Study on Behavior of RC Framed Corner Joints Using Fem Technique

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***Abstract- Objectives*: To analytically investigate the performance of open corner joints reinforced with commonly used detailing arrangements and to identify the most efficient and practical detailing arrangement using non linear FEM techniques.**

***Analysis*: The previous studies reveal that the frame corners subjected to opening moments are more sensitive to the method of detailing of reinforcement than those subjected to closing moments. Therefore, in the present study, initially three different detailing arrangements subjected to opening moment were investigated by Finite Element Technique using ATENA 2D software and structural response was obtained in terms of load deflection curves and cracking pattern etc. to select the detailing arrangement for further study.**

Findings: Out of the three detailing arrangements investigated in the present study, the detailing arrangement with inverted U-type detailing system having diagonal steel exhibited the best structural performance due to the provision of diagonal steel oriented in the direction of diagonal tension induced in the joint under opening moment.

The diagonal steel having 75% of tension steel appears to be optimum beyond which no significant gains of ultimate capacity and ductility ratio were obtained.

With increase in percentage of diagonal steel in the joint, the ultimate load improved.

With increase in tension steel, the increase in ultimate load carrying capacity was observed. However, the crack width at the ultimate load increased with the increase in percentage of tension steel. Therefore, in order to ensure the satisfactory performance of corner joints subjected to opening moments, the corners should be kept lightly reinforced. When tension steel was increased from 0.76% to 1.16%, the ultimate load carrying capacity increased from 7.70kN to 8.61kN.

Improvement: Further research can be extended to study the behavior of steel fiber reinforced concrete opening corner joints and the effect of varying the stiffness of the adjoining members of the corner joint.

Keywords: Study on behavior of RC framed corner joints using FEM technique.

I. INTRODUCTION

Available literature on framed corners indicates that very less work has been reported on application of nonlinear finite element analysis techniques for the investigation of structural behavior of framed corners. Therefore, a need has been felt for analytical investigation on strength and deformation characteristics of reinforced concrete corner joints subjected to opening moment using FEM technique.

In this investigation, it was proposed to employ ATENA 2D software incorporating nonlinear finite element analysis capabilities to investigate the influence of different detailing arrangements on the behavior of RCC corner joints under monotonic loading, throughout the loading regime.

The following specific objectives were identified for the present study:-

(i) To analytically investigate the performance of opening corner joints reinforced with three commonly used detailing arrangements using non-linear FEM techniques

(ii) To identify the most efficient and practical detailing arrangement based on the structural performance of the three detailing arrangements.

(iii) To carry out the comprehensive investigation of the performance of the proposed detailing arrangement in terms of the effect of percentage of tension reinforcement,compression reinforcement, diagonal reinforcement and shear reinforcement.

(iv) To investigate the effect of grade of concrete and grade of steel on the structural performance of the selected detailing arrangement.

II. ANALYTICAL ANALYSIS

To fulfill the objective of present study purpose three different detailing arrangements were investigated using ATENA 2D software. In the software concrete is represented by the SBETA material model. The finite element meshing of concrete was done using four noded 2D isoparamertic elements of size 0.06m, while discrete bars were used to model the reinforcement. The rebar were modeled using 2D isoparametric elements. Because of the symmetry only half of the frame was considered for analysis. The frames were subjected to approximately 50 load steps, each step introducing a displacement of 0.0005m at the loading point.

2.1 Finite Nonlinear Analysis

In this method all the complexities of the problems, like varying shape, boundary conditions and loads are maintained as they are but the solutions obtained are approximate. A number of popular brand of finite element analysis packages are now available commercially. Some of the popular packages are STAAD-PRO, GT-STRUDEL, NASTRAN, NISA, ATENA 2D and ANSYS. Using these packages one can analyze several complex structures.

2.1.1 General Description of Method

The finite element procedure reduces unknowns to a finite number by dividing the solution region into small parts called elements and by expressing the unknown field variables in terms of assumed approximating functions (Interpolating functions/Shape functions) within each element. The approximating functions are defined in terms of field variables of specified points called nodes or nodal points.. After selecting elements and nodal unknowns next step in finite element analysis is to assemble element properties for each element.

2.1.2 Analysis of frame corners

Four frame corners with different detailing arrangement in the joints were investigated in the present study. The plan of the portal frame analysed in the present study has been shown in Fig. 1 The detailing of reinforcement in various frame corners is shown in Fig. 2 to 4.

