Ain Shams University
Faculty of Engineering

Behavior of Stay-in-Place Formwork Flat Slab-Column Connections

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STATEMENT

This thesis is submitted to **Ain Shams University** in partial fulfilment of the requirements for the degree of Master of Science in Civil Engineering (Structural).

The work included was carried out by the author at reinforced concrete laboratory of the Faculty of Engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

TITLE: "Behavior of Stay-in-Place Formwork Flat Slab-Column Connections"

Submitted by: Eng. Manal Mohammed Yehia Akl

Supervised by: Prof. Dr. Amr Ali Abd El Rahman

Dr. Khalid Hilal Riad

The world over population forced the development of non-traditional construction techniques. Last years have shown the development of new construction techniques in the purpose of saving time and cost. Stay-in-place metal formwork system is one of those developed construction techniques.

Stay-in-place formwork system is being used widely in different countries including Egypt and also in different applications proving great success such as walls, beams. Regard other applications such as flat slabs, stay-in-place formwork system has not been used yet in Egypt, hence studies are needed to start the use of this system in flat slabs and columns in Egypt.

The investigated stay-in-place formwork system in this study is a lightweight structural system which is composed of two filtering grids connected by articulated rebar loops. The grids are composed of a steel screen mesh vertically stiffened with cold formed steel channels.

The main objective of this study was to examine the effect of using the structural stay-in-place formwork system on the behavior of flat slab-column connections. Experimental and analytical studies were conducted to investigate the modes of failure, the ultimate load carrying capacity, crack pattern, and the behavior of flat slab-column connection under the effect of flexural and shear loading. The key parameters considered in the experimental program were the use of the stay-in-place formwork system, changing the slab thickness, and the slabs reinforcement ratio.

A total of five specimens divided into two groups were tested to failure. The slab dimensions were the same regard the length and width, column height and diameter with the change of the slab thickness from 200 mm for the first group specimens to 160 mm for the second group specimens.

First group consisted of two specimens of thickness 200 mm connected to a concentric column of 150 mm diameter. The specimens were tested under vertical loads on both edges of the slab to study the effect of changing the stay-in-place formwork orientation on the previously mentioned parameters. Symmetric loading in first group specimens prevented moment transfer from slab to column.

Second group consisted of three specimens of thickness 160 mm connected to an eccentrically positioned column. The specimens were tested under vertical loads on both edges of the slab, which led to unbalanced transferred moment from slab to column to study the effect of using the stay-in-place formwork system on the punching behavior of the specimens. The first specimen in this group was casted using wooden formwork as reference specimen and the other two were casted using stay-in-place formwork system. Electric weld was used in the last specimen on some of the vertical connectors in the zone of the expected critical punching perimeter in order to study the effect of the electric weld on enhancing the punching behavior of the specimen.

The experimental results of each group specimens were analyzed and compared using deformation and strain measurements in order to study the effect of the various parameters on changing the behavior of the specimens. This analysis included studying the effect of the stay-in-place formwork system on the crack pattern, reinforcement ratio, and specimens capacity.

Through the analytical study, three different design codes (ECP - ACI - Eurocode) were used in the prediction of the specimens flexural and punching capacity using the available equations in order to consider the effect of different parameters on the punching behavior of the specimens such as the effect of the slab reinforcement on the punching capacity of the specimens and the contribution of some parts of the stay-in-place formwork system in changing the specimens capacity, and the slab reinforcement ratio.

According to the test results, the stay-in-place formwork system had a contribution in the flexural capacity of flat slab sections. Although this contribution could be verified using the analytical equations, the measured strains on the C-channels indicated a slippage between it and concrete. In addition C-channels rupture was observed indicating a brittle behavior.

It was found that the use of the stay-in-place formwork in the tested specimens definitely changed their behavior regard the crack pattern, failure mode, flexural and punching capacity. As using the stay-in-place formwork enhanced the punching capacity by 9% for the tested specimens.

As for the crack pattern, the presence of the steel mesh acted as crack initiator in the connection parts of the steel mesh. It was also noticed that the crack width increased at the separating line between the two panels of the stay-in-place formwork.

Regard the punching capacity, the Eurocode gave the nearest load capacities for the tested specimens to that of the experimental program.

Keywords: Flat slabs, Flexure capacity, Punching capacity, Stay-in-place formwork

To fulfill the previously mentioned objectives, this research was divided into the following chapters:

Chapter (1): Introduction

This chapter is an introduction to this research discussing the investigated stay-in-place formwork system and its advantages, in addition to the explanation of the objectives and contents of this study.

Chapter (2): Literature Review

This chapter presents summary of the flexural and punching shear behavior of flat slabs, in addition to the flexure and punching capacity prediction equations. Also it presents an introduction to the investigated stay-in-place formwork system, and some of the previous conducted researches related to these fields of study.

Chapter (3): Experimental Work

This chapter describes the experimental program conducted for this study, in addition to the details of the specimens, specimens fabrication and test setup.

Chapter (4): Experimental Results and Discussion

This chapter presents the results for the tested specimens including a description for the structural behavior and failure modes of the tested specimens. It also presents the effect of different parameters considered in the study on the behavior of the specimens, and a comparison between the behavior of the specimens.

Chapter (5): Analytical Work

This chapter introduces the analytical study conducted to investigate the various previously mentioned parameters and a comparison between the predicted specimens capacities and their experimental ones.

Chapter (6): Conclusions

This chapter presents summary and conclusions of the study.

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