10CUEE CONFERENCE PROCEEDINGS
10th International Conference on Urban Earthquake Engineering
March 1-2, 2013, Tokyo Institute of Technology, Tokyo, Japan

LOW DUCTILITY CONCRETE WALL TEST CONSIDERING PERPENDICULAR WALL ACTION

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Abstract: Low ductility wall buildings became part of the Peruvian construction boom of the first decade of the 21st century. Government promote under the Program named Mi Vivienda (My house in English), the construction of low rise buildings of 5 stories using walls with wire mesh reinforcement, provide part of a solution of the apartment deficit, with reasonable cost. However, the height of the buildings started to grow and grow, reaching 12 to 16 stories. In the design of this walls, provisions recommend the confinement of the corners of the walls, due the action of the walls ensemble will give a limited ductility under seismic behavior. In this paper the comparison of the action of perpendicular wall with a one plane wall is presented. Here experimental test has been performed by a cyclic loading test considering the action of a constant axial load of 40 kN, where the elastic stiffness of H shape wall is higher than one plane wall. Also resistant of the H shape wall increase, however ductility remains almost similar in both walls, due to the slip during the H wall test.

1. INTRODUCTION

Low ductility buildings appears at the middle of 1997 in Peru. As an initiative of Professor Galvez from graduate school of FIC-UNI, the promotion of the first multifamily building of four stories with the concept of replacing the masonry on a confines wall by a thin concrete wall reinforce with electrowelded wire mesh, will produce a compose material with similar better characteristics than the masonry. First experiments on this kind of wall where successfully developed at structural laboratory of CISMID-FIC-UNI (Zavala et. al 2003), considering a low stress concrete (100 kg/cm^2) a wall of 10 cm. thickness, 250 cm. height, 300 cm. length and reinforce on corners of 3 bars #3 with wall reinforce of Q91 wire mesh of 3 mm. diameter @ 10 cm. The result was a low ductility wall with low drift, even lower than the masonry limit (where Peruvian standards demands maximum drift of 1/200), with maximum drift near 1/400.

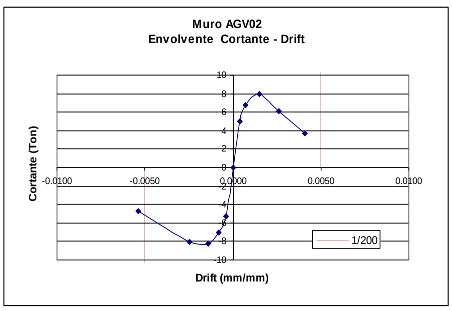

Figure 1: Behavior curve (Zavala et. al 1997)

This took the attention for the design of this kind of wall since the reinforce has upper yield point (65 to 70 ksi) than regular A60 bars (60 ksi), which is one of the reasons of the less ductility.

The Ministry of Housing invest in the research of the behavior of this kind of wall, so configuration variable and reinforce variable area presented(Zavala et. al 2003).

Since 1999 the use of this walls starts to grow on buildings projects. Government, through Ministry of Housing, promote under the Program named Mi Vivienda (My house in English), the construction of low rise buildings of 5 stories, provide part of a solution of the apartment deficit in the country, with reasonable cost.

However constructors started to grow in altitude the buildings to 8 stories, 12, stories and 16 stories, using the same reinforce, without research the behavior as a middle high building.

Therefore, on 2003 the Ministry of Housing introduce an recommendation for the design of low ductility walls on the Peruvian Concrete Standards.

The investigations of this kind of wall continue at UNI during the following years. On 2004 Medina and Zavala produce a research considering ideal conditions on material, construction process and standards. As an example a wall reinforce with normal concrete (210 kg/cm^2), 10 cm. thickness 250 cm. height, 300 cm. length and reinforce of 3 bars #4 with wall reinforce of QE257 wire mesh of 5.7 mm diameter @ 10 cm. gave results with a drift limit similar than confined masonry and upper stress.

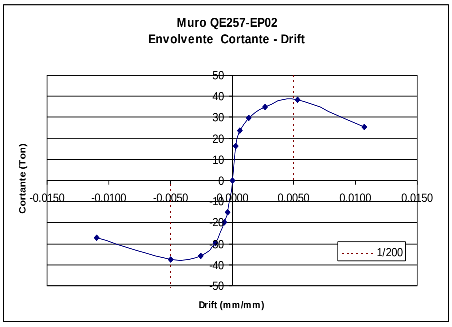

Figure 2:Behavior Curve Medina et. al 2004

Since 2004 investigation has been performed on in plane walls, however non investigation considering this kind of walls have been developed in Peru.

