Strengthening of Cantilever Wall against Lateral Loading Using Externally Bonded Steel Channel

Trupti S. Thite[1]* Dr. Prashant M. Pawar[2] Vidyarani S. Kshirsagar[3] Manik G. Deshmukh[4] Avinash B. Kokare[5] Pooja S. Lachyan[6]

[1] PG Student, Civil Engineering Department, SVERI'S College of Engineering, Pandharpur, Maharashtra

[2] Professor, Civil Engineering Department, SVERI'S College of Engineering, Pandharpur, Maharashtra

[3,4] Associate. Professor, Civil Engineering Department, SVERI'S College of Engineering, Pandharpur, Maharashtra

[5,6] Assistant Professor, Civil Engineering Department, SVERI'S College of Engineering, Pandharpur, Maharashtra

Abstract – The purpose of this experimental study is to investigate the behaviour of cantilever walls that are strengthened by bonding of steel channels. Three, cantilever wall test specimens were constructed and tested under cyclic lateral loading. For this experimental research three wall specimens were strengthened with different steel channels. The different configurations of steel channels were considered the channel at bottom, lateral channel and the combination of both lateral and vertical channels. All steel strip configurations are arranged on one side of the wall. Test results showed that the channel at bottom configurations improved the lateral strength, energy dissipation capacity and deformation capacity of the cantilever wall significantly. Nominal flexural strength developed by strengthened specimens, and hence, the observed maximum base shear was controlled by flexure. As cantilever wall fails due to overturning movement we attached a steel L-channel at junction of stem and base of slab. Steel channels limited the opening of shear cracks and improved the lateral displacement capacity. Using ANSYS the Finite element modeling is carried out for numerical analysis. In this Present work, we have observed that when applied pressure increases then there is an increase in maximum deformation and equivalent stresses. It is observed that for a single brick wall and double brick wall of various dimensions, increase in applied pressure increases the maximum deformation and also equivalent stresses.

Keywords – Brick Masonry, Finite Element Modeling, Material Properties, single brick wall, double brick wall.

---------------------------------x---------------------------------

1. INTRODUCTION:

Cantilever walls are walls that do not have any support and thus have a free unsupported excavation. Cantilever walls restrain retained earth by the passive resistance provided by the soil below the excavation. The base slab serves as a permanent support and prevents overturning and sliding. The cantilevered stem portion is rigid at the bottom and is free at the top. Such wall consists of a vertical stem, and a base slab, of two different sections, i.e., heel slab and a toe slab. All three components behave like one-way cantilever slabs: the "stem" acts as a perpendicular cantilever above the lateral earth pressure; the "heel slab" and the "toe slab" acts as a parallel cantilever under the action of the resulting soil pressure. The walls will provide long-standing stability and serviceability. These walls are constructed of reinforced concrete. There are various forces acting on the cantilever wall like lateral earth pressure, axial load, wind load, impact forces, seismic earth pressure etc. The lateral stability of these walls is the most important factor. An option is installed at the bottom of the base slab. This is to ensure extra safety against sliding. The walls will provide long-standing stability and serviceability. Different modes of failure have different factors of safety. In this paper stability check for a cantilever wall is obtained using a computer program that calculates various sections satisfying the stability criteria, according to the height and properties of earth that the wall is required to support. In this research work different materials were used for analyzing the performance of existing cantilever walls against lateral loading .The main aim of this study is to achieve strength and stability of cantilever wall against lateral loading. There are four basic instability modes to be checked for the service load combinations: Sliding, Overturning, Soil bearing, and Global instability.

1. Sliding: The backfill exerts a lateral pressure against the wall. This sliding force is resisted by the friction between the underlying soil and the footing, and by the passive pressure at the front of the wall. When more sliding resistance is required, a shear key may be provided. The factor of safety against sliding equals the resisting force divided by the driving force, and the minimum value should be 1.50.

