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Behaviour of Prefabricated Steel Reinforced Concrete (PSRC) Column Under Different Loading Conditions

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Abstract— Nowadays non-conventional reinforcement systems are used to replace the conventional Reinforced Concrete (RC) Systems. In this paper Prefabricated Steel Reinforced Concrete (PSRC) system is introduced. PSRC columns, in which, the steel angles are placed at corners of cross section and are connected by transverse reinforcement which provide shear resistance, concrete confinement and bond resistance between concrete and steel angles. For PSRC, field rebar work is unnecessary and the self-erectable steel cage of angles and transverse bars together can provide sufficient strength and rigidity to support the construction loads of other structural members like beams and slabs. Compression test were performed analytically over 15 specimens to evaluate the axial compression capacity and force-deformation behaviour. For comparison a conventional concrete column reinforced with steel bars were also analysed. The analytical results show that the structural performance of PSRC columns were comparable to, or even better than that of the conventional reinforced concrete column.

Index Terms— Composite columns, Compression test, Concentric axial load, Eccentric axial load, High-strength concrete, High-strength steel, Prefabricated steel angle, Reinforced concrete, Steel equal-angle section, Steel unequal–angle section.

1 INTRODUCTION

FOR the construction of various structures such as buildings, parking garages, high-rise structures and bridges, reinforced concrete is used as a very common material. Concrete, as a generally modest material with capacity to oppose high-compression, and steel, as a material with high rigidity, work along providing a mechanism to resist the applied loading has made reinforced cement concrete a typical compound for construction works. Examples of such combinations in structural constructions are Ordinary rebar reinforced concrete, concrete filled tubular (CFT) system, steel-concrete composite system and welded wire fabric system. Steel-concrete composite columns such as concrete-enclosed steel (CES) and concrete-filled steel tube (CFT) columns have large load-bearing capacity due to composite action. High-strength materials improve structural safety and space efficiency. Thus, the employment of high-strength composite columns is growing within the construction of skyscraper and long-span structures.

When using high-strength steel for conventional CES columns, it is necessary to consider early crushing of concrete encasements, as the steel core may not develop its full plastic strength during concrete failure, especially under flexural loading (Kim et al. 2012, 2014).

The steel strain needs to be developed earlier by placing the steel section at the perimeter of the cross-section to maximize the contribution of high-strength steel, and the early concrete crushing needs to be restricted by providing lateral containment. The flexural stiffness of the cross-section can also be increased when the steel section is placed at the perimeter of the cross section as well as the flexural strength. These composite columns with corner steel angles have been examined (Zheng and Ji 2008; Kim et al. 2011; Hwang et al. 2012).

High-strength steel CFT columns show excellent structural performance, as the steel tube provides good lateral confinement to the concrete core prevents early concrete crushing, and under flexural loading, the steel tube strain is greater than the core concrete strain. Thus, the contribution of high-strength steel can be maximized. (Liu et al. 2003; Kim et al. 2014).

A Prefabricated Steel-Reinforced Concrete (PSRC) column was developed to avoid field work for rebar manufacturing of CES columns and conventional reinforced concrete columns. The conventional steel bars at the corners of the cross section are replaced by the prefabricated steel angles. The steel angles are connected with transverse bars or plates in order to provide shear resistance, concrete confinement and bond resistance between concrete and steel angles. The main parameters studied included the type of longitudinal reinforcement and different loading conditions on the behaviour of PSRC specimens are discussed.

2 ANALYTICAL STUDY

2.1 Modelling and Analysis

This study is concerns about comparative study between conventional Rebar Reinforced Column and Prefabricated Steel Reinforced Concrete Column. Table 1 shows the composite

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columns and its properties. The sectional size of the PSRC column is 260 mm × 260 mm with a clear height of 900 mm. The diameter and the spacing of the stirrups are 8 mm and 100 mm (centre), 50 mm (end). Four numbers of (35×35×5) mm, (50×30×4) mm angle sections of grade 345 and 650 are used in PSRC and four numbers of 20 mm Ø bars of grade 415 is used in conventional reinforcing system. Figure 1 shows sthe cross section of PSRC column. Detailed description about theco-lumn is as follows:

