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Study of behaviour of reinforced concrete columns under eccentric loading

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Abstract
This paper discusses behavior of plain reinforced concrete columns under eccentric loading. An experimental Investigation was conducted, where nine reinforced concrete columns has been tested under eccentric loading with varying eccentricity - three tested under zero eccentricity, three under 25mm eccentricity, three with 50mm eccentricity.. The result conforms that the eccentric loaded columns buckles more as compared to the concentric loaded columns, as the eccentricity of the columns increases the buckling of the columns also increases. The results conforms that columns subjected to larger eccentricity has more wider cracks.

Keywords: Reinforced Concrete columns, eccentric loading, Load Strain, Spalling of concrete

Introduction
As we all know that columns has been most crucial structural elements of the any structure. so, i.e, there has been continuous research going on the columns under different loading. Generally nowadays, columns has been found to be subjected under eccentric loading. Reinforced concrete columns has been widely used columns under eccentric loading all over the world. The techniques of reinforcing concrete columns with steel has been very effective under eccentric loading [1-4], it has been also noted the eccentric loaded reinforced concrete columns has more prominent wider cracks, spalling of concrete and buckling [2-5]. In this research programme each and every columns has been tested and analyzed under various eccentric loading and also Comparison has been done to investigate the behavior and the effectiveness of each columns specimen. Based on the result Normalized load Vs Normalized Strain curve, the load Vs strain curve has been plotted and discussed. By the result it has been noticed that as the eccentricity increases the columns gets more damaged with more spalling of concrete, wider cracks.

Experimental Work
Description of sample specimen
All columns had a height of 500 mm, with columns having a cross-section 150 mm x75mm. The columns had the same core area, however a 20 mm clear cover was used in the each set of columns. Choosing of this section has been done with utmost care, it proves beneficial because it is economical, Less crack development, splicing of the column is not required because of its unique cross section full utilization of the cross section.

Materials Used
All the materials used in this experimental programme conforms the requirement of IS standards. Ordinary Portland cement (OPC) of 43 grade from Jharli factory, Haryana, has been used in all mixes in this research. Local crushed sand of gradation zone II has been used in this experimental programme. Coarse aggregates of maximum sizes of 20mm has been used in this experiment**.**
All the required test has been performed on the materials to ensure that the materials used in the experimental programme has been of good quality and as required IS standards. Portable tap water has been used for curing and mixing of the concrete.
Steel bars with nominal diameters 12 mm were used as longitudinal reinforcement, whereas 6 mm diameter bar has been used in lateral ties. There has been also required test has been performed to know the mechanical properties of the steel.

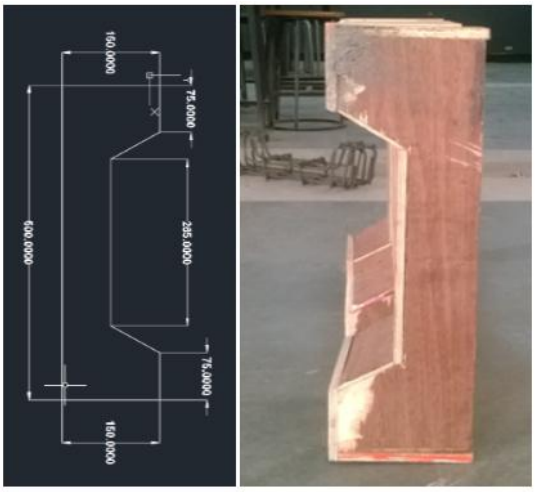
Table 1: Mechanical properties of the steel bars

Steel diameter mm	Steel grade	Actual area mm^2	Yield strength Mpa	Ultimate strength Mpa	Elongation %
6mm	Mild steel	27.4	302	489.3	20%
12mm	HYSD	103.8	520	693.8	17.1%

Mixing of materials
Mixing of the materials has been done with utmost care. A trail mix design has been made to get the target cubic compressive strength of 25Mpa. The 8 cu.ft drum has been used for mixing of materials. First dry mixing of the materials and aggregates has been done in mixer for 5 minutes, when the dry mixing of the materials has been achieved successfully then adding water in several stages (half at the start, and the remaining in several stages over 4 minutes). After a uniform mix was attained, Placing and curing of the concrete columns was been done properly with utmost care.