2. Overturning: The overturning moment from the applied forces must be resisted by an opposite moment produced by the vertical forces, including the wall self weight and the weight of the backfill over the heel. The factor of safety against overturning is defined as the resisting moment divided by the overturning moment, and the minimum value should be 1.50.

3. Soil bearing: The allowable soil bearing pressure should be provided by the soils report, which already includes a safety factor of about 3.0. The resultant of the bearing pressure should fall within the middle third to avoid negative soil pressures at the heel.

4. Global instability: It assumes that a failure surface develops under the wall, causing a massive disturbance and movement of the soil along this surface. This check is a complex analysis that falls in the field of geotechnical engineering.

2. METHODOLOGY:

2.1 Finding critical failure locations by performing analysis of brick walls: From the graph of displacement versus force, the failure location of the wall is evaluated. Junction of wall and foundation is observed as the critical location at the maximum value of force .It shows that the wall fails due to an overturning moment.

2.2 Experimental analysis of wall for strengthening against lateral: An experimental analysis by gradually applying horizontal loads on 1m wide brick wall having height variation with L-channel as a strengthening material is carried out. The ultimate load where the brick wall fails is evaluated from this experiment .After that the analysis is carried out by calculating variations in reading or without and using strengthening materials.

3. SCOPE OF WORK:

Evaluation of pressure for height variation of 1m, 1.5m and 2m with and without using strengthening material. Calculating the more pressure taken by wall after strengthening and achieving the stability of the wall.

4. EXPERIMENTAL PROCEDURE:

1. This device has a column-like structure which will be fixed parallel to the walls.

2. As the height of wall is varying we kept the height of column 1.5 m.

3. Horizontal hydraulic jack which is useful for applying the horizontal load is connected perpendicular to the wall connecting to the vertical column.

4. Load cell is used for measuring the amount of load applied. It is connected between the wall and the loading jack.

5. Dial gauge is also connected between the wall and vertical cantilever column to measure the deflection of the wall.

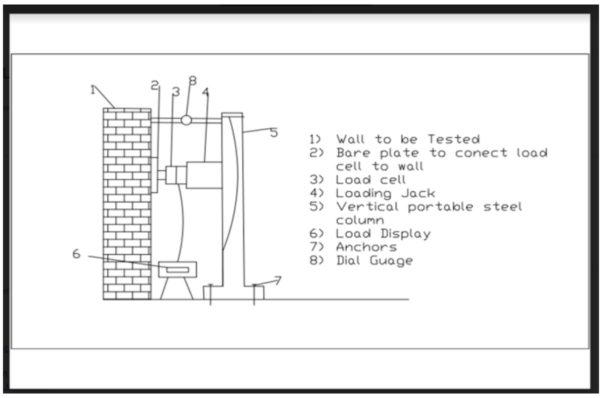

Fig.4.1 Schematic experimental testing setup

Fig.4.2 Actual Experimental setup

4.1 Procedure to use the device:

The device operation procedure is explained in detail with respect to Figure 1.

1. Connect the load cell to the wall shown in fig.1 using the base plate.
2. Fix the vertical steel column parallel to the wall using anchors.
3. The damper is connected between load cell and column as shown in fig.
4. Connect the dial gauge between the wall (1) and vertical column (5) to measure the deformation due to load.
5. Gradually apply the load and measure the deformation.
6. After taking all the reading, attach a steel L-channel as a strengthening material at the base of a wall by using anchors.
7. Compare both previous readings and after attaching L-channel readings by making a table and plot the graph of the same.
8. And check how much further pressure wall will carry after strengthening

5. EXPERIMENTAL RESULTS:

5.1 For 1 m x 1 m wall:

The graph of displacement on X-axis and horizontal force on Y- axis is plotted for definite interval of 5mm displacement the graph presented in fig 5.1