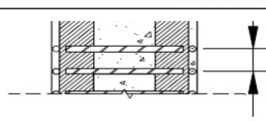
TABLE 1
PROPERTIES OF SPECIMEN

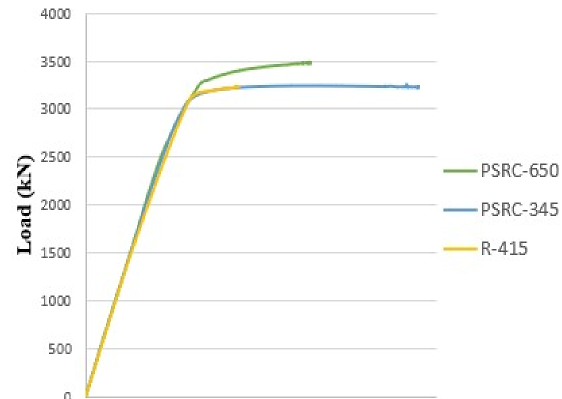
Properties	Specimen	
	Conventional	PSRC
Section		
– B×D (mm)	260 × 260	260 × 260
– A_g = BD (mm²)	67,600	67,600
Concrete		
– f'_c (MPa)	40	40
Steel		
– f_{ys} (MPa)	415	345, 650
– Steel shape	4, 20mm Ø bars	4, ∠35×35×5 4, ∠50×30×4
Height (mm)	900	900
Transverse Reinforcement		
– Type	4,8mm Ø ties	4,8mm Ø ties
– f_{yt} (MPa)	415	415
– Spacing (mm)	100	100

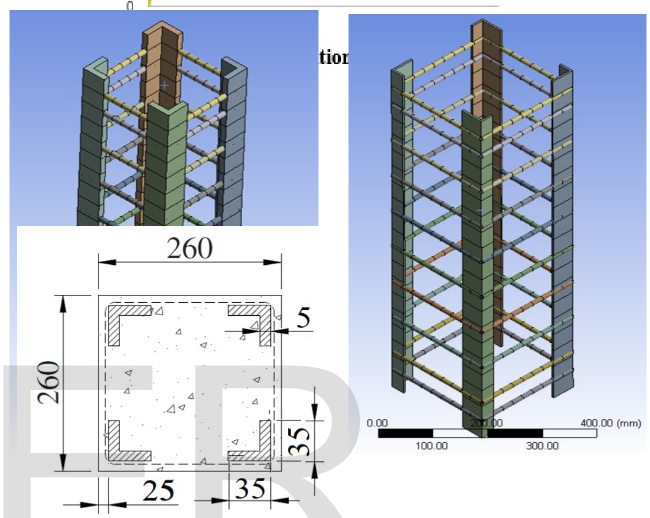
The material parameters of concrete, steel angle, steel bar, stirrups are shown in Table 2 taken into consideration for analysis in Ansys software. Properties of all elements, concrete, ties and angle were fed in Ansys software program for accurate and precise evaluation of the of the problem.

TABLE 2
MATERIAL PROPERTIES

Properties	Concrete	Steel	Transverse Reinforcement
Density	2300 kg/m³	7850 kg/m³	7850 kg/m³
Modulus of Elasticity	31623 MPa	2x10⁵MPa	2x10⁵ MPa
Poisson's Ratio	0.15	0.3	0.3
Strength	4.427 MPa	345 Mpa 650 MPa	415 MPa







For analysis ANSYS 16.1 software is used. The specimens are fixed at bottom and are loaded axially with varying eccentricity. Material properties were assigned to various parts of the column. Structural steel property was assigned to Reinforcements and concrete nonlinear property was assigned to concrete column.

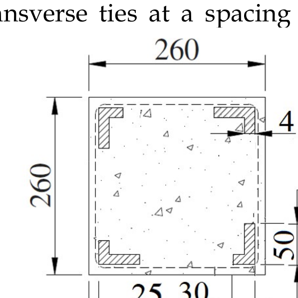
(a)

(b) (c)

Fig. 1. Dimensions of PSRC columns (a) Transverse Reinforcements (mm), (b) Cross Section of PSRC-Equale Angle (mm), (c) Cross Section of PSRC-Unequale Angle (mm)

Fig. 2. Meshing of PSRC Specimens; (a) Equal Angle Column Reinforcement, (b) Un-equal Angle Column Reinforcement

Fig. 2. Shows the meshed PSRC column specimen with corner steel angles are welded with transverse ties at a spacing of



100mm.

