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A Review of the Effect of Corner Loads

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Abstract: In numerous structures , continuity between two adjacent members necessary even though the members meet angle. The joint formed from this meeting usually refers to the "corner". The term "corner" in this investigation is used to describe a corner joint formed by the joining; at 90 degree, of the ends of two flexural members. The terms "opening" and "closing" the corner are used to describe the increase and decrease of this right angle, respectively. Concrete corners are found in wide variety of structures such as retaining wall, bridges and portal frame buildings. They are also common in the field of hydraulic structures, such as reservoirs, tanks, flumes and culverts. Design of the straight members which intersect to form the corner is part of the basic training of the engineer.

Keywords: concrete corner ; corner joint ; opening corner ; closing corner)

1. INTRODUCTION

The principles of detailing and the structural behavior of simple structural members such as beams and columns are well established. on the other hand the detailing, strength and behavior of corner joints, especially those subjected to opening moments as in the case of cantilever retaining walls bridge abutments, channels, rectangular liquid retaining structures and portal frames, have not been conclusively determined. Reinforcement detailing at corner plays a primary role in influencing structural behavior of the joint more so in the case of opening joint or corners. The reinforcement details must be such that their layout and fabrication are easy and the structural members should satisfy the fundamental requirements of strength expressed in terms of joint efficiency, controlled cracking, ductility and last but not the least, ease and simplicity of construction**.**

2. CONCRETE CORNER STUDIES

2.1. CORNER SUBJECTED TO MOMENT TENDING TO OPEN THE ANGLE

Few investigators studied the case where the moment open the angle of concrete corner, there resultant for the information about the subject is not so much.

The earliest of these studies was undertaken by George in 1936 [(1)] ,the purpose of his study was to determine the rigidity and strength of different sized concrete corners reinforced by loops and other reinforcement and to find the best reinforcement design. Seven series of specimens with two different steel strengths were used, (298 MPa) and(504 MPa). All specimens has plain bars as reinforcement and were subjected to moment loading in the corner area. It is obvious from the size of his specimens that these were not prototypes, but scaled down models of full sized joints..

It was concluded that, the failure could not be caused mainly by the horizontal cracks, but rather by the cracks in the plane of the loop and it is seen that the cracks follow the main reinforcement close to the point of failure.

In 1939 , Gumensky (2) tested five different reinforcement patterns in this investigation. The loading in these tests gave tension and shear in addition to bending at the corner. Dimensions of the test specimens were chosen to give the same relation between direct tension and bending moment as would exist in (3 m) square conduit under hydrostatic load.

Although the mode of failure of the different corners was not indicated in these tests, the investigator thought that the ultimate strength is determined by the total strength of steel to concrete anchorage.

In 1943, Posey and Orville (3) tested thirly three corners having different arrangements of reinforcement, but the same outside dimensions and the same concrete mix design. This test series obviously was intended as a study of scaled down models of commonly encountered rigid joints in hydraulic structures such as bench flumes, tanks, and square conduits. The loading arrangement in this study also caused a combination of bending, tension, and shear in the corner region.

In 1954, Morrow (4) tested thirty one knee frames for the purpose of determining the shear strength of reinforced concrete members subjected to combination of moment, shear and axial forces. All knee frames were of rectangular cross section, and were reinforced in tension only. Each frame had two equally long legs, but the length of the legs varied from specimen to specimen, thus the ratio of axial force to shear remained constant throughout the tests, but the ratio of moment to shear was a variable. All frames were loaded along the line connecting the ends of the two legs; and they were subjected to static loading applied in several increments to failure.

In 1961, Berge (5) tested twelve specimens of thin concrete corner. The purpose of this test was to study the behavior of different reinforcements in the critical section of a corner for thin structure such as a folded plate or shell and to determine what percentage of the adjoining beam strength could be developed. The test specimen chosen for these tests was an actual prototype of a typical thin section structure. The loading condition used in this test is a pure ending and not of interaction of axial and bending effect. In order to limit the number of variables, one concrete mix design and the same number and size of reinforcing bars were used in all corners, the only variation of the reinforcement being in the anchorage of the individual bars. The conclusions show that all the specimens in this test series have generally the same mode of failure and it was noted that the hooks of the stirrup have Straightened out some during the test.

