COMPARISON OF CONFINEMENT REINFORCEMENT IN REINFORCED CONCRETE STRUCTURES

M.B. Sharif, M. Ilyas and M. M. A. S. Baig*

Department of Civil Engineering, University of Engineering and Technology, Lahore.
*Water and Power Development Authority, Lahore
Corresponding author's email: burhansharif@uet.edu.pk

ABSTRACT: The major cause of damage of R.C. structures during Kashmir-Hazara earthquake observed was due to improper and insufficient confinement reinforcement in columns. This experimental investigation represents the comparison of improper and insufficient confinement reinforcement and confinement reinforcement specified by the building code. Two reinforced concrete (RC) columns were constructed, each having cross sectional dimension of 230 mm x 230 mm and a height of 1834 mm. A foundation of 800mm x 800mm x 460mm was casted monolithically with each column. Concrete strength and longitudinal reinforcement are kept same for each column. However in one column hoop reinforcement with 90° bend is used as confinement reinforcement while in the other column angle of bend is 135° is used as per specification of seismic code. Strain gauges are fixed on the longitudinal and lateral reinforcement within the zone of plastic hinge for the column. Lateral cyclic load is applied for evaluation of response of column under constant axial compression. The study revealed that seismic hook increased the moment resistance of column by 31% and load carrying capacity by 51%. It is concluded that major loss of structural performance is mainly due to improper confinement reinforcement used in engineered and non engineered structures in Northern areas of Pakistan.

Key words: Confinement reinforcement, reinforced concrete columns, seismic hook angle.

INTRODUCTION

The earthquakes have been recognized as worst natural calamity, which have claimed many human lives in past. So far, researchers are unable to accurately predict the earthquake. Therefore, the only protection left with the societies is to build such structures, which can survive the estimated level and duration of an earthquake. Pakistan, due to its proximity to the intercontinental plate boundaries, is prone to high-level earthquakes. (Ilyas and Rizwan, 2006). The occurrence of Kashmir-Hazara earthquake is an example of severe earthquake in this region. The effects of Kashmir-Hazara earthquake were mammoth. The past earthquake survey of the affected region indicated that structure with improperly designed columns did not perform well during an earthquake and collapsed. The importance of columns in the overall performance of structures has also been highlighted during North-ridge earthquake of 1994. The study of the affected areas of North-ridge earthquake clearly emphasized the significance of strong columns and weak beams concept. The performance of a column during an earthquake depends on many factors such as slenderness, concrete strength, and yield strength of longitudinal & transverse steel, volumetric ratio of transverse steel, ratio of longitudinal steel, axial load, concrete cover and confinement provided in the hinge zone. Out of all these parameters, confinement is the most important factor, which ensures the performance of the column during an earthquake. The columns under affect of applied load during an earthquake suffer from axial shortening and due to Poisson's ratio; corresponding strains are also developed in the lateral direction. The confinement reinforcement, provided as transverse reinforcement in the hinge one, restrain the lateral expansion of the concrete core. This restriction results in a tri-axial compression exerted on the concrete core, thus enhancing its compressive strength under this stress. The column with proper confinement reinforcement indicates increased performance and continues to dissipate energy in the plastic region and this phenomenon is also dependant on compressive strength of concrete. However common practice for hoop reinforcement is shown in the figure-1 and figure-2.

The behavior of large scale high strength concrete columns confined by rectangular ties under concentric loading was studied by Cusson and Paultre (1994) . This study revealed that early spalling of concrete cover results in a loss of axial capacity of column first and then lateral confinement comes into effect. Also strength, toughness and ductility is recorded for well confined columns after loss of concrete cover. Mo and Wang (2000) studied the seismic behavior in columns with various tie configurations and found that the configuration of transverse reinforcement with alternate ties show better seismic performance than the configuration usually used. Kazemi and Morshed (2005) carried out a study on seismic shear strengthening of R. C columns with ferrocement jacket. It results in decreased shear cracking and increased the ductility of columns.

Figure-1 Hoop reinforcement with 90º bend.

Figure-2 Another view of Hoop reinforcement with 90º bend

Vintzileou and Stathatos (2007) studied the effect of uni-axial cyclic bending with or without axial compressive load and found that lower axial compression , high confinement ratio, use of multiple hoops, low value of spacing of hoops normalized to the diameter of longitudinal bars on limiting response of strength degradation due to degradation due to cyclic loading. The literature review clearly indicates that a lot of work has been done regarding the performance of columns against the seismic forces. However in Pakistan the local practice is provision of 90° hooks in-stead of seismic hooks. Hence this study demonstrates not only the problems associated with the provision 90° hooks but also gives mathematical figures like ductility and energy dissipation of the structure which is a strong contributing factor for structures against seismic forces.