Under the SATREPS Peru - Japan joint research project and using the new jack system of capacity of 500 kN and 400 mm. stroke investigation of low ductility wall with the action of a perpendicular has been performed. In this paper preliminary results are presented showing the tendency of the contribution of the perpendicular wall to the in plane wall.

2. ABOUT THE EXPERIMENTAL TEST CONSIDERING PERPENDICULAR WALL ACTION

In order to investigate in experimentally the influence of the perpendicular wall on and H shape configuration against one plane wall, two experiments were performed: an experiment on a one plane wall, and an experiment with a perpendicular wall that produce an H shape wall.

2.1 About Test specimen

Both walls (one plane and H wall) will has the same dimensions: 2500 mm. length with 2600 mm. height and 100 mm. thickness. In the case of H wall, a flange with a total dimension (Bf) of 2500 mm. is incorporated to the one plane wall, in order to investigated it influence by the measured stresses.

The walls have a reinforce on the corners as confinement 3 bars #4. Wire mesh appears as reinforcement of the web and flange with electro welded mesh Q-158 (5.5 mm. diameter @ 0.15m As=1.58 cm2/m). Is common use of 600 mm. dowels between stories on buildings, but in the case of the specimens dowels are same growing from the footing base. Figure 3 presents the configuration of both specimens, one plane and H shape wall, notice that there is a horizontal border beam of 300 mm. by 300 mm. section on the top of each beam. Also foundation of 900 mm. by 300 mm. is on the bottom part of the specimen.

The construction process tried to replicate as near the real environment on the site area. So wire mesh from the footing was fixed with the wire mesh of the wall and three ductile bars #4 were placed on the corners of the specimens. Wood forms were used to encase the reinforcement and set the fluid mix of concrete inside to produce the concrete wall.

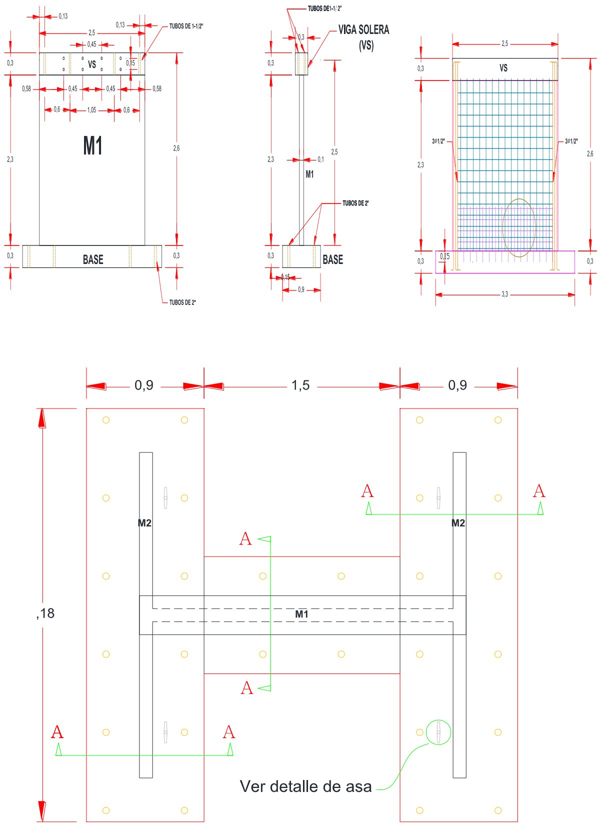

Figure 3: Test specimen configuration for H shape wall

On the top of each wall a loading beam is build to be use for setting of the loading steel frame. Figure 3 presents four stage of the constructions of the specimens.

2.2 About test performance

For the test execution 2 jacks and one actuator were used for the application of the loads. Axial load equivalent to 200 kN that approximately represents the load of four stories over the wall.

Figure 4: Test Setup on Plane and H walls.

During the execution of the test, this load will be applied at the beginning of the load process, and after reaching 200 kN, the load will remain constant during the whole test. To simulate the lateral action such a earthquake movement, an increasing cyclic displacement will be applied to the specimen in order to start the movement of the wall and measure in each step the load.