In 1967, conner and kaar (6) gave in this report result of structural tests on components of a precast reinforced concrete gabled frame loads simulating those in a complete frame applied to each component. The tests indicated that component having a sharp radius of bend in the main tensile reinforcement did not perform at both service and ultimate load is reported.

In 1968, Beaufait et al. (7) studied the behavior of reinforced concrete, pin supported portal frame subjected to sway forces. The program involved the testing of seven frames: four frames were subjected to cyclic sway forces and three frames were loaded to failure with a single sway force. The objectives of this investigation were to study the influence of the placement of the reinforcing steel at the joints on the ultimate load capacity of the structure and to examine the effects of cyclic loading on the behavior of a reinforced concrete frame.

In 1969, Swann (8) tested eighteen reinforced concrete specimens representing a right angle bend of a portal frame. Thirteen of the specimens were tested with the bending moment opening the angle and the remaining five were tested with the bending moment closing the angle. The loading condition was the corner hinged in leg and rolled in the other leg.

In 1971, Nilsson (9) discussed the results of an another investigator (Mayfield 1971 (10)) and twelve different details of corner reinforcement were tested attempted to improve the comer reinforcement detail by using stirrup where that led to some increase in the flexural strength of the joint, but the details tested did not develop the full flexural strength for the adjoining members.

In 1971, Mayfield et al. (10) tested forty eight reinforced concrete corners. The effects of twelve types of reinforcement details of ultimate strength, stiffness, and cracking were studied. A new shape of concrete corner specimen was used in this investigation to open the corner. The load was applied to the soffit of the horizontal leg of the test specimen and to close the corner was applied to the top. It was found that, corner details commonly used in practice are not as efficient as other less conventional but simpler details .

It was decided according to this review that when the applied load is opening the corner, reinforcement, detailing has important effect on strength, though its effects on stiffness and cracking are less obvious. Also, none of details tested developed the full flexural strength of bending members.

In 1971, Mayfield et al. (11) presented results of tests on fifty four reinforced concrete corners subjected to loads opening the corner (i.e. producing tension on the inside). The effects of twenty eight types of reinforcement's details on ultimate flexural strength, stiffness, and cracking were studied. The loading condition and the device were the same used 1971. It was found that, the used of two sets of mutually perpendicular diagonal reinforcement is a promising method for developing flexural strength, reducing crack widths, and producing reasonably ductile behavior.

In 1972, Balint and Taylor (12) tested twenty seven specimens: four of which were to complete the information on the details described earlier and the rest were a mixture of two detail types with the main steel passing through the corner to the compression face. They showed two new methods of detail opening corners, were developed and results of tests on these corners. The loading condition in this investigation is by bolting the specimens on the laboratory floor and loading it by pushing up or down on the free end. Also, strong recommendations were given for the design of opening corners where it was found that the ultimate strength of the corner at test is high if the corner has efficiency of (70 %) and over.

In 1977, Strabo et al. (13) tested four concrete frame corners subjected to an opening bending moment; the purpose of this test was to investigate the efficiency of a common reinforcement arrangement with high percentages of reinforcement.

This investigation showed a Load Carrying capacity down to only about (50) percent of the ultimate bending moment of the adjacent beams.

In 1980, Strabo et al. (14) tested five concrete frame comers with modified reinforcement arrangements subjected to an opening bending moment. The purpose of this investigation is attempted to improve the efficiency of the concrete frame corners tested earlier. The loading and the test device are the same used in the earlier investigation (1977). It was concluded that the new arrangement reinforcement gives a carrying capacity of the corners of the same magnitude as for the adjacent beams.

In 1982, Strabo et al. (15) tested eight concrete frame corners and used in this investigation three new arrangements of reinforcement detail. The purpose of this investigation is trying more new details to choose the detail with high efficiency.

