IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)
ISSN(E): 2321-8843; ISSN(P): 2347-4599
Vol. 3, Issue 10, Oct 2015, 55-64

BEHAVIOUR OF REINFORCED CONCRETE COLUMN UNDER UNIAXIAL AND BIAXIAL LOADING –STATE OF THE ART

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ABSTRACT

Columns are the vertical elements that majorly transmits the load and moments from superstructure to the substructure. Therefore, special attention should be given to their structural response under load reversals. Earthquake effects generally require the inclusion of biaxial loads that are recognized to be more damaging than the single direction loads. For framed structures, columns are responsible for overall strength and stability of the structure. Exterior column and corner columns of framed structures are subjected to varying axial load due to earthquake overturning moment in addition to bi-directional lateral load reversals. The collapse of a RC building is caused, in the majority of cases, by the failure of the vertical members. In this paper, the existing test on reinforced concrete (RC) columns under biaxial load has been reviewed, underlying their main findings. In general, the experimental results show that the RC columns response is highly dependent on the loading pattern, and the biaxial loading induces a decrease in the maximum strength and anticipates each damage state. Thus, in columns where demands are expected with large moments in both directions specific detailing should be provided in their critical regions in order to improve the columns performance and avoid premature failure. Our objective is to present the experimental results of the biaxial loaded column and to check the same with simulation work.

KEYWORDS: Columns, Load Reversals, Failure, Earthquake, Strength

INTRODUCTION

Columns are key structural element that transmits, through compression, the weight of the structure above to other structural element below. In other words, a column is a compression member. The term column applies to a large support with a capital and a base or pedestal or something that is appearing to be so. For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Columns are frequently used to support beams or arches. Columns are responsible for the seismic performance of buildings. Therefore, special attention should be given to their structural response under loading conditions. Moreover, earthquake effects generally require the inclusion of two horizontal component loads that are recognised to be more damaging than single direction actions. The interest in the inelastic response of axially loaded members under biaxial bending moment histories is relatively recent, and the available experimental results are limited. This is possibly due in part to the uncertainty of combining histories of bending moments in the two orthogonal directions, adding considerable complications to the problem. The response of reinforced concrete (RC) members subjected to axial load in conjunction with biaxial bending moment reversals is recognized an important research topic for building structures in earthquake prone regions.

CLASSIFICATION OF COLUMNS ACCORDING TO THE TYPE OF LOADING

The column which carries a purely axial load, is termed as concentrically loaded column. Such an ideal column is rarely encountered in practice. The columns in industrial building are not subjected to high compression but also to reasonable large bending and shear force and are shown in the following figure.

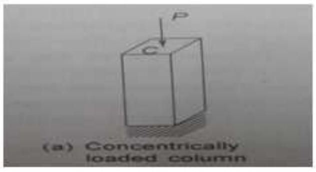

Figure 1: Concentrically Loaded Column

If a column carries an axial load and bending moment about either the x-axis or y-axis only, it is classified as a uniaxially eccentrically loaded column. The peripheral column located on the sides of the building comes under this category as shown in following figure.

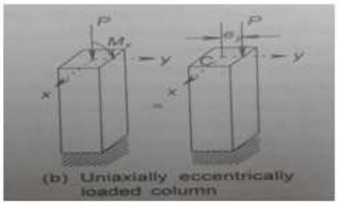

Figure 2: Uniaxially Eccentrically Loaded Column

A column is subjected to an axial load along with moments about both the axes is termed as biaxial eccentrically loaded column. Corner columns of a building carry axial loads along with moments about the x-axis and y-axis as shown in following figure.

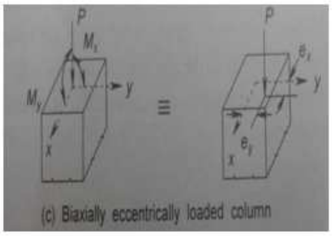

Figure 3: Biaxially Eccentrically Loaded Column

PROCUREMENT OF MATERIALS

The materials required to complete the experimental investigation are to be procured first. The materials required are,

Aggregate

- Coarse aggregate (crushed stone) Crushed granite stone aggregate of maximum size is 12.5 mm is chosen as coarse aggregate as per IS: 2386 (Part I) 1963, surface texture characteristics of the aggregate as classified in IS: 383-1970.
- Fine aggregate (sand) the sand has been sieved in 4.75 mm sieve before it is used.
- Cement the cement used for this study is Portland pozzolana Cement and is conforming to Indian standard IS: 8112 of Grade 53.
- Water Available potable water which was free from all impurities is used for the entire work whenever it is required.
- Steel Steel for reinforcement Fe 415 was used.

Water

The clean water, which was free from all impurities, was used for the entire work of concrete preparation and curing. pH value of water was found to be 6.8.And the water was conforming to IS 3035- 1987(part 1).

Steel

The steel was used 8mm diameter of high strength deformed steel bars conforming to IS 1786-1985.The properties of steel were found and reported.

Tensile Strength

The tensile strength of steel was found to be equal to 415 N/mm2.

