five models are created with d/h ratio of 0.26, where d is the diameter of perforation and h is the height of shear wall. The other five models are created with an increase in opening diameter. The diameter is increased to 1.5 times the original diameter. So, the d/h ratio becomes 0.4. The models include unstiffened LYP shear wall with perforation, perforated LYP shear wall with diagonal stiffeners, combination of horizontal and vertical stiffeners, combination of diagonal and horizontal stiffeners, combination of diagonal, horizontal and vertical stiffeners.

4.2 Square Perforations

Ten models of LYP steel shear wall with square perforation are created using Ansys. Out of the ten models, five models are created with a side of 355 mm, keeping the area of the perforation same as in the case of circular perforation. The other five models are created with an increase in the sides of the square perforation. The side is increased to 1.5 times the original dimension. The models include unstiffened LYP shear wall with square perforation, perforated LYP shear wall with diagonal stiffeners, combination of horizontal and vertical stiffeners, combination of diagonal and horizontal stiffeners, combination of diagonal, horizontal and vertical stiffeners.

4.3 Elliptical Perforations

Ten models of LYP steel shear wall with elliptical perforation are created using Ansys. Out of the ten models, five models are created with dimension a=160mm (x-axis), b=250mm (y-axis), keeping the area of the perforation same as in the case of circular perforation the other five models are created with an increase in the dimensions of the perforation. The side is increased to 1.5 times the original dimension. The models include unstiffened LYP shear wall with elliptical perforation, perforated LYP shear wall with diagonal stiffeners, combination of horizontal and vertical stiffeners, combination of diagonal and horizontal stiffeners, combination of diagonal, horizontal and vertical stiffeners.

4.4 Load comparison and % decrease in load of LYP steel shear wall on the basis of size of perforations

It is clear that LYP steel shear wall with a combination of diagonal, horizontal and vertical (DHV) stiffeners are more preferable. Now we have to compare the shear wall on the basis of size of perforation. The load comparison and % decrease in load of LYP steel shear wall on the basis of size of perforation.

Table 1. Load comparison and % decrease in load of LYP steel shear wall on the basis of size of perforations

LYP shear wall model	Shape of perforation	Perforation size	LOAD (KN)	% decrease in load
Without stiffener	C	400mm	1736.1	5.93
		600mm	1633	
	SQ	355 x 355 mm	3222.8	16.89
		532 x532mm	2678.2	
	EL	160 x 250	3118.6	14.46
		240x 375	2667.6	
Diagonal stiffener	C	400mm	1783.1	6.42
		600mm	1668.6	
	SQ	355 x 355mm	3241.6	10.60
		532 x 532mm	2897.9	
	EL	160 x 250	3195.1	13.89
		240x 375	2751.3	
Horizontal and vertical stiffener	C	400mm	1821.8	5.65
		600mm	1718.8	
	SQ	355 x 355mm	3379.5	11.56
		532 x 532mm	2988.7	
	EL	160 x 250	3314.1	11.91
		240x 375	2919.3	
Diagonal and horizontal stiffener	C	400mm	1985	6.05
		600mm	1865	
	SQ	355 x 355mm	3496.7	12.10
		532 x 532mm	3073.5	
	EL	160 x 250	3569.9	13.17
		240x 375	3099.5	
Diagonal , horizontal and verticalstiffener	C	400mm	2071.1	7.34
		600mm	1919	
	SQ	355 x355mm	3585.1	12.37
		532 x 532mm	3141.4	
	EL	160 x 250	3629.7	14.61
		240x 375	3099.5	

From the table it is clear that as the perforation size increases, the maximum load carrying capacity decreases. In the case of shear wall with circular perforation with 600 mm diameter, the % decrease in load for unstiffened, diagonally stiffened, horizontally and vertically stiffened, diagonally and horizontally stiffened, diagonally, horizontally and vertically stiffened are 5.983 %, 6.42%, 5.65%, 6.045%, 7.34%. In the case of shear wall with square perforation with 532 x 532 mm size, the % decrease in load for unstiffened, diagonally stiffened, horizontally and vertically stiffened, diagonally and horizontally stiffened, diagonally, horizontally and vertically stiffened are 16.89%, 10.602%, 11.56%, 12.102%, 12.37%. In the case of shear wall with elliptical perforation with 240 x 375 mm size, the % decrease in load for unstiffened, diagonally stiffened, horizontally and vertically stiffened, diagonally and horizontally stiffened, diagonally, horizontally and vertically stiffened are 14.46%, 13.89%, 11.91%, 13.17%, 14.607%. So, it is observed that increased size in perforation reduces the stiffness.

5. COMPARISON OF SHAPES OF PERFORATIONS

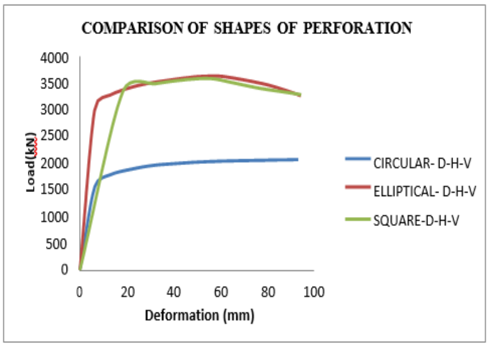

Fig1 Load deformation comparison of different shapes of perforation

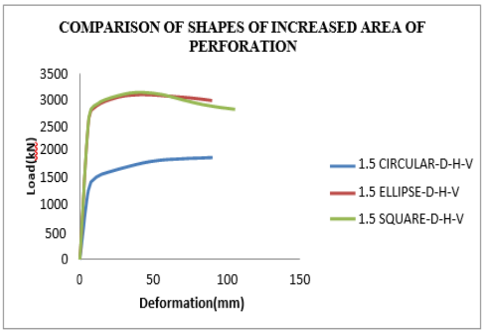

Fig 2 Load deformation comparison of different shapes of increased area of perforation

From the fig 1 and 2, it is observed that the shear wall with circular perforation have low value of load compared to the other two models. The model with circular perforation has a load value of 2071.1kN at 93.283 mm deformation. Even though the model did not failed or there is no decrease in load value. So, we can't say the circular model is not preferable. The models can withstand a drift of 6%. The model with square perforation has an ultimate load capacity of 3585.1kN at a deformation of 55.99mm. The model with elliptical perforation has an ultimate load carrying capacity of 3629.7kN at 53.668mm deformation. So, it is clear that among the three models, model with elliptical perforation is is found to be best compared circular and square perforation walls.

6.CONCLUSION

In this study, a comprehensive numerical analysis of LYP steel shear walls was conducted, focusing on the influence of different perforation shapes and stiffener configurations. The research revealed several significant findings. Firstly, the presence of perforations in shear walls was found to reduce their stiffness, with unstiffened models exhibiting lower stiffness. Stiffeners, however, were shown to improve overall stiffness. Secondly, among various stiffener combinations, shear walls equipped with a combination of diagonal, horizontal, and vertical (DHV) stiffeners demonstrated superior load-carrying capacity compared to other configurations, making DHV stiffeners the preferred choice. Additionally, the study highlighted that increasing the size of perforations led to a decrease in both stiffness and load-carrying capacity. Notably, circular perforation models exhibited lower load values but did not fail, remaining a viable option, particularly since all models were capable of withstanding a 6% drift. Ultimately, the model featuring an elliptical perforation with DHV stiffeners emerged as the most effective design. These findings offer valuable insights for structural engineers and designers working with LYP steel shear walls, emphasizing the importance of selecting appropriate stiffeners and considering perforation size and shape during the design process.

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