In 1984, Strabo et al. (16) tested seventeen reinforced concrete frame corners subjected to an opening bending moment (corresponding to tensile stresses in the reentrant corner). Three fundamentally different reinforcement arrangements were tested. For high percentage of reinforcement, the Load Carrying Capacity of a common reinforcement arrangement proved to be low. Modified reinforcement arrangements resulted in corners that could transfer the same bending moments as the adjacent beams, even with balanced reinforcement. The significance of this

investigation is that tests on reinforced concrete frame corners subjected to an opening bending moment have shown that the Load Carrying Capacity of a common

reinforcement arrangement prove to be low for high percentages of reinforcement. Also, modified reinforcement arrangements resulted in corners that could transfer the same bending moment,as the adjacent beam.

In 2001, Chao – Kuang ku (17) studied numerically the behavior and response of reinforcing bars in fiber reinforced concrete (FRC) knee joints under impulsive opening loads with a hybrid, finite element (FE), finite difference (FD) approach which were developed for this purpose. Nonlinear material models were employed. The effects of adding fibers to the joints, and the location of diagonal reinforcement were studied in this research. The numerical approach is briefly described, and

findings are presented. Twenty four cases with different diagonal bar cross sections and location were investigated and the effects from the addition of (1%) steel fibers were also studied in these cases

In 2003, Singh and Kaushik (18) investigated four different detailing systems for concrete corner modified by steel fiber in this test. The parameters of this investigation were: strength measured in terms of joint efficiency, ductility, crack control and ease of reinforcement layout and fabrication facilitating effective placement of concrete in the member. It has been found that none of the detailing systems investigated satisfied all the four parameters. Also a substantial increase in post cracking tensile strength, ductility and crack control can be achieved by adding steel fibers to the concrete. Therefore, the four detailing systems investigated previously were tested afresh with 50 mm long crimped-type flat steel fibers at a lower bound (0.75 %) volume fraction. The tests revealed at this volume fraction (15% - 45%) improvement in efficiency and a significant enhancement of ductility and toughness in almost all specimens. In extension of the scope of the investigation the next volume fractions investigated were (1.25%,1.50% and 1.75%)

In 2004, Dhar and Singh (19) tested four reinforcement detailing of reinforced concrete corner joints under opening moments, and effort has been made to investigate the effect of chamfer as well as reinforcement detailing on the strength and behavior of opening corners. A linear Finite Element Method (FEM) analysis supported by experimental program has been used for the investigation. A simple strut and tie model (STM) for opening corner has been proposed to decide the area of reinforcement and its layout within the corner tone. Also, the amount of reinforcement and chamfer to be provided in opening corners, including the case of liquid retaining structures, have been suggested. It was found that corner joint subjected to opening moment, as per (FEM) analysis, overall stress level decreases with the increase in chamfer size, the proposed simple STM suggests reinforcement detailing for opening corner with inclined steel across the diagonal with the theoretical area of inclined bar as 0.896 times the area of main steel. Also, the theoretical requirement of loop steel area is 0.731 times the main steel area. The nature of load deflection curves for all the four samples is similar. Ultimate load carrying capacities, as observed in the tests, increase with the increase in chamfer size.

In 2005, Shiohara and Shin (20) applied a new theory for joint shear failure of reinforced concrete beam-column joints on knee joint and interior joint. The theory considers four diagonal flexural critical sections in beam-column joints associated with joint shear deformation observed in tests, and called J-mode deformation .

The equilibrium equations are used to derive relations of forces such as column shear, beam shear, column and axial force to the magnitude of stress resultants in steel and concrete on the critical sections. The results are combined with failure criteria for material such as, concrete, steel and bond stress, to derive joint shear capacities. This investigation focuses on demonstration of the theory with numerical calculation. It is revealed that the theory is universally applicable to beam-column joints with different geometries such as interior, exterior and knee joints.

