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Analytical Investigation on Behaviour of RC Framed Corner Joints

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Abstract — *Beam-Column joints in a reinforced concrete moment resisting frame are crucial zones for transfer of loads effectively between the connecting elements in the structure. It has been observed that during earthquakes, Corner Joints are under heavy distress due to shear in the joints which results in the collapse of the structure. The previous studies have confirmed that corner joints subjected to opening moments are more critically influenced by the detailing of reinforcement than those subjected to closing moments. In the first part of the study four frames with different reinforcement detailing arrangement i.e. conventional L-type detailing arrangement (SP1), inverted U-type detailing with diagonal steel at corner (SP2), inverted L-type detailing with splay steel (SP3) and overlapping U-stirrups type detailing (SP4) were analyzed using ATENA 2D software. Based on the results from ATENA software in terms of ultimate load, first crack load, crack initiation width and crack width at ultimate load, specimen SP3 was selected for further investigations as this specimen performed better structurally. In the second part of study, the effect of different sizes of chamfer at reentrant corner; the effect of different percentage of tension steel; effect of different percentage of compression steel; effect of different spacing of shear reinforcement; effect of different percentage of splay steel; effect of different grades of concrete; and effect of different percentage of grade of steel were observed on specimen SP3.*

***Keywords**-Corner Joints, Opening Moment, Closing Moment, RC Moment Resisting Frame, ATENA Software.*

I. INTRODUCTION

Joints are crucial in Reinforced Concrete framed structures where the elements of the structure such as beams and columns intersect. Beam-Column Joints ensure that various members of RC framed structure behave as one unit and makes RC framed structure continuous. Forces acting at the ends of the members are transferred through these joints. It has been often seen that failure in beams of Reinforced Concrete framed structures occurs at joints making the Beam-Column joint one of the most critical sections of the structure. There is sudden change in geometry and complexity of stress distribution at joints of Reinforced Concrete Framed Structures which makes these joints critical. Design of Beam-Column joints in RC framed structures was generally based to satisfy anchorage requirements initially. But nowadays it has been found out that behaviour of joints depends on a number of factors such as Geometry of structure, reinforcement detailing, strength of concrete, Reinforcement strength, type of loading, etc. Basic requirements so that Beam-Column joints in Reinforced Concrete framed structures perform desirably are:-

i. A RC framed beam-column joint should exhibit a service load performance equal in quality to that of members it joins.
ii. A RC framed beam-column joint should possess a strength that corresponds at least with the most adverse load combinations that the adjoining members could possibly sustain, several times if necessary.
iii. The strength of the joint should not normally govern the strength of structure and its behaviour should not impede the development of the strength of adjoining member.
iv. Ease of construction and access for placing and compacting concrete are other prominent issues of joint design.

II. METHOD OF ANALYSIS

When studying the response of a concrete structure subjected to external load, the traditional way is to carry out experiments in which different parameters are varied. The observations made may then be used to propose mechanical or empirical models that can adequately describe the structure's behaviour. However, not only is this approach quite expensive but it cannot be counted on to give all the information needed. Another approach is to make use of the advanced computational techniques available today. By using the non-linear finite element method, in which the concrete material models are based on non-linear fracture mechanics to account for cracking, together with plasticity models for the reinforcement steel and the concrete in compression, the need for experiments can be greatly reduced. In such a finite element analysis, it is possible to evaluate the response of a structure more thoroughly than can be done in an experiment. However, the experiments cannot be replaced completely since they are still vital to check whether the finite element simulations correspond to reality. This means that even if both methods have their advantages when used alone, they can become an even more powerful tool when used together. Accordingly, in combination with the experiments, the use of non-linear finite element analyses will result in a better understanding and prediction of the mechanical behaviour in a structure during loading to failure.

III. METHODOLOGY

In the present study, four different detailing arrangements subjected to opening moment were critically evaluated by finite element technique using ATENA 2D software and structural response was obtained in terms of load deflection curves and cracking pattern etc.