Table 2: Description of the specimen

Sl. No	Series	Specimen name	Group	Cross- sections	Eccentricity mm
1	A	A0.	Reinforced concrete column	150 mm x 75 mm	0
2	A	A25	Reinforced concrete column	150 mm x 75 mm	25
3	A	A50	Reinforced concrete column	150 mm x75 mm	50
4	B	B0	Reinforced concrete column	150 mm x 75 mm	0
5	B	B25	Reinforced concrete column	150 mm x 75 mm	25
6	B	B50	Reinforced concrete column	150 mm x75 mm	50
7	C	C0	Reinforced concrete column	150 mm x 75 mm	0
8	C	C25	Reinforced concrete column	150 mm x 75 mm	25
9	C	C50	Reinforced concrete column	150 mm x 75 mm	50



a) Sample details & Formwork

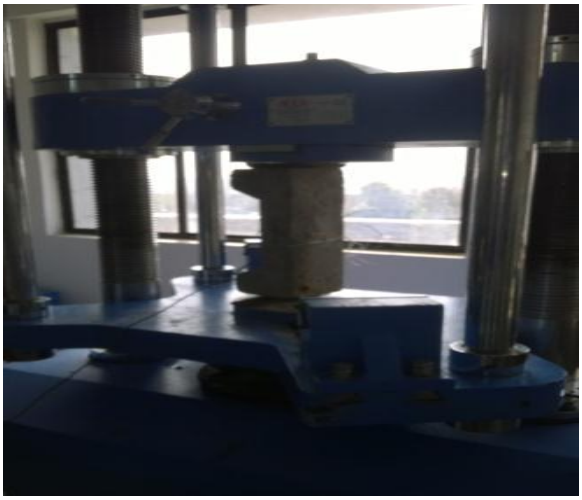
b) Reinforcement details & Reinforcement in formwork

Fig 1: Sample details and Reinforcement used in this experimental programme

Instrumentation and Experimental set up

Universal Testing Machine (1000kN) has been used for the testing of all columns specimen and all the testing of columns has been done in Manav Rachna International University Laboratory under good supervision. Electric resistant strain gauges has been of 350 ohm and having 5mm guage length. All strain gauges are installed at column mid height, all strain gauges are installed to monitor the strain, bar buckling and recording of the strain at which column buckles. Srain gauges has been glued to the column with the help of the cold adhesive. A steel rod of 50mm diameter and length of having 250mm has been cut longitudinally for the application of eccentric loading., First, the specimens were tested under load-control at a rate of 1.5 KN/s up to a load of 400 KN for the columns specimens. Next, loading changed to displacement-control, at a rate of 0.002 mm/s up to machine displacement of 6mm. Thereafter, the loading rate increased to 0.004 mm/s up to 16 mm for specimens. Strain gauges has been glued on both faces of the columns.

a) Specimen and strain gauges on specimen



b) Specimen on UTM (1000kN)

Fig 2: Instrumentations set up for experiment

Test Results and Discussion

From the test and results it has been noted that reinforced concrete columns can resist eccentric load effectively, As the eccentricity increases the buckling of the columns has been found more with wider cracks, i.e C series specimen has found more pronounced cracks and buckling in compared to the A series specimen and B series specimen, Also the Fluctutaions of load in C Series Specimen has been found more compared to the A & B seies specimen due to high continous eccentric loading, In The A series of the specimen the spalling of columns has been found top and bottom while its buckling has been found low, whereas in the C series the Buckling of columns has been found with wider horizontal cracks has been found in the mid areas of the columns. It hs been further noted that the ultimate cracking load has been also more in the high eccentric loaded columns compared low eccentric loaded column, more cracks developed in the columns the spalling of concrete has been found more. The high eccentric loaded columns exhibited better Strain compared to the less eccentric loaded columns. It has been noticed that large tie spacing in the reinforcement in the columns has caused more spalling of concrete and buckling, it would be better to use the columns having small tie spacing, It has been very necessary that columns should be designed in such a way that it can resist more lateral forces and resists high moments also, the reinforcement spacing should not be on the higher side. It has been further noticed that the high eccentric loaded columns has low ultimate peak load compared to low eccentric loaded columns, it defines that as the eccentricity of the columns increases the ultimate peak load capacity of the columns has been starts decreasing

a) Cracks and failure A series specimen

b) Cracks and failure B series specimen

c) Cracks and failure C series specimen

Fig 3

Table 3: Summary of Test result

Series	Eccentricity mm	Ultimate Cracking Load (kN)	Ultimate load (kN)	Ultimate Strain value (cracking) (mm/u)
A series	0	57.4	138.4	0.00283
B series	25	64.5	125.33	0.00614
C series	50	55.1	116.4	0.00701