In 2005, Maclean and Shattarat (21) tested seven knee joint specimens under simulated seismic loading. The primary objective of the study is to define the vulnerabilities of outrigger bents under seismic in plane and out of plane loading and develop appropriate retrofit measures for outrigger knee joints that address the identified deficiencies

In 2006, Shiohara and Shinl (22) tested fifty six specimens to find ultimate strengths and failure modes and also to validity a new theory. The quadruple flexural resistance is a novel concept providing a unified view and explains the mechanics and failure modes, applicable to reinforced concrete interior, exterior as well as knee joint in a consistent way. The performance of knee joints is known to be affected by geometry, dimension, material strength as well as anchorage detailing of longitudinal bars. So, the supplemental criteria for eliminating knee joint with poor anchorage detailing are incorporated into the new theory by considering local failure of anchorage within knee joints.

In 2008, Uma and Prasad (23) present a review of the postulated theories associated with the behavior of joints. They also discussed about the effect of seismic actions on various types of joints and highlight the critical parameters that affect joint performance with special reference to bond and shear transfer.

2.2. CORNER SUBJECTED TO MOMENT TENDING TO CLOSE THE ANGLE

For many investigations studied the case where load closing the concrete corner proved practically and that all the specimens had adequate strength, and the efficiency exceeded unity; hence for this type of loading, the detailing of the corner did not seem to be important (10) . Some investigations are mentioned below:

In 1968, Kemp and Mukherjee (24) tested four specimens. The purpose of this research was to investigate strength and rotational capacity of right angle rectangular reinforced concrete knee joints, with particular reference to the influence of the percentage of longitudinal reinforcement on the behavior of such joints.

In 1969, Swann (8) tested five reinforced concrete specimens representing a right angle bend of a portal frame and the five tested with the bending moment closing the angle of the concrete corner. The detailing arrangements which were used are compared and discussed with regard to strength, flexibility and cracking. He studied the effect of the details on the efficiency.

ln 1971, Mayfietd et al. (10) tested fifteen reinforced concrete corner subjected to moment closing the angle. The effects of twelve types of reinforcement details on ultimate strength, stiffness and cracking were studied, and a new shape of concrete corner was used. The new shape is two corners connected in end of the leg. It was found that some corner details commonly used in practice are not as efficient as other less conventional but simpler details.

In 1981, Al-Khafaji (25) tested twenty six corners under loads tending to close the angle. Every corner was tested under a combination of bending moment and axial and shears loads. Testing of the corners was carried out in a horizontal position. Sixteen of the total number of the tests were carried out under incrementally loading of failure with a constant range of load between 10 and 75 %Pu,. In each case of loading, the tension bar size and percentage of area were variable from corner to corner. The effect of the tension bar size, percentage of area, type of detail on the crack loading, crack pattern, crack type, crack width and corner strength were studied.

In 2000, Johansson (26) showed a new design proposal in concrete frame corners subjected to load to close the angle by using full-scale tests in combination with nonlinear Finite Element analyses. The parameters studied in this investigation were the reinforcement detailing, the reinforcement ratio, the effects of the weakness of the construction joint, and the interaction between reinforcement and concrete. The tests and the Finite Element analyses conducted have shown that the conventional and the new reinforcement detailing for practical purposes are equivalent for a frame corner structure with a low amount of reinforcement.

3. CONCLUTION

From this review, it can be said that studies are required for the estimation of the corner ultimate strength and corner efficiency. The conventional details used in these investigations do not produce the full ultimate strength and in most of these details, the efficiency is below (100%).

4. REFERENCES

[1] George W. "The rigidity and strength of reinforced concrete corners", Report Prepared for the Royal Technical University in Stockholm, (July 1936).

[2] Gumensky . D.B. concrete corner in tension .engineering new-record,vol.123 (sep. 1939), 411 P.

[3] Posey C. J. and Orville K. "reinforced concrete corners" ACI journal, Vol.15, (sep. 1943), pp. 41-52

[4] Morrow, J.D. "strength of reinforced concrete knee frames without web reinforcement " M.Sc. Thesis, university of Illinois, U.S.A. , 1954, 74 P.