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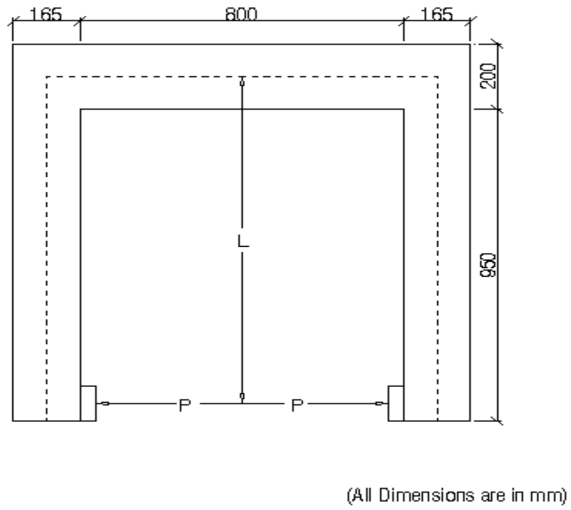

Fig 1: Plan of Specimen

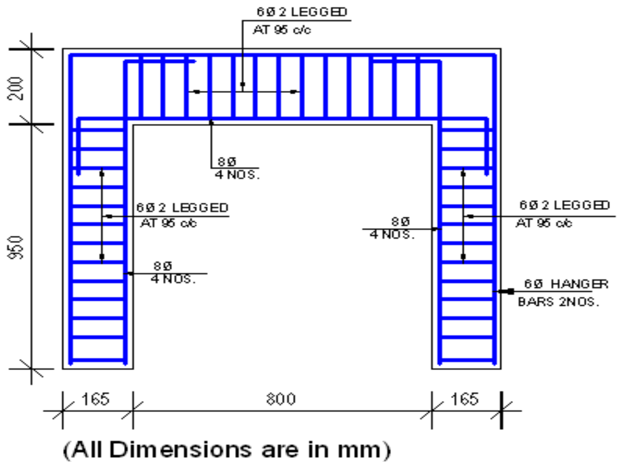

Fig.2: Conventional L type detailing arrangement (SP1)

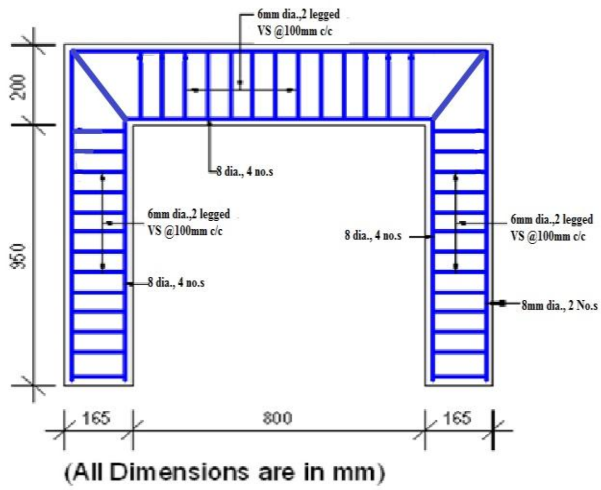

Fig.3: U type detailing arrangement with diagonal steel (SP2)

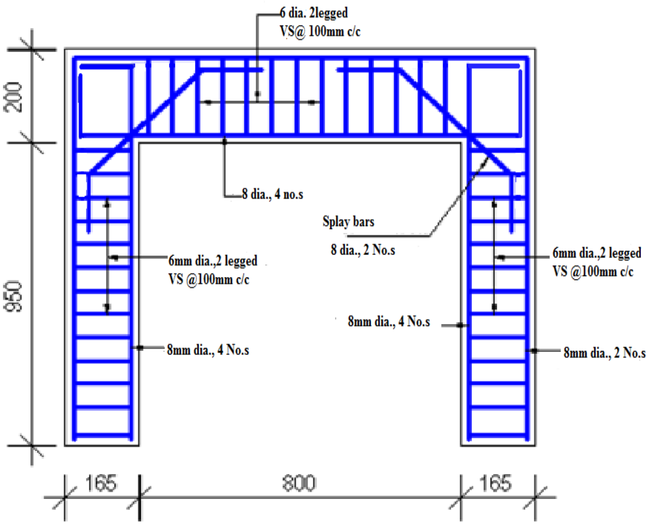

Fig.4: Inverted L- type detailing arrangement with splay steel (SP3)