2.2 Results and Discussions

By doing analysis of these specimens with the help of ANSYS 16.1 software following results was determined. Analysis of Reference Specimen (R-415), PSRC- 345 and PSRC – 345 was carried out in Ansys for load - deformation of columns at ultimate loading condition.
Table 3 shows the results obtained from the analysis of column specimens under axially loading conditions.

Fig. 3, 4, 5, 6 and 7 shows Load v/s Deflection curves for specimen R-415, PSRC-345, PSRC-650 with eccentricities of 0%, 25%, 50%, 75% and 92% respectively.

TABLE 3
RESULT FROM THE ANALYSIS

Specimen	Eccentricity (%)	Load (kN)	Deformation (mm)
PSRC-650	E-0	3484.3	6.389
	E-25	2764.4	13.486
	E-50	2270.9	14.356
	E-75	1880.5	15.671
	E-92	1613.8	11.611
PSRC-345	E-0	3245.8	9.138
	E-25	2597.7	14.553
	E-50	2053.4	16.811
	E-75	1654.2	16.663
	E-92	1467.3	15.978
R-415	E-0	3226.5	4.302
	E-25	2398.8	15.426
	E-50	2029.4	17.626
	E-75	1695.8	17.074
	E-92	1433.4	14.436

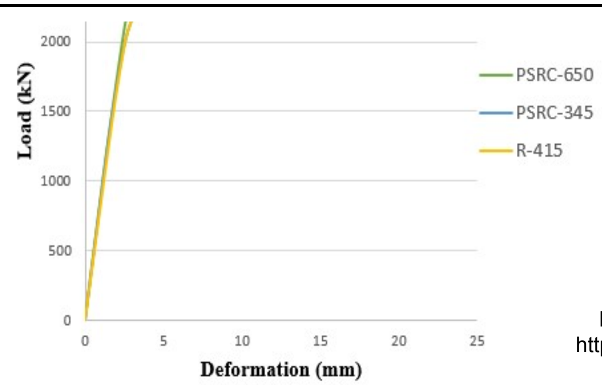


Fig. 3 Load – Deformation Curve for Eccentricity 0%

Fig. 4 Load – Deformation Curve for Eccentricity 25%

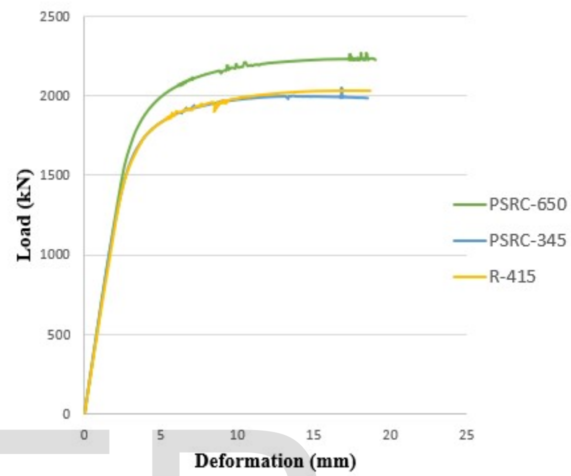
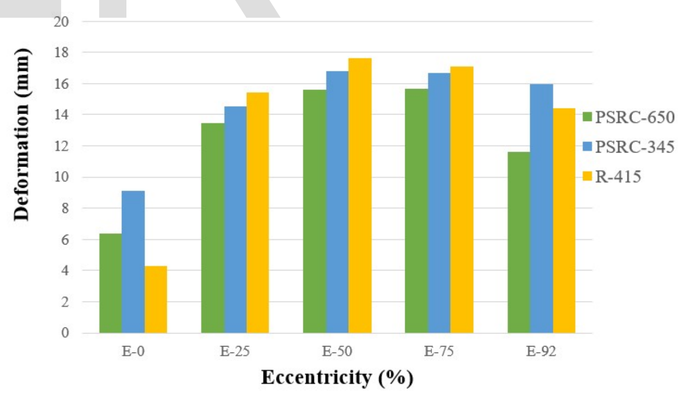


