



شبكة المعلومات الجامعية  
التوثيق الإلكتروني والميكرو فيلم

# بسم الله الرحمن الرحيم



**HANAA ALY**



شبكة المعلومات الجامعية  
التوثيق الإلكتروني والميكروفيلم



# شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



**HANAA ALY**



شبكة المعلومات الجامعية  
التوثيق الإلكتروني والميكروفيلم

# جامعة عين شمس التوثيق الإلكتروني والميكروفيلم

## قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها  
علي هذه الأقراص المدمجة قد أعدت دون أية تغييرات



## يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



**HANAA ALY**



AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING

**BEHAVIOR OF PRESTRESSED HOLLOW CORE  
SLABS WITH OPENINGS STRENGTHENED  
WITH NEAR SURFACE MOUNTED FRP STRIPS**

BY

**Omar Hesham Mokhtar Abd-Elrehim EL-Harouney**

B.Sc. 2017, Structural Engineering  
Faculty of Engineering – Ainshams university

**A Thesis**

Submitted in partial fulfillment for the requirements of the  
Degree of **Master of Science** in Structural Engineering

**Supervised by**

**Prof. Dr. Ayman Hussein Hosny Khalil**

Professor of Concrete Structures  
Structural Engineering Department  
Faculty of Engineering  
Ain Shams University

**Dr. Mahmoud Mohamed Mahmoud Elkateb**

Assistant Professor  
Structural Engineering Department  
Faculty of Engineering  
Ain Shams University

Cairo - 2020





AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING

**BEHAVIOR OF PRESTRESSED HOLLOW CORE  
SLABS WITH OPENINGS STRENGTHENED  
WITH NEAR SURFACE MOUNTED FRP STRIPS**

BY

**Omar Hesham Mokhtar Abd-Elrehim EL-Harouney**

B.Sc. 2017, Structural Engineering  
Faculty of Engineering – Ainshams university

**A Thesis**

Submitted in partial fulfillment for the requirements of the  
Degree of **Master of Science** in Structural Engineering

**Examiners Committee:**

**Signature**

**Prof. Dr. Adel Galal Tawfik ElAttar**

.....

Professor of Concrete Structures  
Structural Engineering Department  
Faculty of Engineering – Cairo University

**Prof. Dr. Amr Hussein Abdel Azeem Zaher**

.....

Professor of Concrete Structures  
Structural Engineering Department  
Faculty of Engineering - Ain Shams University

**Prof. Dr. Ayman Hussein Hosny Khalil**

.....

Professor of Concrete Structures  
Structural Engineering Department  
Faculty of Engineering - Ain Shams University

**Date**

/ /2020



## **AUTHOR**

Name :Omar Hesham Mokhtar Abd-Elrehim EL-Harouney  
Date of birth :27 July 1994  
Place of birth : Cairo, Egypt  
Academic Degree : B.Sc. in Structural Engineering  
University : Ain Shams University  
Date of Award : July 2017  
Average grade : Distinction with an honorary degree  
Current job : Teaching Assistant, Structural Engineering  
Department, Faculty of Engineering, Ain Shams  
University



## STATEMENT

This thesis is submitted to Ain Shams University, Cairo, Egypt, in partial fulfillment of the requirements for the degree of Master of Science in Structural Engineering. The work included was carried out by the author. No part of this thesis has been submitted for a degree or qualification at any other university or institution.

Date : / / 2020

Name : Omar Hesham Mokhtar

Signature : *Omar Hesham*



## ACKNOWLEDGMENTS

I would first like to express my sincerest appreciation and gratitude to my advisors, **Prof. Dr. Ayman Hussein Hosny Khalil** and **Dr. Mahmoud Elkateb** for their invaluable guidance whenever I ran into a trouble spot or had a question about my research.

I would also like to extend sincere thanks for their expert instruction, and the investments they have made in me throughout the research duration, giving me the chance to be involved in such interesting research.

Many people supported me in ways beyond what I could have wished during the completion of this thesis. I would not have been able to accomplish this research if it weren't for the support, love and sacrifices made by my family on my behalf and especially my mother. I would like to thank them for their encouragement, fruitful care and patience. At last, I would like to express my special appreciation to my brother who always assisted me during this work.



## **ABSTRACT**

The Prestressed Hollow Core Slabs (PHCSs) are mostly used in the construction industry nowadays owing to the economic benefits they achieve. Openings are probable to be needed in a PHCS after construction to allow the installation of an equipment or the passage of facilities ducts due to changes that could appear in the use of the building.

Moreover, the presence of openings along the span of an existing slab can severely decrease the ultimate capacity of the slab due to the discontinuity resulting from cutting the concrete and the prestressing steel reinforcement according to Saint-Venant's principle.

The Near Surface Mounted (NSM) strengthening technique is among the practical and feasible solutions to rehabilitate or enhance the performance of the PHCSs with openings. Compared to the strengthening of other concrete elements, a limitation exists in the case of strengthening of the PHCSs. The longitudinal voids of the PHCSs constrain the positioning of the FRP reinforcement and make it limited to be at the location of the webs, due to the smaller thicknesses of the PHCSs' flanges.

In this study, Finite Element (FE) numerical simulations for PHCSs with openings provided and consequently strengthened with NSM FRP strips. The Concrete Damage Plasticity (CDP) model was successfully implemented

to model the non-linear behaviour of concrete. The bond failure for the strengthened specimens was accommodated in this research, where shear stress-slip and normal stress-gap models were utilized to consider different debonding modes. An acceptable accuracy, in terms of the cracking, ultimate loads and the corresponding deformations, as well as, the PHCSs failure modes, was monitored. Maximum differences, compared to the experimentally attained results in the ultimate loads and the corresponding deformations of nearly 4% and -8.4%, respectively, were detected.

Additionally, an extensive set of parametric study variables influencing the PHCSs response were investigated. The PHCS cross-sectional shape, openings locations and sizes, the average precompression and the FRP reinforcement percentages were among the considered parameters. This made it possible to visualize ranges in which the proposed strengthening technique is feasible in restoring and further enhancing the ultimate-load carrying capacities, together with others in which changes in the failure modes hinders the utilization of the NSM strengthening.

Moreover, the suggested FE modelling approach along with the parametric study results could assist to formulate design guidelines that evaluate reductions in the ultimate capacities of the PHCSs associated with the presence of openings at multiple locations along their spans and improvements experienced by employing the NSM strengthening technique.