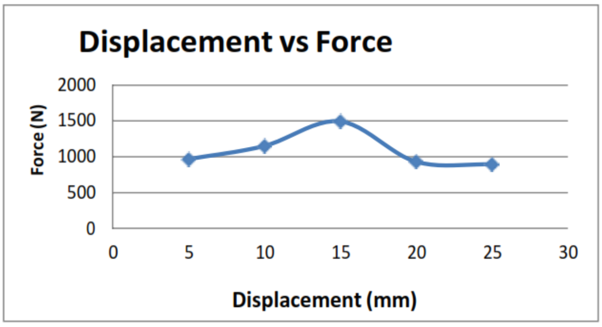

Fig.5.1 Force Displacement plot for 1m x 1 m wall only

The graph of displacement vs. Force after attaching L-channel is plotted for definite interval of 5mm displacement the graph presented in fig 5.2

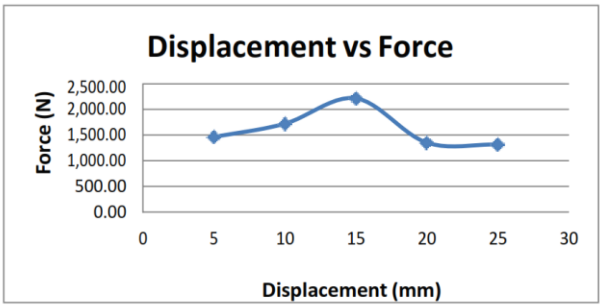

Fig.5.2 Force vs. Displacement plot for 1m x 1 m wall after using L-channel

5.2 For 1 m x 1.5 m wall:

The graph of displacement on X-axis and horizontal force on Y- axis is plotted for definite interval of 5mm displacement the graph presented in fig 5.3

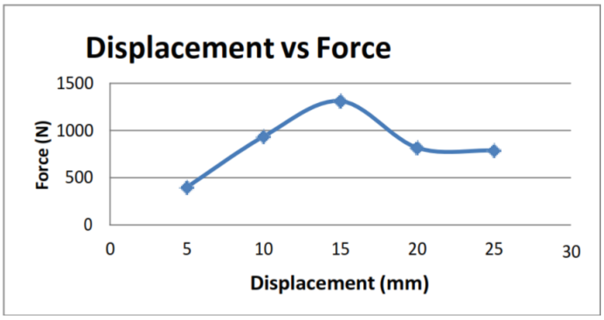

Fig.5.3 Force Displacement plot for 1m x 1.5 m wall only

The graph of displacement vs. Force after attaching L-channel is plotted for definite interval of 5mm displacement the graph presented in fig 5.4

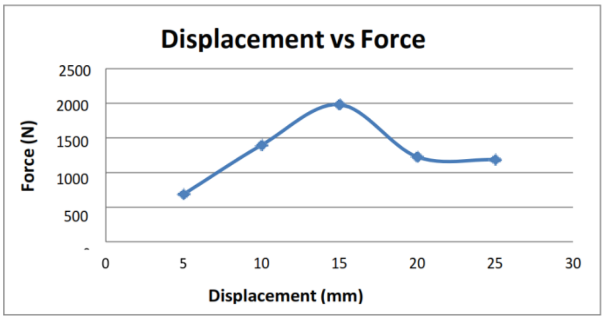

Fig.5.4 Force Displacement plot for 1m x 1.5 m wall after using L-channel

5.3 For 1 m x 2 m wall:

The graph of displacement on X-axis and horizontal force on Y- axis is plotted for definite interval of 5mm displacement the graph presented in fig5.5

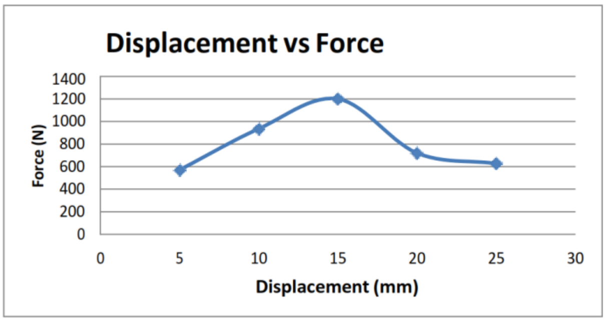

Fig.5.5 Force Displacement plot for 1m x 2.0m wall only

The graph of displacement vs. Force after attaching L-channel is plotted for definite interval of 5mm displacement the graph presented in fig 8.