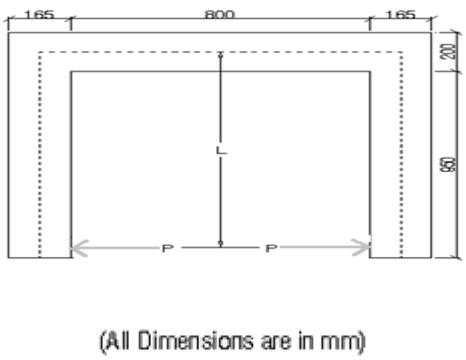

Fig. 1 Plan of Specimen

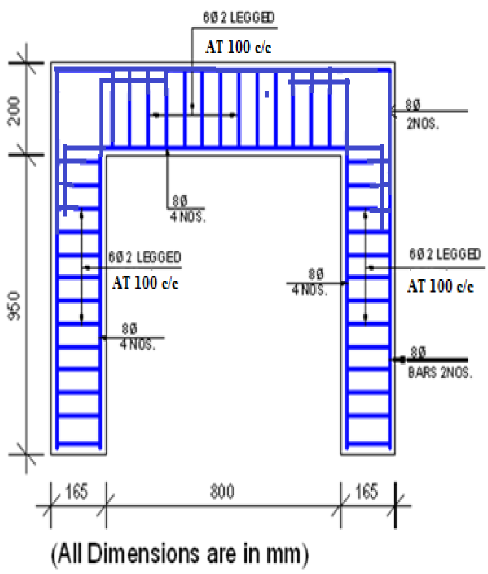

Fig. 2 L- type detailing arrangement (SP1)

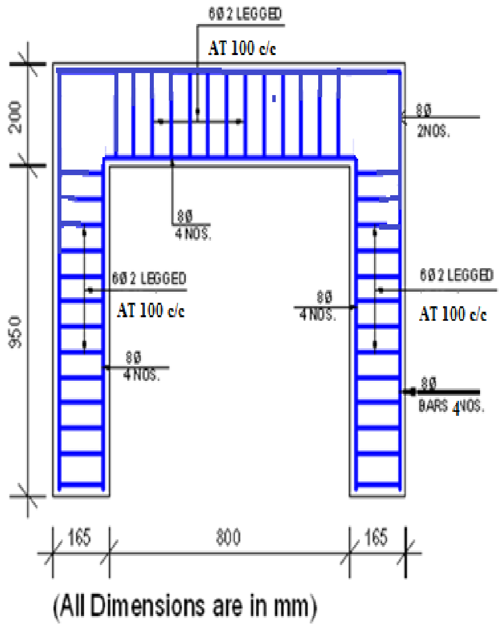

Fig. 3 Inverted U-type detailing arrangement

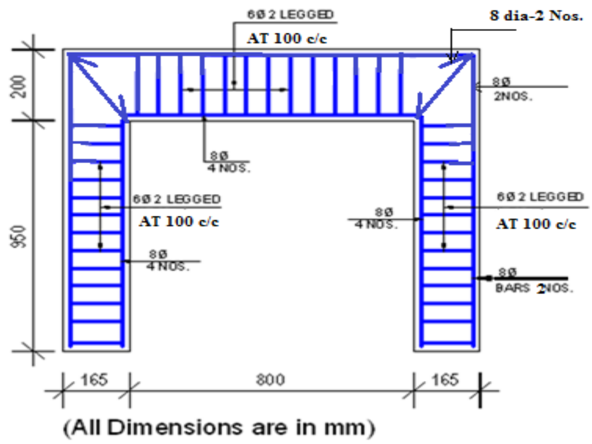

Fig. 4 Inverted U type detailing arrangement with diagonal steel (SP3)

Material Properties

Concrete

- Material type Material: *SBETA
- Cube strength: 25 MPa
- Elastic Modulus: $5000 \sqrt{f_{ck}}$
- Poisson's Ratio: 0.2
- Flexural Tensile Strength: $0.7\sqrt{f_{ck}}$
- Compressive Strength: $0.677 f_{ck}$
- Compressive Strain: 0.002

Reinforcement

- Material type Reinforcement
- Elastic Modulus 2.0E+05 MPa
- Yield Strength 415MPa

Other specifications

Type of Element	Quadrilateral
Element Size	0.06m
Prescribed Deformation	0.0005m per load step
No. of load steps	50

The material model SBETA includes the following effects of concrete behavior:

I. Nonlinear behavior in compression including hardening and tensioning.
II. Fracture of concrete in tension based on the nonlinear fracture mechanics.
III. Biaxial strength failure criterion.
IV. Reduction of compressive strength after cracking.
V. Tension stiffening effect.

Reduction of the shear stiffness after cracking.