For the measure of the displacements a set of transducer were placed to measure displacement in different locations on the walls. In the one plane wall and web wall (on H shape specimen), displacements transducers were set on the positions presented on Figure 5, here sensors on the body of the wall were setting on the diagonal, vertical and horizontal in order to reproduce the displacement on all directions. For the measure of the stress on points strain gauges were glued to the surface of the concrete and to the reinforce bars. All the sensors and gauges, were connected to an scanning box and data logger Tokyo Sokki TDS 530.

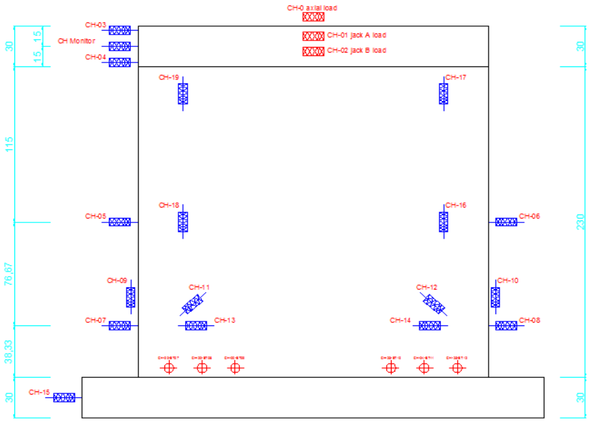

Figure 5: Displacement transducer setting

On Figure 4, the test setup of both specimens are presented. Here is possible to notice the difference on the setup due to need of application of the axial load and lateral load simultaneously in special in the case of the H shape wall were space is quite narrow to applied both loads. In the case of H shape wall the perpendicular wall (flange wall) has three lines of sensors in order to investigated the displacement on that positions and the dissipation of the stress. Also strain gages were set for the same purpose.

2.3 Test results

The cyclic displacement versus base shear on the experimented walls are presented on

Figure 6, where hysteresis curves of the development of each test are presented. It is possible to read that both specimens had almost the same level of maximum stress, but in different failure mode. The reason of this similitude of stress level is due to an slip on the foundation occurs after 4 mm displacement. In the case of the one plane wall, shear cracking appears on the base of the experiment. Then flexural cracks starts to appear on both borders elements, propagation horizontally. Finally diagonal cracks appear and a combination of shear failure with slip failure of the base, is the final failure pattern.

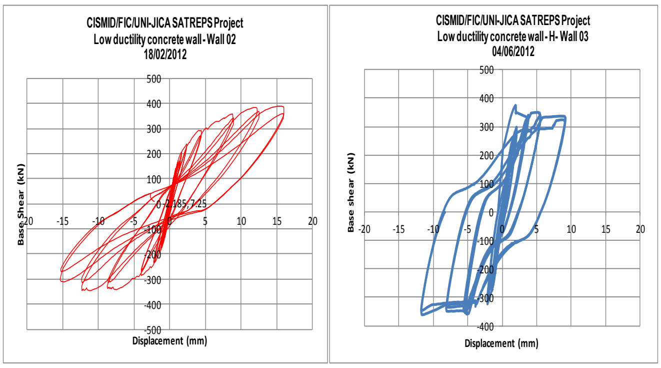

Figure 6: Hysteresis curves of one plane wall and H shape wall

Due to the slip of the specimen, we will consider the behavior of the H wall previous to the slip and compare the behavior curves of both specimens for this condition. The slip of the specimen occurred for 1/1600 drift, just after the cracking starts on the specimen. Figure 7 presents the behavior curve showing that both curves almost reached the same capacity. However, considering the first stage of the test, when drift is less than 1/1600, the behavior will introduce a difference on the resistant.