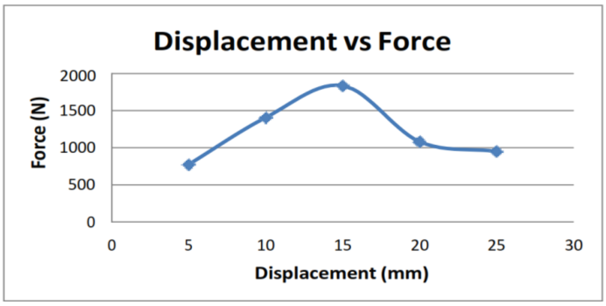

Fig.5.6 Force Displacement plot for 1m x 2m wall after using L-channel

6. FAILURE PATTERN OBSERVED FOR VARIOUS HEIGHTS OF WALLS:

Above figures shows the force-displacement graphs for varying heights of wall viz 1m, 1.5m and 2m.For the height of wall 1m failure of the wall starts at lateral pressure of 1500 N/mm^2 for which displacement of the wall is observed as 15 mm. The junction of the wall and foundation is the main failure region. So we use L-channel at the junction. After using it the wall will take 720.666 N/mm^2 more pressure. Similarly, 1.5m and 2m wall will take 669.51N/mm^2 and 636.795N/mm^2 more pressure than previous.

Fig.6.1 Failure of Double Brick Wall without Channel

Fig.6.2 Failure of Double Brick Wall after attaching channel

Fig 6.3 shows the graphical interpretation of both i.e. Wall without and with L- channel as height of wall on X-axis and the failure shows on Y-axis.

From the figure 6.3 it is observed that failure shows having highest values at height of 1.0 m without L-channel and walls having L-channels attached can sustain with more pressure. Hence we can strengthen a wall by attaching steel L-channel.

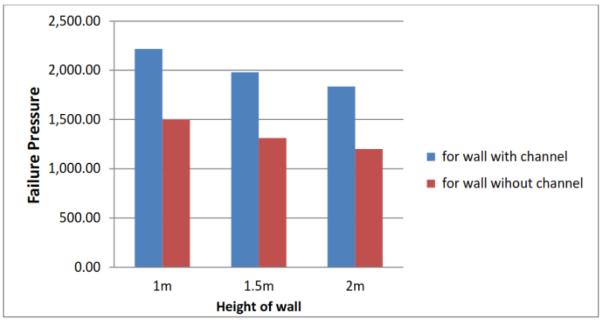

Fig. 4.15 Effect of Height of wall on Failure Pressure of Wall

Above figures shows the force–displacement plots for varying heights of wall viz. 1m, 1.5m and 2m.For the height of wall 1m failure of the wall starts at lateral pressure of 1500 N/mm^2 displacement for which displacement of the wall is observed as 10 mm. This failure was observed at the junction the wall and foundation.

From these pictures it was noted that wall fails due to overturning moment and not due to faulty material. After first failure the pressure requirement decreases drastically and goes in to plastic failure. Similarly for the wall with height of 1.5 m fails at lateral pressure of 1300 N/mm^2 where as wall with height of 2m fails at lateral pressure of 1200N/mm^2.

As the failure is observed at the junction of the wall and wall was fails due to overturning movement we attach a steel L-channels at the bottom i.e.at junction

Journal of Advances and Scholarly Researches in Allied Education
Vol. 18, Issue No. 4, July-2021, ISSN 2230-7540

region for strengthening purpose. The 1m height wall withstand with the max. lateral pressure of 2200 N/mm^2, for which displacement of the wall is observed as 10 mm. After that the further failure of wall is started.