Fig. 5 Load - Deformation Curve for Eccentricity of 50%



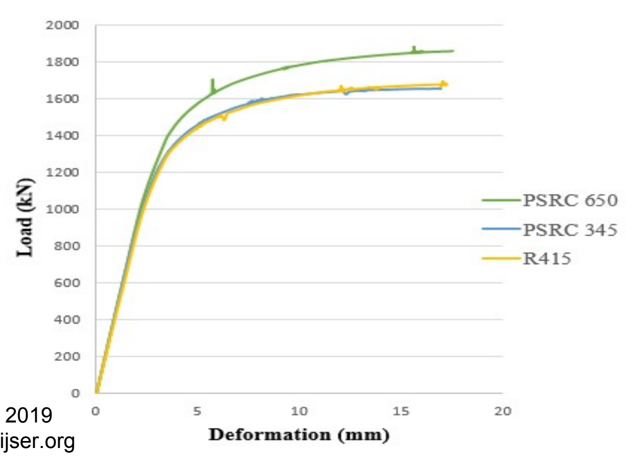


Fig. 6 Load - Deformation Curve for Eccentricity of 75%

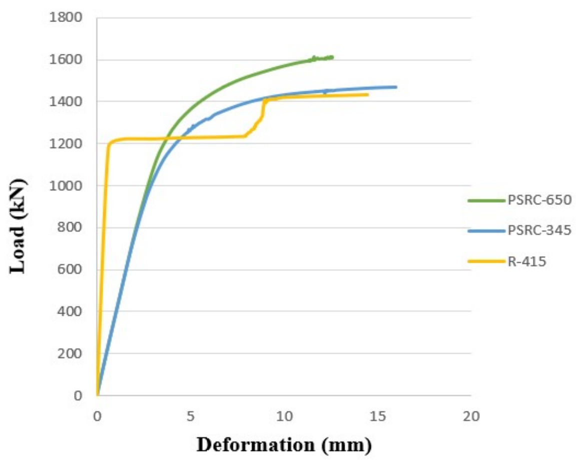


Fig. 7 Load - Deformation Curve for Eccentricity of 92%

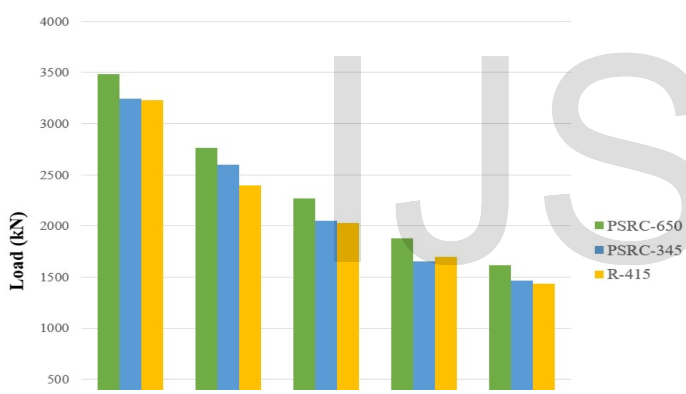
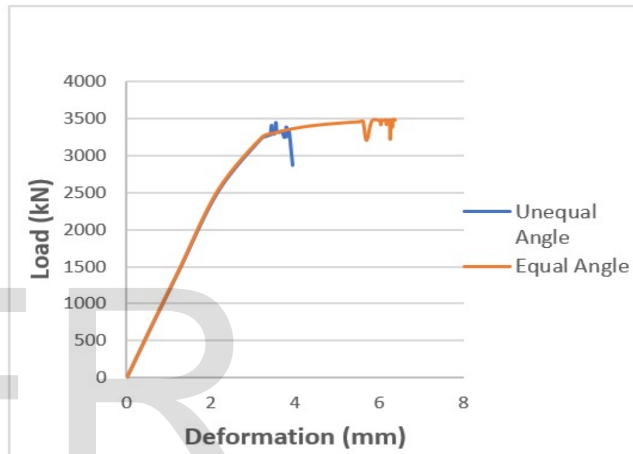


Fig. 8 Load – Eccentricity Chart of PSRCs and Reference specimen

Fig. 9 Deformation – Eccentricity Chart of PSRCs and Reference specimen

By analyzing the load – deformation graph, the performance, PSRC specimen is better than that of the reference specimen in load carrying capacity and also in deformation capacity. The performance of R-415 and PSRC-345 is likely to be same in 0% to 75% eccentricity. But in 92% eccentricity the beahaviour of columns totally changes. This may due to the load applying point is within the cover region. By comparing both the PSRC-345 and PSRC-650, the performance of PSRC-650 is better than that of PSRC-345, due to high strength steel as steel angle reinforcement.



The comparison of PSRC-650 with equal angle and unequal angle are also analysed. The results are shown in Table 4. PSRC with equal angle of size (35×35×5) mm and unequal angle section of size (50×30×4) mm of four numbers at the coreners of the cross section and are tied together by 8mm Ø bars.

From Table 4 the PSRC specimens reinforced with equal and unequal angle sections; the specimen with unequal angle ection has better deformation capacity.

TABLE 4
LOAD – DEFORMATION VALUES OF PSRC-650 WITH EQUAL AND UNEQUAL ANGLE SECTIONS

Specimen	Eccentricity (%)	Load (kN)	Deformation (mm)
PSRC-650 ∠35×35×5	E-0	3484.3	6.389
	E-25	2764.4	13.486
	E-50	2270.9	14.356
	E-75	1880.5	15.671
	E-92	1613.8	11.611
PSRC-650 ∠50×30×4	E-0	3439.3	3.546
	E-25	2381	3.037
	E-50	1823	3.461
	E-75	1420	3.731
	E-92	1228	3.845

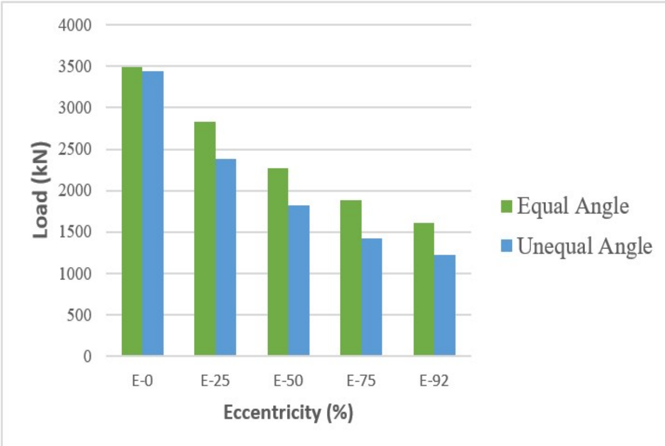


Fig. 10 Load – Eccentricity Chart of PSRC Specimen with reinforcement of equal angle and unequal angle sections

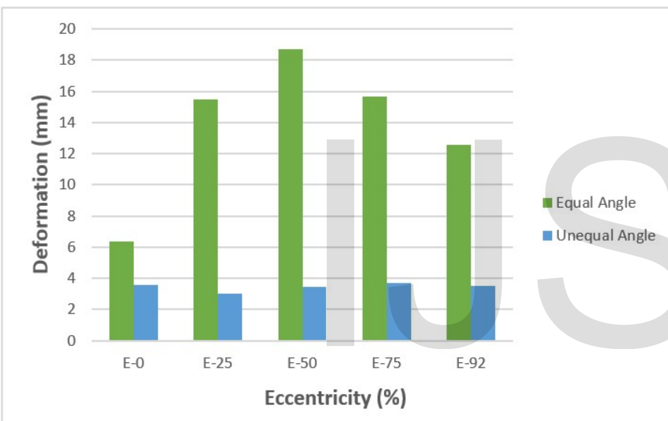


Fig. 11 Deformation – Eccentricity Chart of PSRC Specimen with reinforcement of equal angle and unequal angle sections

Both these fig. 10 anf Fig. 11 shows the comparison of both PSRC specimen with reinforcement systems of equal and unequal angle section. Here, the PSRC specimen with equal angle section perform better than that of specimen with unequal angle section.