Confinement reinforcement is a type of transverse reinforcement. It plays dual role in performance of structural component during excessive dynamic loading. It is not only used to confine the concrete core but it also helps to improve the shear capacity of the structural members. A properly confined column can help in delay of collapse mechanism and energy dissipation of the whole structure. The role of confinement reinforcement is very much recognized and emphasized in earthquake resistant design of R.C structures. In past, the hoops with 90º bend at the end were common and now-a-days seismic hoops and ties bent at 135° are common.

MATERIALS AND METHODS

a) Columns and Tie Configuration: In this study two actual concrete columns (C-1 & C-2) have been casted as shown in the figure-1. These columns have been designed as per ACI 318-05. These full scale columns have been designed for typical loading for an interior column of second floor of a 3-storey building. The designed column was then cut from the point of contra flexure of bending moment diagram to enable the application of equivalent lateral force that would induce a moment equivalent to the plastic moment capacity of column at the base of the column.

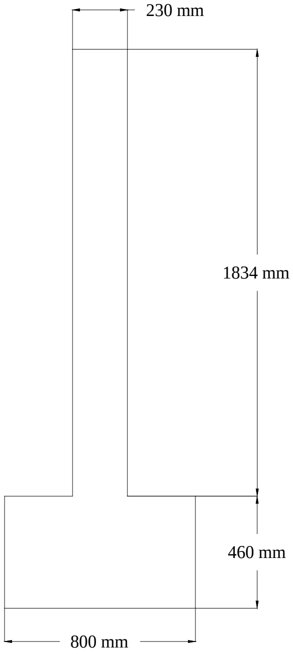

Figure-3 Longitudinal section of the column.

The X- Sectional dimension of the column and its longitudinal and transverse reinforcement is given in figure-3 and figure -4.

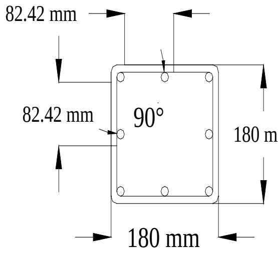

Figure-4 Lateral reinforcement for Column-1

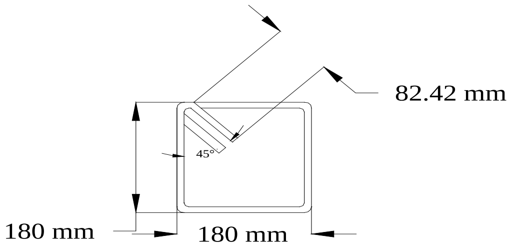

Figure-5 Lateral reinforcement for Column-2

The detail of the transverse reinforcement along the height for both the columns is given in figure-5 while the details of the reinforcing bars are given in table-1 for both column-1 and column-2.

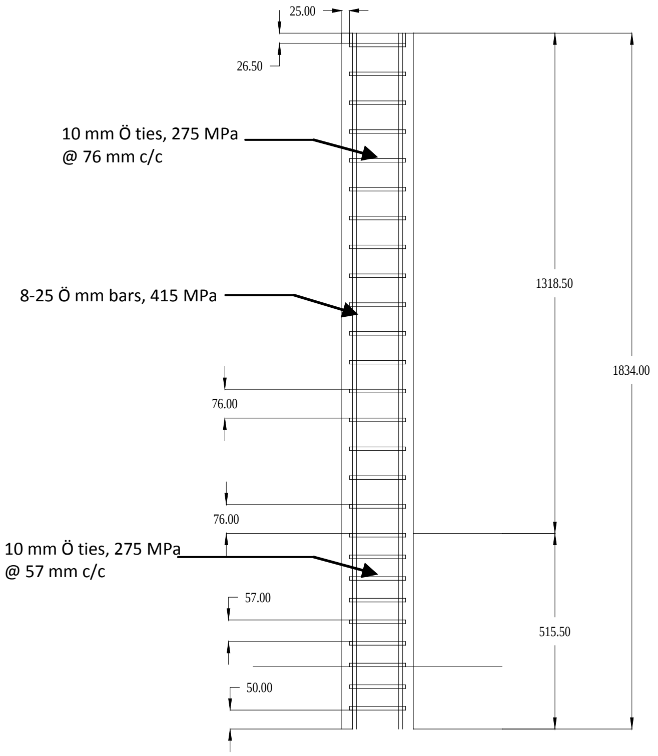

Figure-6 Transverse reinforcement detail for columns 1 & 2

The hoop configuration for test columns is given in table-1

Table 1: Hoop configuration for column 1 & 2

Column	Inside Plastic Hinge Region			Outside Plastic Hinge Region		
	No. of Hoop sets	Bar Dia. (mm)	Spacing c/c (mm)	No. of Hoop sets	Bar Dia. (mm)	Spacing c/c (mm)
1	9	10	57	17	10	76
2	9	10	57	17	10	76

b) Foundation for Test Columns: The test columns (1 &2) were provided with 800x800x460mm reinforced concrete foundation to generate the fixity at the base of the columns. It is also incorporated with the plastic pipes for the large bolts to pass through it during in order to fix the column base with strong floor during lateral loading of the column.