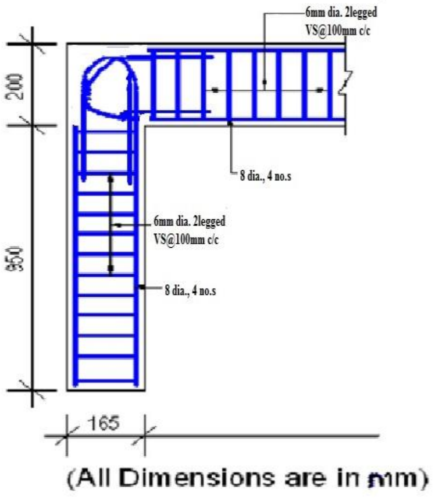

Fig.5: Overlapping U Stirrups type detailing arrangement (SP4)

The complete geometry is defined and a finite element is prepared for nonlinear analysis by ATENA. The purpose of the geometric model is to describe the geometry of the structure, its material properties and boundary conditions. The analytical model for the finite element analysis is created during the preprocessing with the help of fully automated mesh generator. The geometrical model is prepared in the following steps.

- First, geometric joints are defined.
- These joints are later connected into the boundary lines. It is possible to create straight lines, arc or circular lines.
- The subsequent step is to define macro elements or regions, by specifying a list of boundary conditions, which surround the macro-element.
- After the macro elements are defined, it is possible to start an automatic mesh generation. Based on the element sizes that are defined for each macro element, a finite element mesh is generated automatically.
- In the next step, the reinforcing bars are defined which includes both the longitudinal and transverse reinforcement. This includes specifying the number of bars, their spacing and their diameter.
- In this step, the supports and actions are defined. The beam is loaded by prescribed displacements at the loading points. It is possible to apply load by the horizontal forces, which will be increased in each step. In this case, two load case are defined: one containing the vertical and horizontal supports, and second with the prescribed deformations at the inner side of a beam of defined loading points.
- The loading history is defined. Next, each load step is defined as a combination of load cases, which is defined previously. Each load step contains also a definition of the solution parameters, which define solution methods that are to be used during the load steps.

- During the nonlinear analysis it is useful to monitor forces, displacements or stresses in the model. The monitored data can provide important information about the state of structure. The monitoring of applied forces determines whether the maximum applied load reaches or not. In this case, the first monitoring point is placed at the inner side of column where prescribed displacements are applied. The second monitoring point should be located at the outer side of the column near its bottom surface, where the largest vertical displacements are expected.

In the pre-processing section, to obtain a complete geometry of the model, the material properties are defined as follows:

Concrete

- Material type — *SBETA Material
- Cube strength — 30 MPa
- Elastic Modulus — 5000 $\sqrt{f_{ck}}$
- Poisson's Ratio — 0.2
- Tensile Strength — $0.7\sqrt{f_{ck}}$
- Compressive Strength — $0.677f_{ck}$
- Compressive Strain — 0.002

Steel Plates

- Material type — Plane stress elastic isotropic
- Elastic Modulus — 2.1E+05 MPa
- Size — 200 x 100 mm
- Thickness — 50 mm
- Poisson's Ratio — 0.3

Reinforcement

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

Other specifications

Type of Element	Quadrilateral
Element Size	0.058m
Prescribed Deformation	0.0005m per load step
No. of load steps	50

IV EVALUATION OF STRUCTURAL PERFORMANCE

The structural performance of test specimens was evaluated in terms of following parameters.

1. Load-Deflection Behaviour

The load vs. deflection curve plots are taken from ATENA after post processing and the displacement component along x-axis and the load or applied forces component along y-axis. The deflection is observed at the opposite side of point of application of applied load.

2. Cracking Pattern and Mode of Failure

The general patterns of cracking in all the portal type reinforced concrete specimens were closely observed during the analysis. The crack width before failure, load at first crack, crack width at service load and ultimate load for all the portal type specimens were also critically recorded. The mode of failure can be explosive failure, fracture of rebar, spalling of concrete, crushing of concrete in compression zone or diagonal tension failure.

3. Efficiency

The ultimate moment (M_{UT}) based on ultimate load given by ATENA was compared with the nominal theoretical ultimate moment of resistance of the design section (M_{UC}), the design section being located in the weaker framing member of the specimen. The value (M_{UT} / M_{UC}) x 100 is a measure of the percentage efficiency of the joint. This value must be greater than or at least equal to 100 % in order that the joint may be as strong as the weaker cross section framing into it.