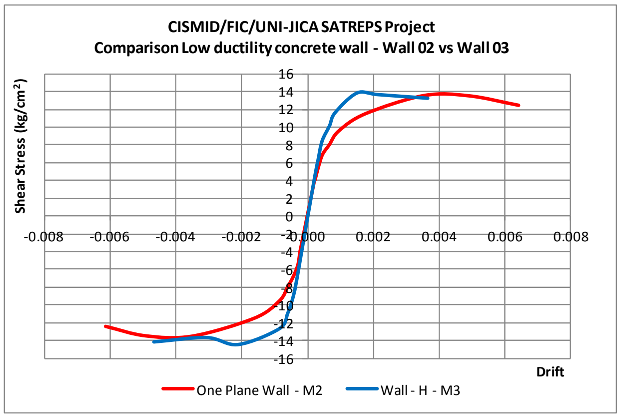

Figure 7: Behavior curves plane wall and H shape wall

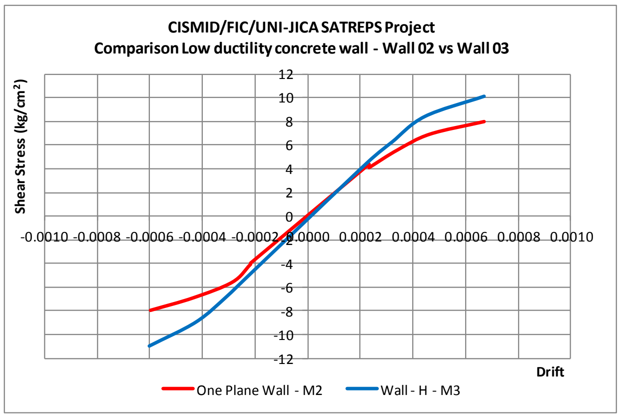

Figure 8: Behavior curves plane wall and H shape wall for drift less than 1/1600

On Figure 8 is presented the behavior curve prior the slip of the specimen. There is a notorious contribution of the perpendicular wall on the behavior.

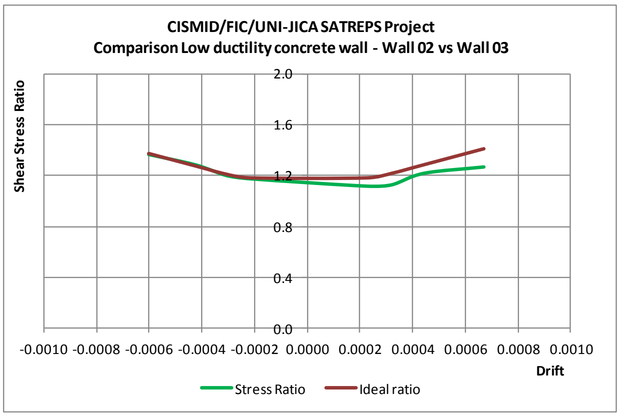

Figure 9: Stress ratio between H wall and plane wall

On green color is presented the shear stress ratio between the H wall and plane wall, that was compute from the test results. It is possible to the that when jack is pushing the curve shows a very defined ratio, however when jack is pull, the capacity of the system gave lower values. It is possible to recognize that ideal behavior on a simulation is given when jack is pushing the specimen. On red color in Figure 9, is presented ideal shear stress ratio for the wall. Here we can see that till behavior is elastic the ratio is about 1.18, so perpendicular wall action will increase 18% of shear stress capacity. After cracking of the specimen the increment became higher and reach a value of 1.40, so it means an increment of 40% in the shear resistance due to the perpendicular wall action.

A preliminary formula for the variation of the shear stress to evaluate the contribution of the perpendicular walls to the plane wall is the following:

$$\tau_H/\tau_{plane} = 552.98\gamma + 1.039 \qquad (1)$$

where τ_H/τ_{plane} is the shear stress ratio between the H wall with the plane wall and γ is the interstory drift.

3. CONCLUSIONS

Low ductility walls are an alternative to build middle rice buildings in Peru. Many research has been performed on plane walls however non research has been performed on this kind of wall to measure the perpendicular wall action. Therefore the present research present the first contribution in Peru for the knowledge of this action.

Two walls were investigate: one in plane and the other with H shape where the contribution of the flange to the in plane wall intend to be measure.

Unfortunately the H specimen slip occurs at 1/1600 drift during the test, after cracking occurs so test was completed showing similar results for the capacity of the walls.

Therefore, considering the behavior prior of the slip of the specimen shows a notorious difference between plane and H wall shear resistance.

This difference was evaluated in terms of ratio of both stresses for the same drift. Results shows that during elastic stage of the specimen, perpendicular walls contribute 18% to the shear resistance, but after cracking stress ratio increase till 40%. So the contribution of the perpendicular wall will be very important during the inelastic behavior of the wall

We need to continue the study in order to verify the spread of stress on perpendicular flange wall and web wall. We need to consider more study for the perpendicular action on the non linear behavior developing more test to prove the tendency of the preliminary formula (1) presented in this paper.

Acknowledgements:

The authors would like to express our gratitude to the Ministry of Education of Japan, thorough the Japan Science and Technology Agency (JST) and the Japan International cooperation Agency (JICA) for the support the Japan-Peru SATREPS Project for the support to this research. Also our gratitude to Dr. Fumio Yamazaki PI investigator of the SATRPES project and promoter of this investigation.

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