Failure pattern can be seen in the pictured experiments shows in fig.6.1 and 6.2. From these pictures it was noted that, the already generated cracks will not be propagated further in due to steel used and it can sustain with some more pressure. Similarly for the wall with height of 1.5 m fails at lateral pressure of 1900 N/mm^2 where as wall with height of 2m fails at lateral pressure of 1800 N/mm$^{2.}$

7. MODELLING:

Use the Model cell for presentation of that system. These options are used to define loads, boundary conditions, and otherwise configure your analysis. Go back to the Project window and right-click on the Model cell and select Edit You will work again in the same Mechanical model window but to access the functions needed, will need to right-click on the Static Structural leaf**.**

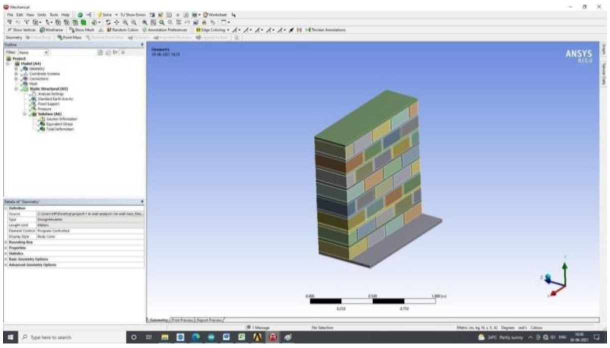

Fig.7.1 Modeling

The modeling is done by using ANSYS Software and the sample model is shown in figure no.as follows.

7.1 Properties of Mortar Material used in ANSYS software:

Brick Density =2332 Kg/m^3

Poisson's Ratio, v = 0.165 Pa.

Young Modulus =2.65E+09 (Pa)

Bulk modulus =1.3184E+09 (Pa)

Shear Modulus=1.1373E+09 (Pa)

Tensile Ultimate strength =5E+06 (Pa)

Compressive Ultimate strength=4.1E+07 (Pa)

7.2 Properties of Brick Material used in ANSYS software:

Brick Density =2300 Kg/m^3

Poisson's Ratio, v = 0.21 Pa

Young Modulus =3.5E+10 (Pa)

Bulk modulus =2.0115E+10 (Pa)

Shear Modulus=1.4463E+10 (Pa)

Tensile Ultimate strength =5E+06 (Pa)

Compressive Ultimate strength=4.1E+07 (Pa)

7.3 Properties Structural Steel used in ANSYS software:

Structural Steel Density =7850 Kg/m^3

Tensile Yield strength =2.5E+08 (Pa)

Compressive Ultimate strength=2.5E+08(Pa)

Tensile Ultimate strength =4.6E+08 (Pa)

To set-up a viewer for the Deformation we will select Solution->Insert->Deformation->Total Now you can run the analysis again by right-clicking on Solution and then Evaluate All Results or right clicking on Solution and then Solve. Just left click on the Directional Deformation leaf to view the deformation occurring in the bar. The colour represents the stress levels as shown below. This window should look like figure.8

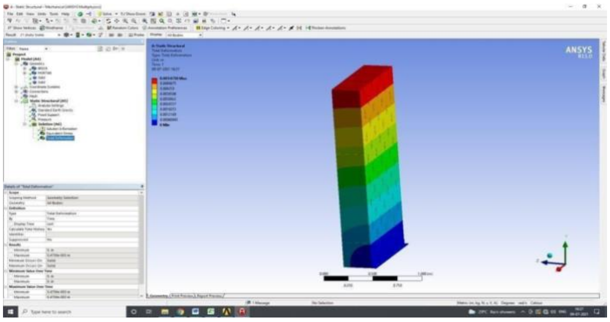

Fig.7.2 Total Deformation

To set-up a viewer for the (Equivalent) Stress we will select. Solution->Insert->Stress->Equivalent Stress and running the analysis again. This window should look like figure.9