Reinforcement detail of the footing along with the spacing is shown in figure-7.

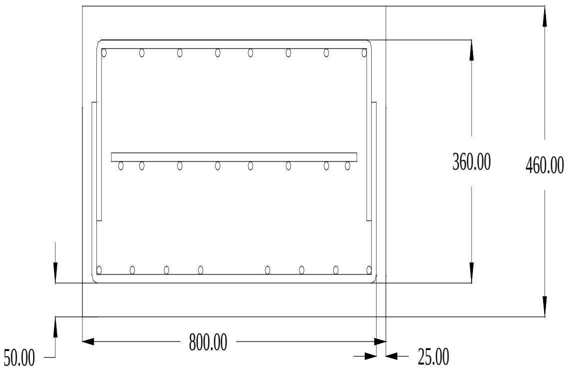

Figure-7 Vertical X-Section of Foundation(All dimensions in mm)

c) Physical Properties of Concrete and Steel: Concrete used in the test columns 1 & 2 was having a compressive strength of 25 MPa (average of three concrete cylinders) at 28 days while the yield stress for the longitudinal steel in columns and foundation steel was found to be 414 MPa. The yield stress for lateral ties was 275 MPa.

d) Testing Equipment and Arrangement: Column foundation is tied to the strong floor and an axial load equivalent to $0.1xfc'xA_g$ is applied with the help of the hydraulic jack as shown in Figure-8.

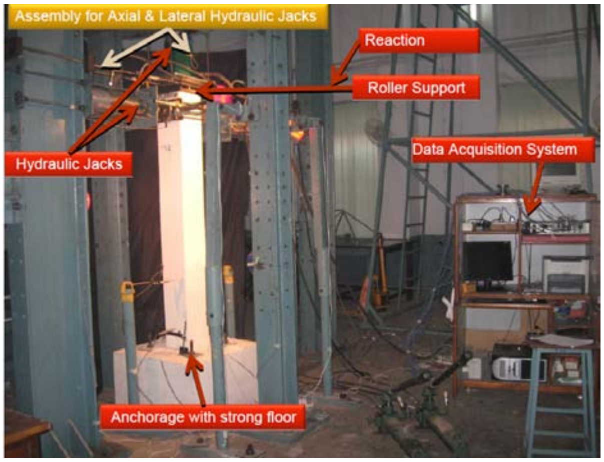

Figure-8 Test arrangement for the columns during lateral loading.

Lateral loads are applied with the help of the two hydraulic jacks attached with the reaction frame having 50 Ton capacity each. Linear Variable displacement transducers (LVDT's) were installed at the top of the column, mid height of the column and at the base of the column within the plastic hinge zone. Strain gauges were also installed to measure the axial strain. Vishay Micro-Measurements system 5000 model 56100B scanner was used for data acquisition. All strain gauges, load cells and linear displacement transducers were connected to the data acquisition system. The details of LVDT's is shown in figure-9.

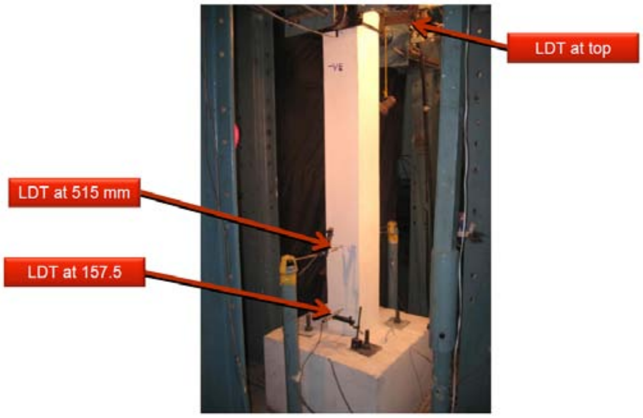

Figure-9 Location of lvdt's for the test columns1 &2

RESULTS AND DISCUSSION

An axial load of 132.5 kN was applied at the top of the column. Lateral load was applied from the side of the column with the help of jacks as shown in Figure-8. The load was applied in sequence from left and right side of the column. The load is considered positive when applied from one side while the other side was taken as negative. The cycle commences with the lateral load being applied from positive(+ve) side at a steady rate and then it is unloaded at the same rate. Each cycle(i.e. loading and un-loading) was completed in four minutes time duration. This test was displacement controlled with pr-defined set of displacements. The increment of displacements was ranging from 0.25% to 5.5%. Whereas % Drift is obtained from the Eq.1.

