Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

A REVIEW ON IMPROVEMENT OF PUNCHING SHEAR FAILURE OF FLAT SLAB

Savan A. Pansuriya[1], Grishma Thaker[2], Anuj Chandiwala[3].

[1]*Civil Engineering Department, Chhotubhai Gopalbhai Patel Institute of Technology,*
[2] *Civil Engineering Department, Chhotubhai Gopalbhai Patel Institute of Technology,*
[3]*Civil Engineering Department, Chhotubhai Gopalbhai Patel Institute of Technology,*

Abstract — *Flat slab construction is among the most efficient methods of construction, enabling a consistent head space to be achieved across the entire floor with the resulting benefits of easier layout of services and reduced overall floor to floor heights. The design of a flat plate structure is generally governed either by serviceability limits on deflection or punching shear strength of the column slab connections. However, the punching shear failure at the slab column junction has to be considered properly in such flat slab. Disregards to this criterion has resulted in several collapses in the past. Using traditional link as punching shear reinforcement is time consuming and expansive. To increase the strength of a column-slab connection, a new type of shear reinforcement, referred to as shear stud, is popular now a days. Therefore, study of the flat slab will be carried out with comparison of different structural parameters. Conclusion will be carried out on improvement of punching shear failure due to shear stud rail.*

Keywords- *Reinforced concrete flat slab, Punching shear, Shear stud rail, column slab connection.*

I. INTRODUCTION

Although the introduction of Reinforced Concrete flat slab floors is a significant advancement in the building technology. From 1910- 1911 slab, beam and girder system reigned supreme but at this time the girder less floors sometimes called as Mushroom slab, known as flat slab were also happening Historically, flat slabs predate both two-way slabs on beams and flat plates, several systems of placing of reinforcement have been developed.

Reinforcement concrete flat slab are being adopted increasingly in several parts of the world due to their aesthetic appearance, as well as economic advantages and speed of construction. In addition, the elimination of beams and girders reduces the overall floor depths of multistory buildings thus creating additional floor space for a given building height. For these reasons, flat plates are widely used for multistory structures such as office buildings and carparks in many countries. In the design of concrete flat slabs, the punching shear strength around the column slab connections always poses a critical analysis problem. Punching shear failure would occur at a load well below the flexural capacity due to the concentration of shear forces. The local and brittle nature of the punching shear failure is in the form of column punching through the slab along a truncated cone caused by diagonal cracking around the column.

If the punching shear is critical, either the slab thickness may be increased or punching shear reinforcement be provided. The first option is expensive and hence punching shear reinforcement is often provided. A number of alternative punching shear reinforcement have been developed and used.

In the recent past, a range of alternative prefabricated punching shear reinforcing system have been developed and many of these have been used in situ concrete buildings. These alternative system have been found to offer saving in time and cost.

Figure 1. Punching shear failure

II. LITERATURE REVIEW

A. Evaluation and enhancing the punching shear resistance of flat slabs using HSC

N. Subramanian; "Evaluation and enhancing the punching shear resistance of flat slabs using HSC". In this paper, the existing design code reviewed for punching shear failure. The Indian code only predict the punching shear resistance of high strength concrete slabs. The use of high strength concrete, with strength exceeding 40 MPa, in reinforced concrete slabs, is becoming popular in India and other countries because the use of high strength concrete improves the punching shear resistance allowing higher forces to be transferred through the column slab connection. In this paper they evaluate of punching shear resistance of flat slabs by help of different design codes of practices are compared with some of the published experimental data.
The shear stud reinforcement is found to provide economic and aesthetic solution. It does not only enhance the shear capacity but also result in flexural failure of the slab and so increasing the ductility of flat slab, which is very important in earthquake prone zones and stress concentration area near column.

B. Behavior of high-strength fibrous concrete slab–column

M.M. Smadi , I.S. Bani Yasin; "Behavior of high-strength fibrous concrete slab–column". This paper is focusing on the behavior and design of interior slab column connections under lateral seismic loading. It also review current design procedure of flat slab and performance based on seismic design. Around ten slab and column connections were tested by different lateral and gravitational loading condition and investigate effect due to steel fibers in concrete near slab column connection.
Compressive strength of concrete is reduced by small margin due to steel fiber. The stiffness reduced for both normal and high-strength concrete slab sample because of steel fiber therefore ductility of slab increased.

Seismic Design Criteria for Slab-Column Connections

Mary Beth D. Hueste, JoAnn Browning, Andres Lepage, and John W. Wallace; "Seismic Design Criteria for Slab-Column Connections". In this paper author focuses on the behavior and design of slab-column connections for both gravity and lateral loading conditions. They reviewed current design procedures, performance-based design approaches, and relevant experimental data. This type of structural system is common in area where seismic risk is in between low to moderate, where it is allowed as a lateral-force-resisting system, but for regions of high seismic risk for gravity systems they provided shear wall with main frames.
Shear reinforcement provide very low shear resistance during earth quake. By using of story drift ratio we can direct compare experimental data to readily available when doing a structural analysis.