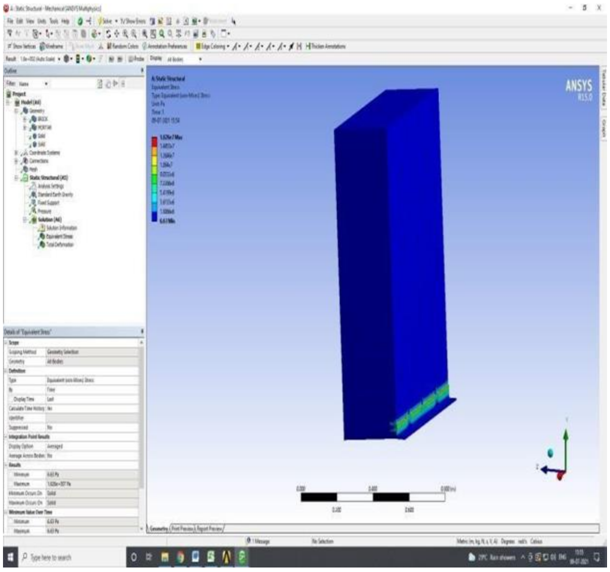

Fig. 7.3 Equivalent Stress

8. GRAPHS OF ANSYS RESULTS:

8.1 For 1m x 1m wall:

The graph of pressure vs. deformation and pressure vs. equivalent stress is plotted for both cases at definite interval is presented in 8.1 and 8.2

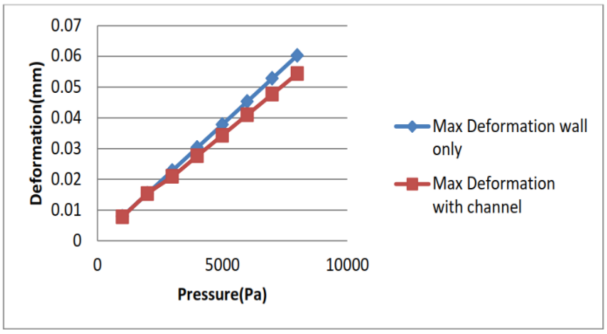

Fig.8.1 Pressure vs. deformation plot for 1m x 1m wall

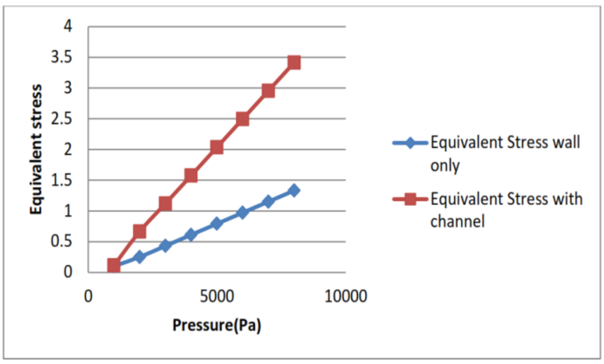

Fig.8.2 Pressure vs. equivalent stress plot for 1m x 1m wall

8.2 For 1m x 1.5m wall:

The graph of pressure vs. deformation and pressure vs. equivalent stress is plotted for both cases at definite interval is presented in 8.3 and 8.4