This Fe415 bars have the advantages as follows

- Due to high yield strength, amount of steel required is considerably reduced.
- The twisted or deformed bars provide a better bond with concrete than mild steel bars and thus end hooks in bars can be omitted, resulting in further saving of steel.

SPECIMEN GEOMETRY AND TESTING

Column Details

No of columns: 9

Grade of concrete: M20

Grade of steel: Fe 415

Dimension: 0.1mx0.1m

Height: 1m

No of bars for main reinforcement: 4

Dia of main reinforcement bars: 6mm

Dia of bars for ties: 6mm

Reinforcement for the Column

As concrete is strong in compression and weak in tension, steel bars are used to reinforce the concrete to resist tensile stresses resulting from the applied load. Additional reinforcement is occasionally provided to reinforce the compression zone of the concrete beam section and also in column. Such reinforcement is necessary for heavy loads in order to reduce long-term deflection. It is the shear stress at the interface of reinforcement bar and concrete developed to resist the slippage of bars relative to its surrounding concrete.

Figure 4: Reinforcement Cages 6mm DIA Bars Are Used As Ties

Mould

The mould is a hollow wooden box made as per the column dimension. The pre-prepared reinforcement cage is been inserted inside the mould. Before the placement of prepared reinforcement cage, surface of the wooden box is oiled to ensure the non-adherence of concrete to the box walls.

Figure 5: Mould

Filled Mould

Concrete is been filled in the mould by pouring and tampering to get rid of voids. The picture shows the view of filled mould with reinforcement cage inside. It was allowed to set for 24 hrs and removed from the mould. The column dimensions were checked for accuracy.

Curing

Curing was done for 27 days from the day of casting. Initially for 3 days, curing was done by placing the concrete column in a water tank later it was placed in a sand bed over which gunny bags were placed and watered.

EXPERIMENTAL CAMPAIGN

Our experimental testing was done in the Structural testing laboratory of L&T Construction ECC division. Equipments used are the Universal Testing Machine (UTM) for the testing of columns and Compression Testing Machine (CTM) for testing of cubes to find the compression strength.

Universal Testing Machine

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures. It consists of components such as,

Load frame - Usually consisting of two strong supports for the machine. Some small machines have a single support. Load cell - A force transducer or other means of measuring the load is required. Periodic calibration is usually required by governing regulations or quality system. Cross head - A movable cross head (crosshead) is controlled to move up or down. Usually this is at a constant speed: sometimes called a constant rate of extension (CRE) machine. Some machines can program the crosshead speed or conduct cyclical testing, testing at constant force, testing at constant deformation, etc. Electromechanical, servo-hydraulic, linear drive and resonance drive are used. Means of measuring extension or deformation - Many tests require a measure of the response of the test specimen to the movement of the cross head. Extensometers are sometimes used. Output device - A means of providing the test result is needed. Some older machines have dial or digital displays and chart recorders. Many newer machines have a computer interface for analysis and printing. Conditioning - Many tests require controlled conditioning (temperature, humidity, pressure, etc.). The machine can be in a controlled room or a special environmental chamber can be placed around the test specimen for the test. Test fixtures, specimen holding jaws, and related sample making equipment are called for in many test methods.

Experimental Testing

First the demec points were marked in the columns for finding the position of ball placement. The specimens were placed in the loading frame with the ball placed on the demec point over which a steel plate is placed. The first three specimens A1, A2, A3 were tested for axial concentrated loading. Here the ball was placed in the intersection point of axes and load was applied in the increment of 1000N

The next three specimens B1, B2, B3were tested for axial eccentric loading. Here the ball was placed in the eccentric point of e = 30mm from the intersection point of axes and load was applied in the increment of 1000N. Here an additional moment is created due to the eccentricity.

The last three specimens C1, C2, C3were tested for biaxial loading. Here the ball was placed in the eccentric point of e = 30mm from the intersection point of both axes and load was applied in the increment of 1000N. Here an additional moment is created due to the eccentricity.

Cube Strength

In order to find the concrete strength, the cube is casted in standard dimensions of 150mmX150mmX150mm. The casted cube is then set for curing for the desired number of days and tested for compressive strength.

The cube we have casted was tested for 14 day strength using a compressive testing machine, CTM. The cube strength was found out to be 21.44 N/mm2.