$$\% \ Drift = \frac{Displacement\ at\ the\ top\ x\ 100}{Length\ of\ the\ column} \qquad \text{Eq. 1.}$$

It was observed that the cracking initiated in both the columns at about 1% drift i.e 17 mm of displacement at the top. The cracks initiated within the plastic hinge region i.e. 515.5 mm from base. However, fine cracks were observed up to the mid height of column in column-2 having seismic hooks. At 5.2% Drift ratio the behavior of both the columns was different in terms of cracking. Column-1 having 90º bends showed that the cracks remained concentrated to the base of the column, on the lower part of the plastic hinge near the foundation and the cracking did not spread with in the plastic hinge. Whereas in Column-2 having seismic hook showed the cracking spread out evenly within the plastic hinge zone.

The area under the hysteresis curve for column -2 is more than Column-1 as shown in figure -10 &11. It also shows the maximum displacement attained by column before failure. (Baig, 2009)

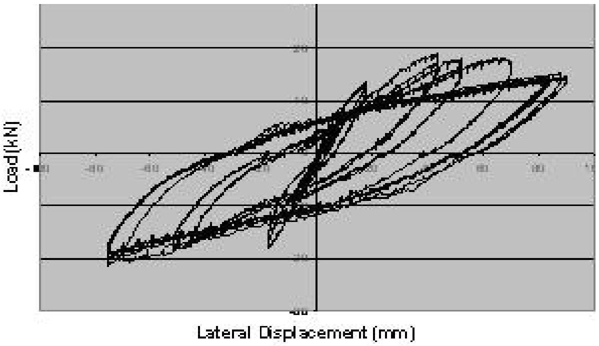

Figure-10 Hysteresis loop for column-1

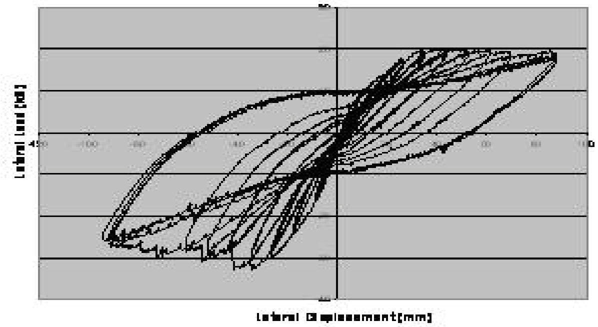

Figure-11 Hysteresis loop for column-2

The maximum moment sustained by column-1 was 46.89 KN-m whereas column-2 sustained 61.77 KN-m. Ductility ($\mu=\frac{\Delta u}{\Delta y}$) was also determined which was found to be 4.6 for column-1 and 5.25 for column-2.

Conclusions: The conclusion drawn and observation made from the experimental investigation related to comparison of confinement reinforcement are as follows.

1. Columns without seismic hooks have stress concentration at the base of the column while seismic hooks distribute the stress concentration in the entire plastic hinge zone of the column.
2. Moment resisted by the column having seismic hooks was 31% more than the conventional columns i.e. without seismic hooks. The load carrying capacity of the column having seismic hook was also increased by 51%.
3. The inelastic behavior of the column improves incase of seismic hoops as it is necessary for earthquake resistant structures.
4. The hysteresis obtained shows more energy dissipation in case of seismic hoops with ends at 135º.

REFERENCES

Baig, M.M.A.S, “Reinforced Concrete columns under static cyclic lateral loads”, M.Sc. Thesis, Civil Engineering Department, University of Engineering and Technology, Lahore, Pakistan (2009).

Cusson, D. and P. Paultre, High strength concrete columns confined by rectangular ties, Structural Engg., 120(3): 783-504 (1994).

Ilyas, M. and M. Rizwan, Devastating effects of Kashmir-Hazara earthquake, Proceedings of International Conference & Expo on Safe & Quality Building in Asia-Review of Practices, Lahore, 39-44 (2006).

Kazemi M.T and R. Morshed, Seismic shear strengthening of R.C. columns with ferro-cement jackets, Cement and Concrete composites, 27: 834-842 (2005).

Mo, Y.L. and S.J. Wang, Seismic behavior of R.C. columns with various tie configurations, Magazine of Concrete Research, 52(6): 419-432 (2000).

Vintzileou, E. and A. Stathatos, Assessment of seismic behavior of R.C. columns, Engineering Structure, 27: 1296-1311 (2007).