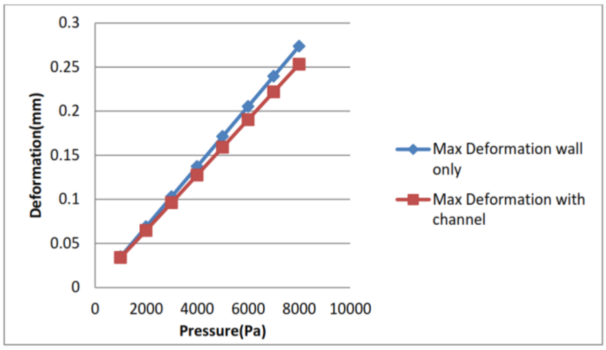

Fig.8.3 Pressure vs. deformation plot for 1m x 1.5m wall

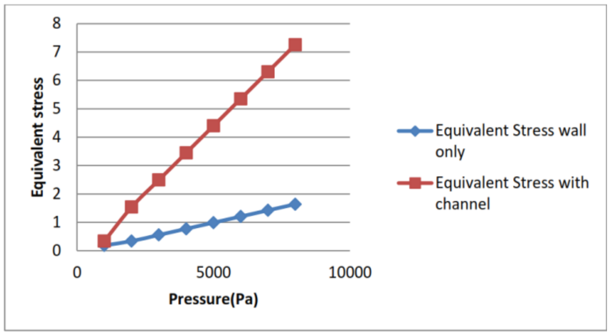

Fig.8.4 Pressure vs. Equivalent stress plot for 1m x 1.5m wall

8.3 For 1m x 2m wall:

The graph of pressure vs. deformation and pressure vs. equivalent stress is plotted for both cases at definite interval is presented in 8.5 and 8.6

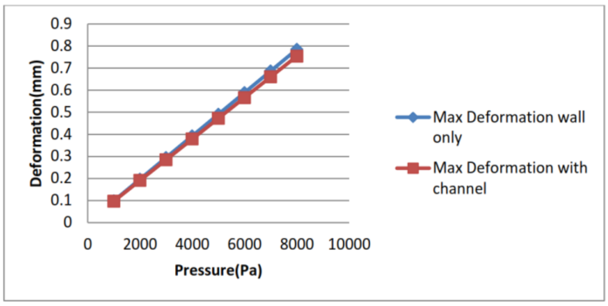

Fig.8.5 Pressure vs. deformation plot for 1m x 2m wall

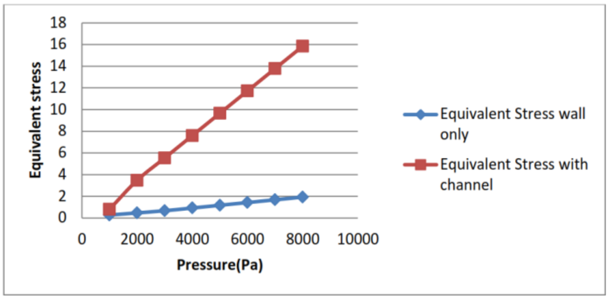

Fig.8.6 Pressure vs. Equivalent stress plot for 1m x 2m wall

For evaluation of strength and stiffness characteristics of the specimens response curves are used and their general behavior is also evaluated. As compared to the reference wall the lateral strengths of all strengthened wall significantly increased. Maximum shear strengths of the strengthened specimens were increased by 45% than that of the reference specimen on average. Opening of cracks at the bottom is controlled by steel channels attached it helps in maintaining lateral stability.

While calculating the shear carried by the steel channels, failure of bonding between mortar and bricks was assumed .The failure of wall occurs after strengthening also when the strength of the bricks and mortar was exceeded.

9. CONCLUSIONS:

In this study, the behaviour of shear deficient reinforced concrete shear walls strengthened by externally bonding steel channels was experimentally investigated. Specimens were strengthened with steel channels having different configurations, channel at bottom, lateral channel and the combination of both lateral and vertical channels.

The research focused on the effect of using steel channels for enhancing lateral strength of cantilever walls. The following conclusions were drawn From this study.

1. The analytical approach was utilized to find out the region of the failure wall under the lateral Pressure generated due to wind pressure. This shows that the failure of the wall was due to increased lateral pressure. Further, it is illustrated that Failure of wall is less for minimum height.

2. An experimental setup is developed to perform the experiments to demonstrate failure of walls due to wind pressure. Till the failure of the wall nearly linear force displacement is observed. After the first failure in the wall, force requirements start reducing with increase in displacement of the wall.