Hence, Efficiency 'η' $= \frac{M_{UT}}{M_{UC}} \times 100$

Where M_{UT} = Ultimate moment based on ultimate load given by ATENA

M_{UC} = Nominal theoretical ultimate moment of resistance of the design section.

V CONCLUSIONS

The conclusions are drawn based on the analytical study carried out on behavior of RC framed beam-column corner joints subjected to loads that tend to impart opening moment to the corner joint. Four frames with different reinforcement detailing arrangement were analyzed using ATENA 2D software. Four detailing types that was analyzed were conventional L-type detailing arrangement (SP1), inverted U-type detailing with diagonal steel at corner (SP2), inverted L-type detailing with splay steel (SP3) and overlapping U-stirrups type detailing (SP4). The grade of concrete (M30), grade of steel (Fe415), percentage of tension steel (0.76%), spacing of shear reinforcement(100mm) and percentage of compression reinforcement (50% of main steel) was kept same for all the specimens. After that the effect of different sizes of chamfer at reentrant corner i.e. 25mm, 50mm and 75mm; the effect of different percentage of tension steel i.e. 0.76%, 0.96%, 1.16%; effect of different percentage of compression steel i.e. 50%, 75% and 100% of tension steel; effect of different spacing of shear reinforcement i.e. 75mm, 100mm, 125mm; effect of different percentage of splay steel i.e. 50%,75% and 100% of tension steel; effect of different grades of concrete i.e. M20, M30 and M40; and effect of different percentage of grade of steel i.e. Fe250, Fe415 and Fe500 were observed on specimen SP3.

The following conclusions can be drawn on the behavior of RC framed corner joints subjected to loads that imparts opening bending moments:-

a) The structural response of frame corners subjected to opening bending moment could be faithfully captured to a significant degree of accuracy with the use of non linear finite element analysis techniques.

b) The structural performance of inverted L-type detailing with splay steel (SP3) was better in terms of ultimate load, joint efficiency and crack widths.

c) The ultimate load sustained by specimens SP1, SP2, SP3 AND SP4 was 5.15KN, 8.65KN, 12.15 KN and 10.38KN respectively.

d) The joint efficiency exhibited by specimens SP1, SP2, SP3 and SP4 was 46.17%, 77.54%, 108.9% and 93.05% respectively.

e) The crack width at service load level was observed to be least for specimen SP3. The crack widths at service load of 0.351mm, 0.0.211mm and 0.330mm were recorded for specimens SP1, SP2 and SP4 respectively, where as for specimen SP3 the crack width was recorded as 0.195mm

f) Increase in percentage of tension steel resulted in decrease in efficiency of joint. The efficiency of joint decreased from 108.9% to 99.07% when the percentage of tension steel was increased from 0.76% to 1.16%.

g) The decrease in spacing of shear reinforcement resulted in improvement in performance characteristics of the joint measured in terms of ultimate load, joint efficiency and maximum crack width. The ultimate load and joint efficiency increased from 11.75 kN to 12.42 kN and 105.33% to 111.33% respectively when the spacing of shear reinforcement was decreased from 125mm to 75mm.

h) The increase in percentage of splay steel in the joint resulted in improvement in all the performance characteristics of the joint. However, the improvement due to splay steel beyond 50% is not significant.

i) The increase in grade of steel resulted in improvement of the structural performance quantified in terms of ultimate load and crack width but joint efficiency values decreases. However, the ductility values decreases with increase in grade of steel. This behavior is due to better ductility characteristics of mild steel.

j) There is insignificant effect of compression reinforcement on the ultimate load carrying capacity of the specimen. However, an improvement in ductility was observed which is attributed to the confining action of compression steel provided in form of continuous U-bars.

k) There is insignificant effect of size of chamfer on the ultimate load carrying capacity of the specimen. However, it is observed that specimen with chamfer size 25mm has more ductility and as the chamfer size is increased, ductility of specimen decreases.

l) The increase in the grade of concrete resulted in the improvement of the structural performance quantified in terms of ultimate load, crack width and ductility.