III. RESULTS AND DISCUSSION

Performance of different detailing arrangements under opening moment and effects of varying steel on structural performances is tabulated at the end.

IV. CONCLUSION

Based on the present study, the following conclusions can be drawn on the behavior of reinforced concrete corner joints subjected to opening bending moments:

i. Out of the three detailing arrangements investigated in the present study, the detailing arrangement with inverted U-type detailing system having diagonal steel exhibited the best structural performance due to the provision of diagonal steel oriented in the direction of diagonal tension induced in the joint under opening moment.
ii. The diagonal steel having 75% of tension steel appears to be optimum beyond which no significant gains of ultimate capacity and ductility ratio were obtained.
iii. With increase in percentage of diagonal steel in the joint, the ultimate load improved. The ultimate load improved to 8.670kN from 7.701kN when the diagonal steel was increased from 50% to 75% in specimen SP3.
iv. With increase in tension steel ,the increase in ultimate load carrying capacity was observed. However, the crack width at the ultimate load increased with the increase in percentage of tension steel. Therefore, in order to ensure the satisfactory performance of corner joints subjected to opening moments, the corners should be kept lightly reinforced. When tension steel was increased from 0.76% to 1.16%, the ultimate load carrying capacity increased from 7.70kN to 8.61kN.
v. With increase in compression reinforcement, no significant gain in ultimate load carrying capacity was obtained when the compression reinforcement was increased from 50% to 100% . However, with the increase in percentage of compression steel, the ductility value is improved. The ductility value improved from 1.62 to 2.12 when the compression steel was increase from 50% to 100% of tension steel.
vi. The increase in spacing of shear reinforcement resulted in decrease in load carrying capacity of specimens. When the spacing of shear reinforcement was increased from 75mm to 125mm, the ultimate load carrying capacity decreased from 7.8kN to 7.0kN. The ductility ratios also decreased with increase in spacing of shear reinforcement.
vii. With the increase in diagonal reinforcement from 50% to 100% to tension steel, the ultimate load carrying capacity increased from 7.7kN to 8.8kN. The ductility values also increase with the increase in diagonal reinforcement.

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Performance of different detailing arrangements under opening moment

Table 1 Ultimate MOR for Different Detailing Arrangements

Sr. No.	Specimen Detail	Ultimate Load (kN)	Ultimate MOR (kNm)
1	SP1	5.227	4.966
2	SP2	4.525	4.300
3	SP3	7.701	7.316

Table 2 Crack width Values for Different Detailing Arrangements

Sr. No.	Specimen Detail	First Crack Load (kN)	Crack Initiation Width (mm)	Crack Width at Ultimate load (mm)
1	SP1	2.76	0.12	1.47
2	SP2	3.25	0.16	2.25
3	SP3	2.92	0.23	1.23

Effect of Different Percentage of Tension Steel

Table 3 Crack Width Values for Different Percentage of Tension Steel

Sr. No.	%age of tension steel	Crack initiation width (mm)	Crack width at ultimate load (mm)	Ductility ratio $\mu = Ø_u/Ø_y$
1	0.76%	0.2369	1.227	1.62
2	0.96%	0.2132	2.841	1.57
3	1.16%	0.1651	2.929	1.41

Table 4 First Crack and Ultimate Load for Different Percentage of Tension Steel

S .No	Specimen detail	First crack load (kN)	Ultimate Load (kN)
1	0.76%	2.92	7.701
2	0.96%	3.75	7.918
3	1.16%	3.89	8.615

Effect of Percentage of Compression Steel

Table 5 Crack Width Values for Different Percentage of Compression Steel

Sr. No.	%age of compression steel	Crack initiation width (mm)	Crack width at ultimate load (mm)	First crack load (kN)	Ultimate Load (kN)	Ductility Ratio $\mu = Ø_u/Ø_y$
1	50%	0.23	1.22	2.92	7.70	1.62
2	75%	0.21	3.09	3.70	7.77	2.01
3	100%	0.21	4.26	3.96	8.06	2.12

Effect of Different Percentage of Diagonal Steel

Table 6 Crack Width Values for Different percentage of diagonal bars

Sr. No.	% of diagonal bars	Crack initiation width (mm)	Crack width at ultimate load (mm)	Ductility Ratio $\mu = Ø_u/Ø_y$
1	50	0.286	2.927	1.62
2	75	0.268	2.790	2.45
3	100	0.231	2.117	2.89

Table 7 First Crack and Ultimate Load for Different percentage of diagonal bars

Sr. No.	% of diagonal bars	First crack load (kN)	Ultimate Load (kN)
1	50	2.92	7.701
2	75	3.345	8.670
3	100	3.36	8.876