[5] Berge H.J. "Behavior of various types of reinforcement in concrete corners subjected ti pure bending causing tension on the inside" M.Sc. Thesis, university of Colorado, England, 1963, 96 p

[6] Conner H.W. and Kaar H. "precast rigid frame building-component tests" Journal of the PCA Research and Development Laboratories, No.2, (sep. 1967) pp 43-55.

[7] Beaufait F. and Williams R. R. "Experimental study of reinforced concrete frames subjected to alternating sway forces" ACI Journal, vol.65, (nov. 1968), pp.980-984.

[8] Swann R.A. "Flexural strength of corners of reinforced concrete portal frames" Cement and Concrete Association, Technical Report, TRA 434, London, (Nov. 1969), 14 p.

[9] Nilsson B. "Corner joint details in structural highweight concrete", ACI Journal, (Nov. 1971), pp.873-875.

[10] Mayfield B., Kong F. K., Bennison A. and Davies J. C. D. T., "Corner joint details in structural lightweight concrete" ACI Journal, (May. 1971), Vol.68, No.37, pp. 366-371.

[11] Mayfield B., Kong F. K., Bennison A. "Strength and stiffness of lightweight concrete corners" ACI Journal, (July 1972), Vol.69, No.38, pp. 420-427.

[12] Balint P.S. and Taylor H.P.J. "Reinforcement detailing of frame corner joints with particular reference to opening corners" Cement and Concrete Association, Technical Report, TRA 434, London, (Feb.1972), 14 p.

[13] Strabo H., Andersen N.H. and Nilsen T.B. "Concrete frame corners" ACI Journal, (May 1977), Vol.30, No.5, pp. 87-93.

[14] Strabo H., Andersen N.H. and Nilsen T.B. "Concrete frame corners" ACI Journal, (Nov.-Des. 1980), Vol.69, No.1, pp.14-19.

[15] Strabo H., Andersen N.H. and Nilsen T.B. "Concrete frame corners" ACI Journal, (July 1982), Vol.81, No.4, pp.310-317.

[16] Strabo J., Andersen N.H. and Nielsen T.B. "Concrete frame corners" ACI Journal, (Nov.-Des.1984), Vol.81, No.4, pp.587-593.

[17] Chao-Kuang Ku. "Numerical simulation of fiber reinforcement concrete knee-joints under impulsive opening loads" Report Prepared for the Kao Yuan Institute of Technology, Taiwan 2001.

[18] Singh B. and Kaushik S.K. "Investigation on fiber reinforced concrete opening corners" IE (I) Journal-CV, Vol.84, (Nov.2003), pp.201-209.

[19] Dhar V.N. and Singh P.K. "Chamfering and reinforcement detailing in reinforcement concrete corner subjected to opening moment" IE (I) Journal-CV, Vol.84, (Feb. 2004), pp.244-251.

[20] Shiohara H.and Shin Y. "New model for joint shear failure of R/C knee joints" Report prepared for theTokyo University, Japan, (July 2005), 15 p.

[21] Maclean D.I. and Shattarat N. K. "Seismic behavior and retrofit of bridge knee joints systems" Research Project to Washington State University, ()July 2005), 82 p.

[22] Shiohara H.and Shin Y. "Analysis of reinforced concrete knee joints based on quadruple flexural resistance" Proceedings of the 8th U.S. National Conference on Earthquake Engineering, April 18-22, 2006, San Francisco, California, U.S.A, 10 p.

[23] Uma S.R. and Prasad A.M. "Seismic behavior of beam column joints in reinforced concrete moment resisting frame" Research Project Produce to Indian Institute of Technology, Madras Chennai, 2008, 29 p.

[24] Kemp E.L. and Mukherjee P.R. "Inelastic behavior of concrete knee joints" The Consulting Engineer, (Oct. 1968), pp.44-49.

[25] AL-Khafaji J. M. N. "The effect of size and percentage of tension on the behavior of reinforced concrete corners under static and repeated loading" Ph.D. Thesis, University of South Ampton, England, (March 1981).

[26] Johansson M. "Nonlinear finite-element analyses of concrete frame corners" Journal of Structural Engineering, Vol.126, No.2, (Feb. 2000), pp.190-198.