EFFECT OF REINFORCEMENT ON PUNCHING BEHAVIOR OF FLAT SLAB

By

Eng. Ahmed Mohamed El.said Said Issa

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Structural Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Effect of Reinforcement on Punching Behavior of Flat Slab

Key Words:

Flat Slabs, Punching Shear, Slab-Column Connection, Shear Reinforcement, Vertical Closed Stirrups.

Summary:

This study investigated the behavior of reinforced concrete flat plates under concentric punching loading which experimentally investigated. The experimental results showed the performance of flat slabs with different types and placement configurations of shear reinforcement of slabs. The general deformational behavior of the tested slab specimens were recorded and examined. To evaluate the results of the tested slabs, several of international codes had been used to estimate the punching shear and obtain that the difference between the experimental and international code results were acceptable. These provisions of different national and international codes summarize and evaluate the strength of the punching shear for interior slab-column connections with axial load and moment transfer.

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Ahmed Mohamed Elsaid Issa

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ABSTRACT

Shear reinforcement can be used to maximize the ductility and strength of the reinforced concrete flat slabs. However to be efficient, the shear reinforcement must be anchored well in the tension and compression zones of the slab. The test results on the slab-column connection models which provided with shear reinforcement are introduced in this research paper. The benefits of using shear reinforcement are to reduce the slab thickness, cost, and weight of the structure.

The experimental test program included eight flat slab specimens having average concrete compressive strength 35MPa except two specimens (S_2 & S_4) have compressive strength (25 & 45MPa) respectively. The slab specimens were 1100*1100mm and 120mm thickness with bottom and top reinforcement (RFT) 10Ø16/m in both directions (high grade steel) except specimen (S_5) was 1100*1100mm and 140mm thickness with the same slab reinforcement. The slabs were divided into three types; the first type had no shear reinforcement and consider the control slab (S_1), the second type ($S_{2\text{-}5}$ & S_7) had shear reinforcement of vertical stirrups at a distance of d/2 from the column face (loaded area), and the third type (S_6 & S_8) had vertical stirrups at a distance of 1.5d from the column face. The eight specimens were loaded with a concentrated load at the mid span until failure.

The general behaviour of the deformation of the tested slab specimens was examined and recorded (cracking, deflection, and strain in both steel and concrete). To calculate the results of the tested specimens, different of international codes had been used to evaluate the strength of the punching shear and confirm that the difference between the international code and experimental results was acceptable.

Recommendations for the experimental analysis and execution for flat slabs were obtained. A comparison had been made between the research test results and the codes equations to improve the methods of the analysis about the flat plates.

CHAPTER (1)

INTRODUCTION

1.1 GENERAL

Flat plate structures of reinforced concrete, i.e. slabs directly supported by columns without any dropped beams, are common in various types of buildings and structures such as office buildings, car park buildings, and bridges. The absence of drop panels or dropped beams simplifies formwork, increases the used space, and reduces the overall height of a building. Since most of the analysis concrete is defined by some characteristics such as cracking and crushing, so the flat slab column connection behavior under static load can be marked out through them.

One of the most economical systems in reinforced concrete structures is the flat slab. It provides flexibility in the architectural design; which maximize the clear space, minimize the building height, and minimize the construction time. However, the punching failure due to transfer of unbalanced moments and shearing forces between columns and slabs is considered a critical problem in flat slab system. The unbalanced moment is transferred by the combination of flexure, shear, and torsion in the slab next to column faces. When shear stresses due to shear forces and moment transfer in the region of flat slab next to column become too high, a punching failure will occur.

The reinforced concrete slabs which developed in US. And Europe in 20^{th} century typically included large column capitals looked like mushroom in shape to improve the local introduction of forces from the slab to the column. In 1950, slabs without capitals started to become popular. Because of their construction simplicity therefor they have been used for medium height office, residential buildings, and parking garages. Flat slab design depends on the conditions of serviceability and the ultimate grade of punching shear which called two-way shear. These two conditions lead to the suitable slab thickness selection.

Since many years ago, punching has been a problem to engineers who tried to fully understand it. It does not matter how many experiments, analysis, and models were made which relied on empiric results that did not describe the totally phenomenon. The test parameters which used are the reinforcement properties, the geometry of the slabs, aggregate size, and loading modes. Although all of these were planned in an intelligent way, providing a huge range of results, it is impossible to cover all parameters. However, this system has a lot of problems which is failure of punching shear of the slabs due to the high concentration of stresses near slab-column connections. This failure type is critical due to its brittle nature. Once, the failure of punching shear occurs, structure resistance is typically reduced due to separation between column and slab therefor joint connection failure will occurs.