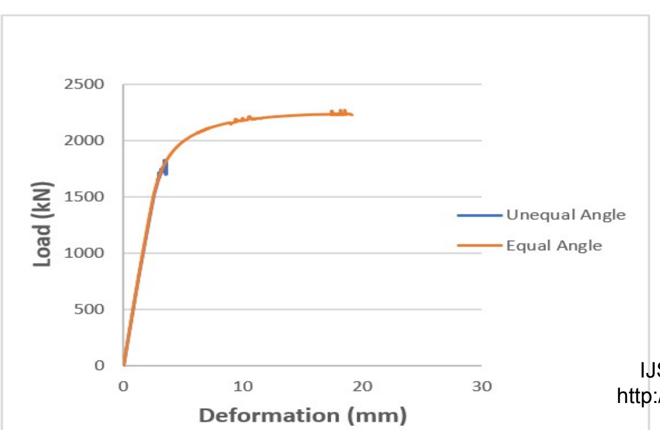
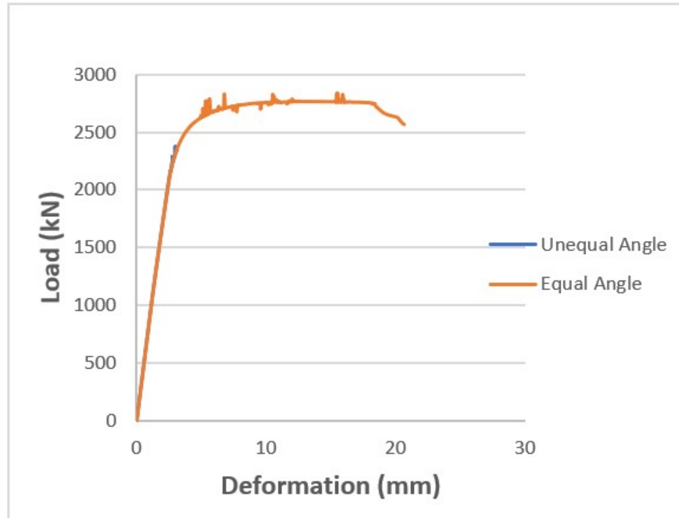


Fig. 12 Load - Deformation Curve for Eccentricity of 0%

Fig. 13 Load - Deformation Curve for Eccentricity of 25%



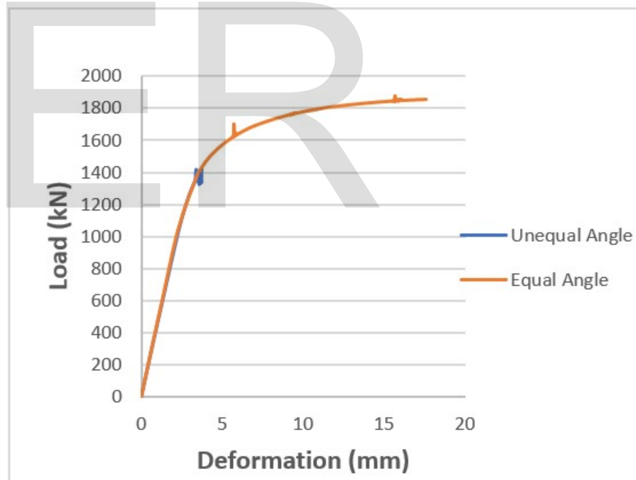


Fig. 14 Load - Deformation Curve for Eccentricity of 50%

Fig. 15 Load - Deformation Curve for Eccentricity of 75%

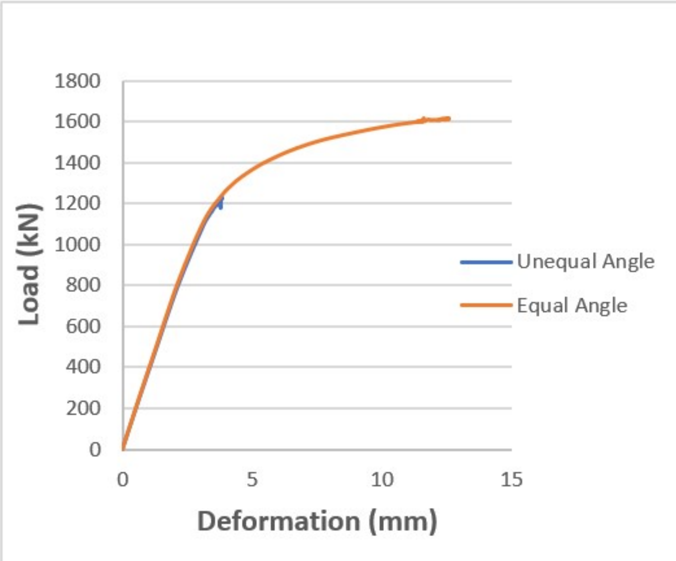


Fig. 16 Load - Deformation Curve for Eccentricity of 92%

Fig. 12 to Fig.16 shows the load – deformation curves obtained by the analysis of PSRC specimen with reinforcements of equal angle and unequal anglesections.

4 Conclusion

According to the results obtained from the analytical investigations of column specimen, it is concluded that the axial load-carrying capacity and deformation capacity of PSRC composite columns are comparable to, or even better than, those of conventional composite columns under concentric and eccentric loading condition. In case of PSRc specimen with equal angle section and unequal angle section, the specimen with equal angle sections shows better results in loading.

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