C. Punching of flat slabs with in-plane forces.

A. Pinho Ramos, Válter J.G. Lúcio, Paul E. Regan; "Punching of flat slabs with in plane forces". In this study researchers aims to study of flat slab models under punching. Behavior of flat slabs under punching load, in order to accurately calculate the effect of the in-plane forces on the punching resistance of flat slab. The FIP allow to use the same control boundary and almost the same shear resistance for flat slabs without in-plane forces as Eurocode2, but treat the effect of in-plane compression by the addition of the load at decompression of the slab's top surface near a column. This involves factors such as the moments due to prestress, which are not considered in Eurocode2.
Due to in-plane compression there are very little strains at slab top reinforcement and smaller deflections. Fédération Internationale de la Précontrainte provide more accurate results but have the complication of punching force. The strengths of the slabs expected using ACI318 are very low.

D. Flexurally-triggered punching shear failure of reinforced concrete slab–column connections reinforced with headed shear studs arranged in orthogonal and radial layouts.

Thai X. Dam, James K. Wight; "Flexurally-triggered punching shear failure of reinforced concrete slab–column connections reinforced with headed shear studs arranged in orthogonal and radial layouts". In Context to this paper, some tests have indicate that with out radial stud rails there may be chance of shear failure near slab column connections. Study to estimate the effectiveness of these stud layouts in slab column connections and slabs who having comparatively low flexural reinforcement ratios. The principle tensile stresses induced by these shear stresses may cause the development of inclined cracks that spread around the column. As a result of these cracks, an inverted truncated cone surface is created around the column. Punching shear failures happen due to cracking surface develops throughout the whole depth of the slab and splits the slab from the supporting column.
Shear studs are very effective for increasing shear strength of slab column connections. Building Code does not give proper value for the shear strength of slab column connections for slabs who contain shear reinforcement near slab column connection.

E. Structural performance of RC flat slabs connected to steel columns with shear heads.

D.V. Bompa, A.Y. Elghazouli; "Structural performance of RC flat slabs connected to steel columns with shear heads". This paper, Help to evaluate the behavior of the specimens and the ultimate punching shear failure near the region of slab- column perimeter. Shear head helps to increase punching shear resistance of flat slab up to 75%. Other complex shear-head systems were developed in recent year for flat slabs, it also comprising composite cruciform systems consisting of vertical plates behave as shear heads and provided with welded studs, fan-shaped systems made of wide tee pieces, and the Geilinger mushroom-head made of vertical plates bolted to the flanges of the column and surrounded by U-shaped edge beams. Author did some test on different type of specimens of typical cruciform systems having various arrangements of steel beams, with a closed-type system provided with edge beams.
They analyze behavior of hybrid members consisting of reinforced concrete flat slabs, with and without shear reinforcement, connected to steel columns by fully integrated shear-heads.

F. Punching-shear behavior of slabs with bar truss shear reinforcement on rectangular columns.

Thai X. Dam, James K. Wight; "Punching-shear behavior of slabs with bar truss shear reinforcement on rectangular columns". In this study they were used Column cover near slab column joints and prefabricated bar trusses were placed at the periphery of the top of the column. Rectangular columns and column capitals are effective because it helps to decrease clear distance between column, thereby reducing negative design moments near the columns. The corners of the rectangular column and column capital were smooth-edged to reduce shear stress concentration near corners of the critical perimeter for shear.
The bar truss helps to increase punching-shear strength of the slabs. The diagonal bar trusses were most effective because they contribute more to shear resistance by undergoing significant strains.

G. Punching of flat slabs supported on rectangular columns.

J. Sagaseta, L. Tassinari, M. Fernández Ruiz, A. Muttoni; "Punching of flat slabs supported on rectangular columns". Investigates the structural behavior of RC flat slabs supported on rectangular interior columns and the effect of different loading conditions on their punching shear strength. The rectangular column have less punching shear strength of slabs compare to square columns with a similar length of the control perimeter, because it have more shear force concentration along the perimeter. There are actual distribution of shear forces along the control perimeter around the column. Effect of the loading conditions and bending moments cause the critical shear crack which will lead punching failure.
The reduction in punching strength due to the concentration of shear forces near the corners of rectangular columns and square columns which depends on the bending deflections of the slab and column geometry. The experiment in that paper show that the failure mode, ultimate strength and rotation capacity were highly affected by the alignment of the column with respect to the main spanning.

III. CONCLUSION

From the above literature we conclude that

- The old flat slab were not designed considering the punching shear effect.
- In the modern times it is important to study punching shear of flat slab cause by earth quake or load concentration.
- It will be helpful to use shear stud rail, which can improve punching shear failure and also make structure more economical.

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