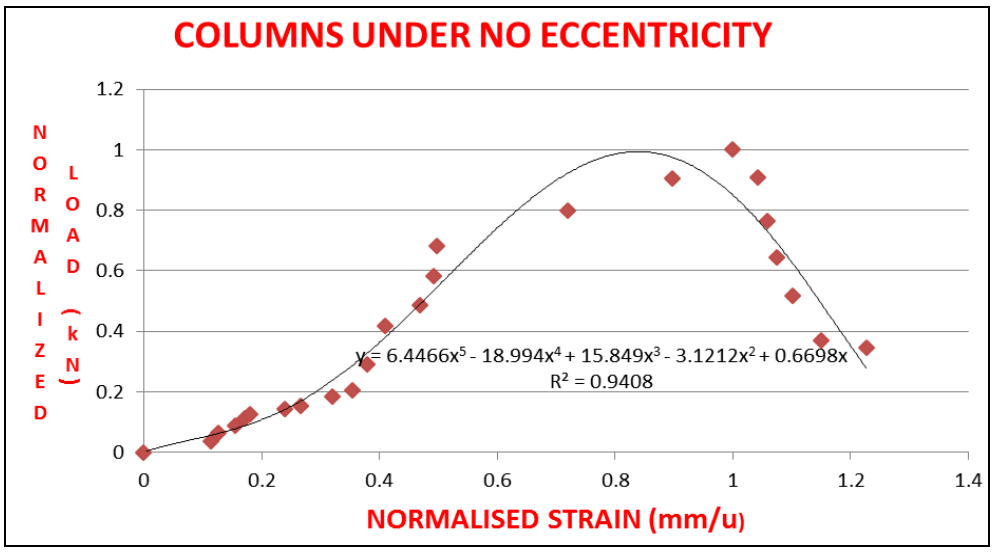


Fig 4: Normalized Load Vs Normalized Strain response of A series columns

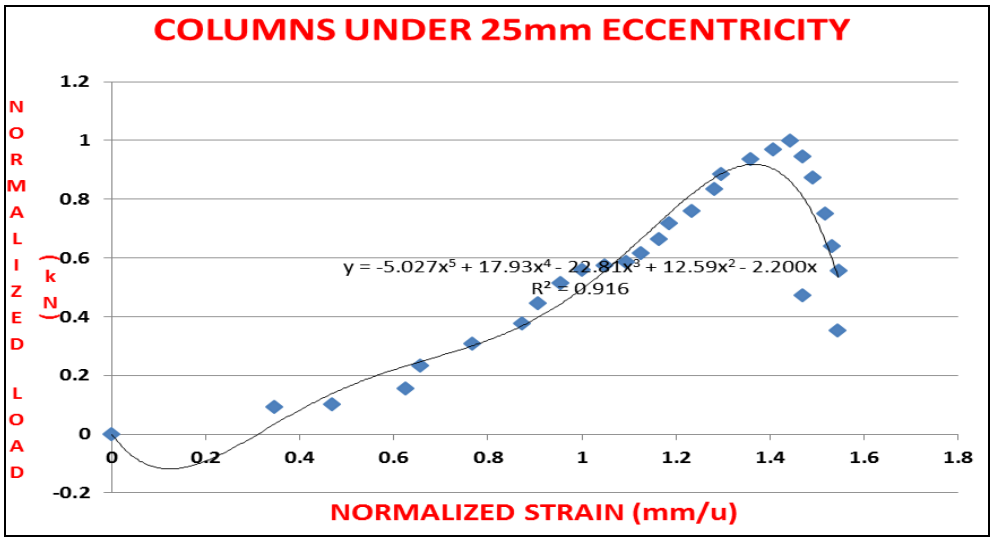


Fig 5: Normalized Load Vs Normalized Strain response of B series columns

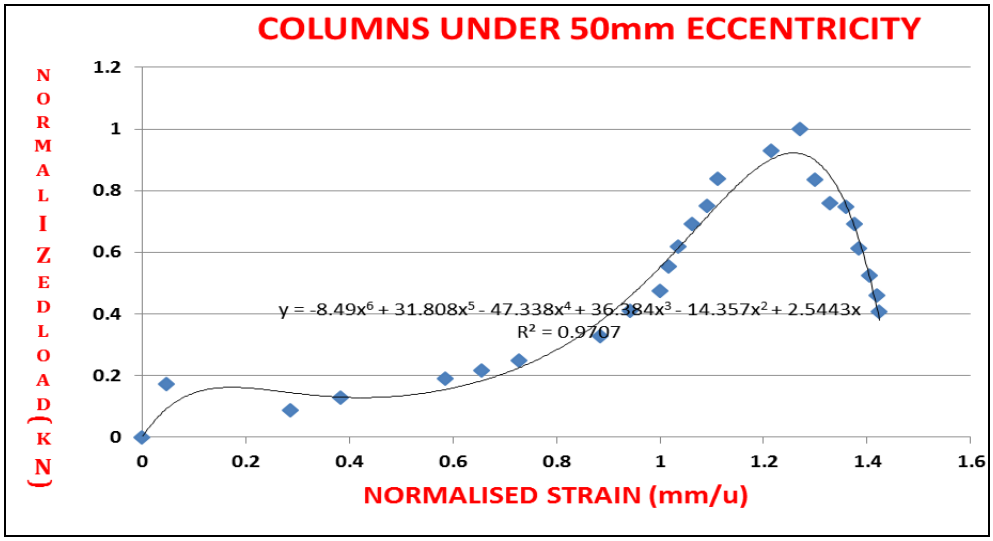


Fig 6: Normalized Load Vs Normalized Strain response of C series columns

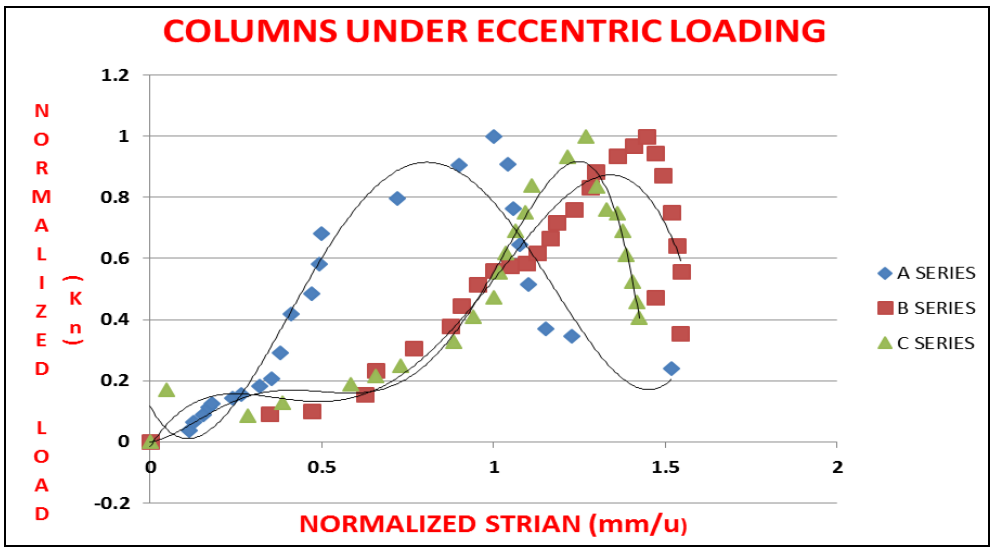


Fig 7: Normalized Load Vs Normalized Strain response of columns under concentric loading

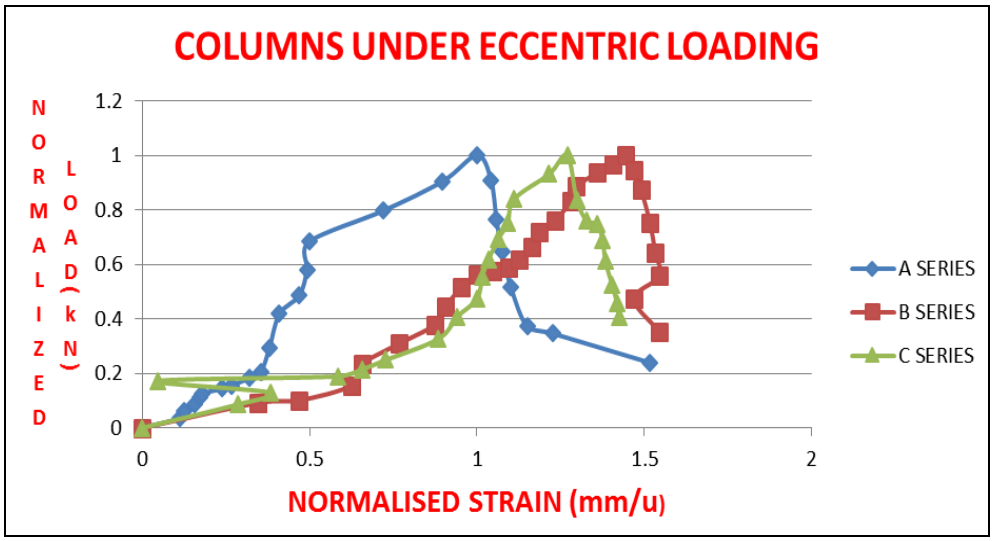


Fig 8: typical Load VS Strain response of columns under concentric loading

Conclusions

From the experimental work conducted in this study, the following conclusions can be drawn:

- The high eccentric loaded columns buckles more as compared to the low eccentric loaded columns, as the eccentricity of the columns increases the buckling of the columns also increases.
- The high eccentric loaded columns has more wider cracks compared to the low eccentric loaded columns..
- Fluctuations of the load has been found more high eccentric loaded columns.
- Reinforced concrete columns exhibits effective resistance under eccentricity
- As the eccentricity of the columns increases the ultimate peak load decreases.
- As the eccentricity of reinforced concrete columns increases the ultimate strain (cracking) also increases

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