VI RECOMMENDATIONS

From a perusal of the performance of the detailing systems under investigation it is recommended that the detailing system in the specimen SP3 is more suitable for reinforced concrete corners to encounter positive moments. By incorporating inverted L-Type reinforcement with splay steel in the corner, the improvement in corner efficiency and stiffness were obtained. Inverted L-Type detailing resulted in confining action of the concrete core as when opening moment is applied to the structure, reinforcement tends to close inside the joint which results in confining action of concrete core. Moreover splay steel at the re-entrant corner helps in arresting the cracks that emerge at the re-entrant corner which prolongs the failure of the joint as it has been seen that cracks start to develop at re-entrant corners initially when opening moment is applied on the joint.

REFERENCES

1. Swann R.A., 1968, Flexural Strength of Corners of Reinforced Concrete Portal Frames, Technical Report TRA 434, Cement and Concrete Association, London.
2. Mayfield B., Kong F.K. and Bennison A., 1972, Strength and Stiffness of Lightweight Concrete Corners, ACI Journal, Vol. 69, pp 420-427.
3. Balint P.S. & Taylor H.P.J., 1972, Reinforcement Detailing of Frame corner Joints with particular Reference to Opening Corners, Technical Report 42.462, Cement and Concrete Association, London, pp 1-16.
4. Nilsson I.H.E., 1973, Reinforced Concrete Corners and Joints Subjected to Bending Moment-Design of Corners and joints in frame Structures, Document No.D7-1973, National Swedish Institute for Building Research, Stockholm.
5. Taylor H.P.J., 1974, the Behavior of In-Situ Concrete Beam-Column Joints, Technical Report 42.492, Cement and Concrete Association, London, pp 1-32.
6. Park R. & Paulay T., 1975, Reinforced Concrete Structures, John Wiley & Sons Publishers, New York.
7. Skettrup E., Strabo J., Andresen N. H. & Nielsson T. B., 1984, Concrete Frame Corners, American Concrete Institute Journal,Vol. 81, pp 587-593.
8. Jackson N., 1995, Design of Reinforced Concrete Opening Corners, The Structural Engineer Journal, Vol. 73, pp 209-213.
9. Johansson M., 2000, Non Linear Finite-Element Analyses of Concrete Frame Corners, Structural Engineering Journal, Vol. 126, pp 190-199.
10. Dhar V.N. & Singh R.P., 2004, Chamfering and Reinforcement Detailing in Reinforced Concrete Corner Subjected to Opening Moment, IE (I) Journal-CV, Vol. 84, pp 244-251.
11. Uma S. R. & Jain S. K., 2006, Seismic Design of Beam-Column Joints in RC Moment Resisting Frames – Review of Codes, Technical Report, Structural Engineering and Mechanics, Vol. 23, pp 579-597.
12. Ramadan M. A., Ahmed M. M., Abdel-Mageed M. A., & Megahid A. A, 2011, Performance of External Reinforced Concrete Beam-Column Joints made of High Strength Concrete, Journal of Engineering Sciences, Assiut University, Vol. 39, pp 485-496.
13. Harish R, Nambiyanna B, Prabhakara R., 2015, Analytical Investigation on External Beam-Column Joint Using ANSYS by varying the diameter of the longitudinal reinforcement in beam, Int. Journal of Engineering Research and Applications, Vol. 5, pp 01-05.
14. Tran M. T., 2016, Influence Factors for the Shear Strength of Exterior and Interior Reinforced Concrete Beam-Column Joints, Proceedings of the Sustainable Development of Civil, Urban and Transportation Engineering Conference, Procedia Engineering,Vol. 142, pp 63-70.
15. Venkatesan B., Ilangovan R., Jayabalan P., Mahendran N. & Sakthieswaran N., 2016, Finite Element Analysis (FEA) for the Beam-Column Joint Subjected to Cyclic Loading Was Performed Using ANSYS, Circuits and Systems Journal, Vol. 7, pp 1581-1597.
16. SP 34:1987, "Handbook on Concrete Reinforcement and Detailing", Bureau of Indian Standards, New Delhi.
17. IS 13920-2016, "Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces ", Bureau of Indian Standards, New Delhi.
18. IS: 456-2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi.