Comparative Study of Flat Slab with and Without Punching Shear Reinforcement by using Shear Stud Rails

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***Abstract**- Deal for choosing flat slabs includes a minimum depth solution, speed of construction, flexibility in the plan layout, a flat soffit, scope and space for use of flying forms. During the earthquake, unbalanced moments can produce significant shear stresses that causes slab column connections to brittle punching shear failure. Flat slabs are catastrophic to punching shear because of absence of beam. For enhancing the effect of punching shear either we have to increase the thickness of slab or optimizing the thickness by designing punching shear reinforcement. If we increase the depth of slab then it will affect on the cost of the project. So many foreign researchers have performed the experimental and design work on the punching shear reinforcement and also many international codes are updated with detailed information.*

In this study G+4 storey flat slab was designed without drop and with drop, with different panel size (5m x 5m , 6m x 6m , 7m x 7m) and with different grade of concrete (M25,M30). We have mainly focused on the optimization of flat slab thickness by designing shear stud rail as punching shear reinforcement. G+4 storey office building is designed with gravity loads and lateral loads in the ETABS software and then each storey is transferred in SAFE software which gives final output of shear stud rail design. At the time of study, different codes like ACI – 318 , IS : 456 – 2000 , IS : 1893 - 2002 was referred.

Key words - Flat slabs, punching shear, shear stud rail, ETABS software, SAFE software, ACI-318 , IS 456.

1. Introduction

In a developing country like India , the modern Era demands some extraordinary architectural design of structure which consist flat soffit with wide column free area which can be provided by provision of a long span structure such as a Flat slab.Flat slab is a two way reinforced concrete slab in which the slab directly rest on the column without provision of beam. Thus through utilization of maximum available space flat slab brings economy to overall construction. Due to elimination of the beam in flat slab, the lateral load transfers directly from slab to column during action of seismic forces, resulting in punching failure of the slab and slab would collapse. Thus punching shear failure at the critical slab – column junction is the main regulating parameter in case of the flat slab which need to be enhanced against the seismic effects. For increasing the strength of slab against the punching effect, the utilization of various punching shear reinforcement such as a shear stud rail, shear stirrups, shear heads, shear links etc. are applicable. Actually a lot of research works are going on this shear reinforcement and it has been noted that shear stud rail as a punching shear reinforcement has been proved most effective against the punching shear failure. Also our standard codal provisions IS 456 : 2000 have some lacking points as it gives only design of shear stirrups as a punching shear reinforcement. Hence we have to collaborate with some international codes such as ACI – 318 which gives the detailed information of shear stud rail as punching reinforcement.

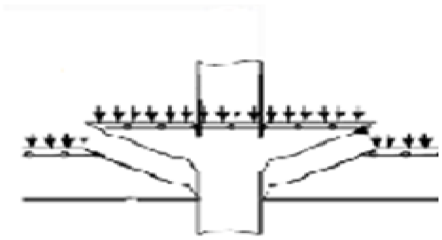
Objectives of study area

- To increase the efficiency of flat slab by reduction in thickness of the slab and by enhancing its punching shear strength. Our main focus is to carry out the comparative study on slab thickness with punching shear reinforcement and without punching shear reinforcement.

- Provision of drop and/or column head results in ineffective architectural view. But eliminating drop and/or column head results in failure of slabs in vicinity of critical slab column junction. But the lateral load carrying capacity of the flat slab is questionable and for that reason requirement of shear reinforcement arises.

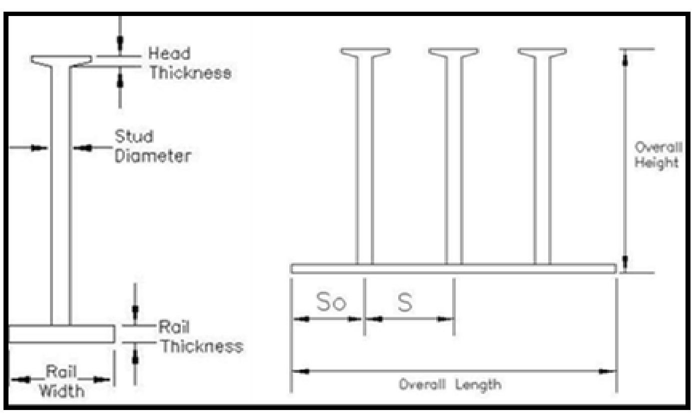
- The provision of **shear stud rail** as a punching shear reinforcement is also ain concentration.

Punching shear Failure



Due to load transmission directly from slab to supporting column, the portion adjacent to the column is subjected to the shear stress which leads to the development of the crack. This crack is generate from bottom and propagates towards the top of slab leading to the ultimate failure. Due to such higher concentration of shear forces and unbalanced moments there may be chances that slab may get punched into the column. This punching failure occurs at the distance d/2 from the face of the column where d is effective depth of column. When the drop or column capital is provided then it consider from the face of drop or capital.

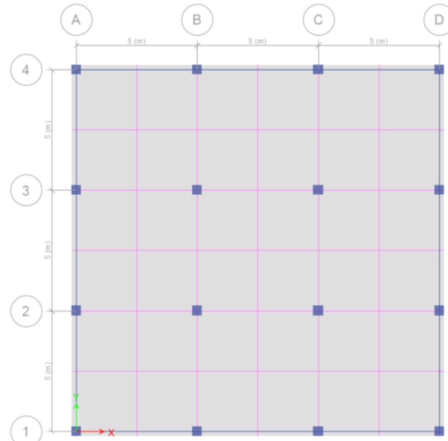
Shear stud rail



The shear stud rails are the shear reinforcements, available in market, such that they can be installed directly, hence it is economical. It consists of two components shear studs and shear rails. The studs are fabricated from plain or deformed reinforcement bars. Studs are having enlarged head welded to one or both ends. Shear stud rails can be get as a output value from the SAFE software.

Design Procedure

3D analysis of flat slab for gravity loading and lateral loading is carried out using software ETABS (Extended 3D Analysis of Building Systems).This software is used for modeling of flat slab. Gravity and lateral load effect analyzed in ETABS software for the flat slab is then transferred to the SAFE (Slab Analysis by the Finite Element Method) software for analyzing punching shear effect along with lateral loads.



Four storey building consisting flat slab with periphery beams is prepared in the ETABS software first.
The prepared model is then analyzed in ETABS by assigning the gravity and lateral loads.
Model is then exported to the SAFE software.
Finally SAFE software gives the shear stud rail design as output.

Selection criteria of slab thickness

Selection criteria of slab thickness are based on punching shear stress value. As per IS 456, when the shear stress value exceeds the value of $V_c = 0.25\sqrt{f_{ck}}$, but is less than 1.5 times V_c shear reinforcement shall be provided. If the shear stress is more than 1.5 V_c, the flat slab shall be redesigned.

For example,

M25 Grade of concrete,

Concrete shear stress $= 0.25\sqrt{f_{ck}} = 0.25\sqrt{25}$
$= 1.25$ N/mm^2

Permissible shear stress = 1.5x1.25
$= 1.875$ N/mm^2

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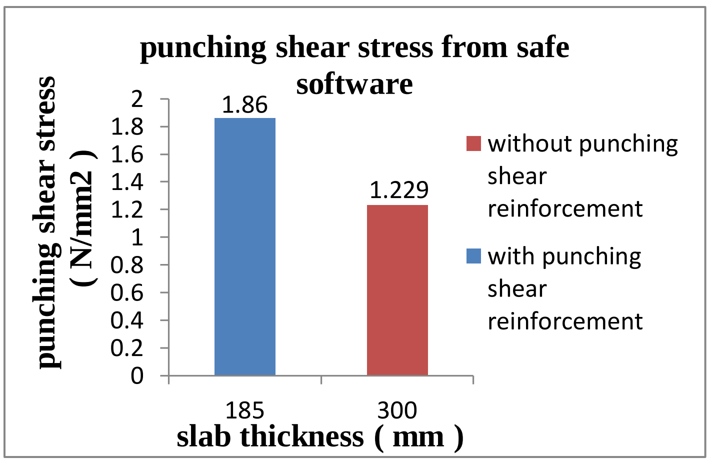
Result Analysis For M25 grade concrete :

1. **5m x 5m panel wherein slab thickness vary from 185 to 300 mm**

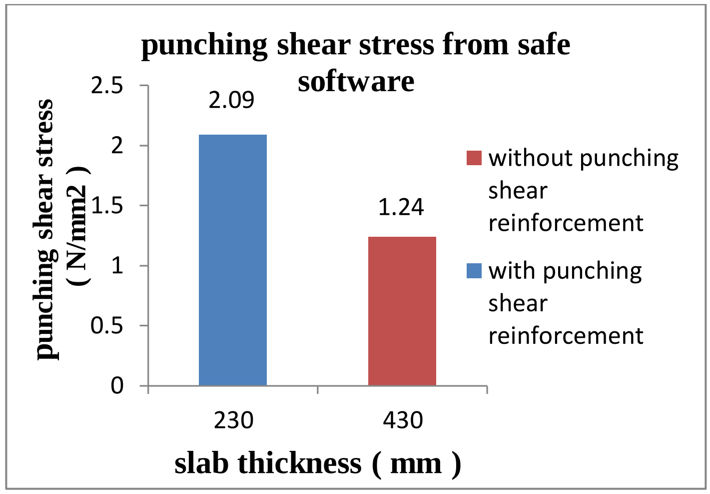
SLAB THICKNESS (mm)	PUNCHING SHEAR STRESS (N/mm^2)	SHEAR STUD RAIL
Min = 185	1.86	11 X 8 – 10d @100
Max = 300	1.229	Safe (punching reinforcement design is not required)



For minimum slab thickness 185 mm the punching shear stress will be maximum. If we provide slab with punching shear reinforcement than slab thickness can be reduced by 38.33 % as compared to slab without shear reinforcement.

6m x 6m panel wherein slab thickness vary from 230 to 430 mm

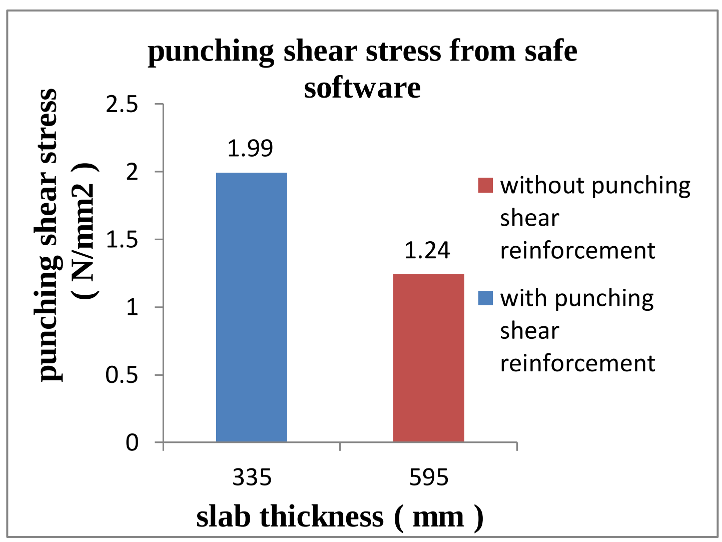
SLAB THICKNESS	PUNCHING SHEAR STRESS	SHEAR STUD RAIL
Min =230	2.09	15 X 10 – 10d @100
Max = 430	1.24	Safe (punching reinf. design is not required)



For minimum slab thickness 230 mm the punching shear stress will be maximum. If we provide slab with punching shear reinforcement than slab thickness can be reduced by 46.51 % as compared to slab without shear reinforcement.

7m x 7m panel wherein slab thickness vary from 335 to 595 mm

SLAB THICKNESS (mm)	PUNCHING SHEAR STRESS (N/mm2)	SHEAR STUD RAIL
Min = 335	1.99	17 X 13 – 10d @100
Max = 595	1.24	Safe (punching reinf. design is not required)



For minimum slab thickness 335 mm the punching shear stress will be maximum. If we provide slab with punching shear reinforcement than slab thickness can be reduced by 43.69 % as compared to slab without shear reinforcement.

Conclusion

- The Results shows that when thickness is increasing in slab without drop and also with the drop, punching shear stress is reduced.
- It can be concluded that increasing grade of concrete helps in reducing the shear stress. It also provides benefit such as reduction of thickness of slab or drop.
- It is observed that when we provide punching shear reinforcement, slab thickness can be reduced by 35 – 45 % compared to slab without punching shear reinforcement.

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