Load Calculation as Per Design

Concrete grade – M25, Steel grade – Fe415

Allowable load capacity is P = σcc Ac + σsc As

σcc = 6N/mm2 for M25

σsc = 190N/mm2 for Fe415

As = 24mm2

P = 6×(100×100 - 24) + (190 × 24)

= 64.416 × 103 N = 65K N

Allowable load capacity is P= 65K N

Ultimate load capacity of section is Puz = 0.446fckBD + (0.75fy – 0.446 fck) As

As = 24mm2

Puz = (0.446 × 25×100×100) + (0.75 × 415 – 0.446×25) 24

= 118.70 × 103 N = 120 K N

Ultimate load capacity of section is Puz = 120 K N

Ultimate load capacity of section subjected to biaxial bending = 106.43 K N

EXPERIMENTAL RESULTS

Uniaxial Load

Table 1

Description	A_1	A_2	A_3
First crack load in KN	133	132	133
Average load	132.667		
Ultimate crack load in KN	149	152	151
Average load	150.778		

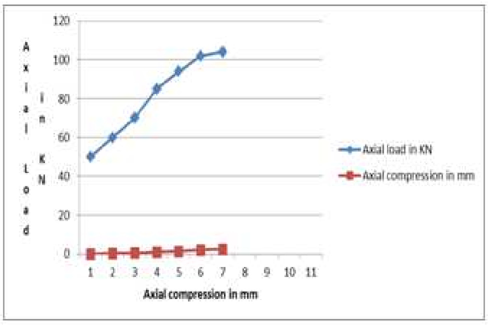

Figure 6: Uniaxial

Biaxial Load

Table 2

Description	A_1	A_2	A_3
First crack load in KN	86	89	87
Average load	87.333		
Ultimate crack load in KN	99	102	102
Average load	101		

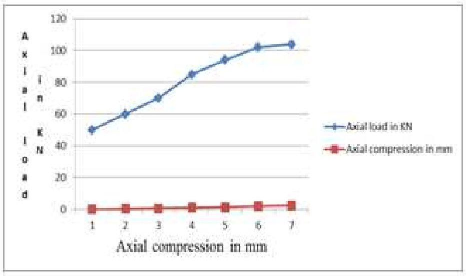

Figure 7

Crack Pattern

Figure6: Crack Pattern for Axial Load

The axial load was applied at the demec point and eccentricity e=0, the crack was formed at the bottom of the column and only mild cracks were formed. Initial crack was observed at the load of 132.667KN and the ultimate cracking load was observed at the load of 150.778KN. Resistance to the applied load was observed to be high.

Figure 7: Crack Pattern for Axial Eccentric Loading

For axial load with eccentricity of 30mm from the demec point, the crack was formed at the bottom of the column and the crack formation was high compared to the axial load case. Due to the additional moment created as a result of eccentricity crack were severe. Also cracks were observed at the top of column. Initial crack was observed at 108.667KN and the ultimate crack was observed at 122.2KN. Buckling of bars was also observed.

Figure 8: Crack Pattern for Biaxial Load

Severe crack pattern was observed during the application of biaxial loading to the column specimen at an eccentricity of 30mm from both the axes of column. Crack formation was observed at the initial stages of loading itself. Initial crack was observed when the load was 87.33KN and the ultimate cracking occurred at 101KN; which was very early compared to the uniaxial load cracking.

ANSYS SOFTWARE

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.

So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment.

ANSYS Result

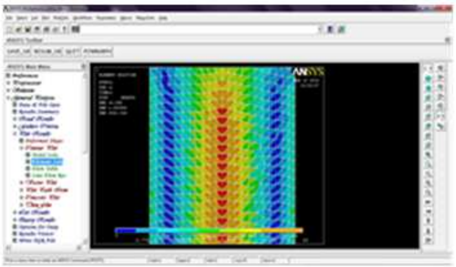

Figure 9: Stress Distribution

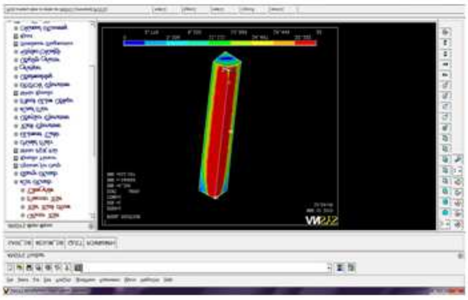

Figure 10: Stress Distribution Uniaxial

Stress distribution pattern of the columns subjected to axial loads is shown by red lines which shows the intensity of loading and its influence in the column.

Outcome from Study

- When a column experiences biaxial load damage evolution is very high compared to the damage that occurs in uniaxial loading.
- The flexural response of the columns, governs the distribution of horizontal cracks along the column length.
- Under the biaxial loading, it induces a higher level of damage in the column base than the uniaxial loading.
- In the biaxial tests, after horizontal cracks form, larger lateral demands initiate concrete spalling in the column corners.
- More abrupt decay of the column strength was observed with increasing load application.
- The ultimate ductility is significantly reduced in columns subjected to biaxial load paths.
- Crack formation was severe under the application of biaxial loading compared to the case of uniaxial loading.
- Additional moment formed when the biaxial load applied lead to high cracking.
- Buckling of bars took place.
- Severe cracks were observed at the bottom and mild cracks were observed at the top of column.

CONCLUSIONS

From the results of this analytical investigation and experiment, the following conclusions can be drawn:

- The initial stiffness in both directions is not significantly affected by the biaxial loading path.
- The ultimate ductility is significantly lower in columns subjected to biaxial loading paths when compared with uniaxial loading.
- For biaxial loading strength degradation is high.
- Stiffness degradation is not significantly affected by biaxial loading.
- Failure of the RC column highly depends upon the loading pattern.

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