3. Experimental results of the walls show that all the three walls fail at the junction of foundation and superstructure of the walls. It was also observed that with the height of the wall with the same width, the amount of failure pressure requirement reduces.

4. Finite element models developed of brick walls show similar trends of force-displacement relations. The stiffness values obtained from the force-displacement results show that with increase in height of the wall the stiffness values decreases.

5. The stress analysis results of finite element methods also show similar failure patterns by showing highest stresses at the junction of the wall and foundation which is the cause of failure of walls.

6. All steel channels combinations improved the strength of the cantilever walls significantly under cyclic loads. Nominal flexural strength is developed in strengthened specimens, and hence, the observed maximum base shear was controlled by flexure. Maximum stress measured in strengthened wall is on average 45% higher than that of reference wall.

7. After reaching the nominal flexural capacity, wall strengthened with steel channels failed by the damage localization in a single critical section which is a typical collapse mechanism.

REFERENCES:

[1] Lachyan, Pooja S., et. al. (2021), “Evaluation of Lateral Stability of Cantilever Wall." Techno-Societal 2020. Springer, Cham, 2021. pp. 525-536

[2] Altin, Sinan, Yağmur Kopraman, and Mehmet Baran (2013). "Strengthening of RC walls using externally bonding of steel strips." Engineering Structures 49 (2013): pp. 686-695.

[3] Sinthiya Ravi Selvakumar, Viswanathan, Thanikasalam, Pradeep Nagarajan, V. Srinivas, Premavathi Narayanan (2014), “Experimental and Numerical Investigations on Material Behaviour of Brick Masonry,” 2nd International Conference on Research in Science, Engineering and Technology (ICET 2014), March 21-22, 2014 Dubai (UAE).

[4] U. Sobana and S. Gayathri (2018), “Design and Analysis of Lateral Earth Pressure

Effect on Cantilever Retaining Wall," International Journal of Innovative Research in Science, Engineering and Technology, An ISO 3297: 2007 Certified Organization, Volume 7, Special Issue 5.

[5] Chetan Sharma, Vijay Baradiya (2014)," Evaluation of the effect of lateral soil pressure on cantilever retaining wall with soil type variation," Journal of Mechanical and Civil Engineering (IOSR- JMCE), Volume 11, Issue 2 Ver. III (Mar- Apr. 2014), PP 36-42.

[6] Shejwal Neha, Danish Ali, Bhutekar S.B. Domale A.P.: "Evaluation of Suitability of Retaining Wall for Different Heights,"IOSR Journal of Engineering (IOSR JEN), pp. 44-47.

[7] Narayanan S P, Sirajuddin M.: "Properties of Brick Masonry for FE modeling," American Journal of Engineering Research (AJER), Volume-1 pp-06-11.

[8] Morteza Nikooravesh, Masoud Soltani (2018), "Behavior of unreinforced masonry piers strengthened using the center core method; experimental investigation," Construction and Building Materials, Volume 189, 20 November 2018.

[9] T C Nwofor (2012), "Numerical Evaluation of the Elastic Properties of Brick-Mortar Prisms: The Effect of Varying Thickness of Mortar Joint," International Journal of Engineering and Technology, Vol. 2 No. 6, pp. 987-991.

[10] Naraine, K., Sinha, S.N. (1989), "Behavior of Brick Masonry under Cyclic Compressive Loading, "Journal of Structural Engineering, ASCE.

[11] S. S. Patil, A. A. R. Babgan (2015), "Analysis and design of reinforced concrete stepped cantilever retaining wall", IJRET, vol. 04, Feb-2015, page 46-67.

[12] Yash Chaliawala, Gunvant Solanki, Anuj K. Chandiwala (2015), "Comparative study of cantilever and counterfort retaining wall", International journal of advanced engineering and research development, Vol. 2, pp. 221-22.

Corresponding Author

Trupti S. Thite*

PG Student, Civil Engineering Department, SVERI'S College of Engineering, Pandharpur, Maharashtra