شبكة المعلومات الجامعية

التوثيق الإلكتروني والميكروفيلم

بسم الله الرحمن الرحيم

Ain Shams University Information Network

جامعة عين شمس

شبكة المعلومات الجامعية

@ ASUNET

HANAA ALY

شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

شبكة المعلومات الجامعية

التوثيق الالكتروني 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 تغيرات

يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار

HANAA ALY

EFFECT OF SHEAR CONNECTORS DISTRIBUTION AND CONCRETE COMPRESSIVE STRENGTH ON THE SHEAR TRANSFER OF ONE-WAY COMPOSITE PRE-SLABS

By

MAHMOUD MOSTAFA MOHAMED EL-HAWARY

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
In
STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

EFFECT OF SHEAR CONNECTORS DISTRIBUTION AND CONCRETE COMPRESSIVE STRENGTH ON THE SHEAR TRANSFER OF ONE-WAY COMPOSITE PRE-SLABS

By

MAHMOUD MOSTAFA MOHAMED EL-HAWARY

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
In
STRUCTURAL ENGINEERING

Under the Supervision of

Prof. Dr. Mohamed Rabie Mahmoud

……………………………….

Professor of Reinforced Concrete Design
Faculty of Engineering
Cairo university

Dr. Wael Salah El-Din Zaki

……………………………….

Assistant Prof. of Structural Engineer
Faculty of Engineering
Beni Suef University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

EFFECT OF SHEAR CONNECTORS DISTRIBUTION AND CONCRETE COMPRESSIVE STRENGTH ON THE SHEAR TRANSFER OF ONE-WAY COMPOSITE PRE-SLABS

By

MAHMOUD MOSTAFA MOHAMED EL-HAWARY

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
In
STRUCTURAL ENGINEERING

Approved by the Examining Committee

Prof. Dr. Mohamed Rabie Mahmoud **Thesis Main Advisor**
Professor of Reinforced Concrete structures, Cairo University

Prof. Dr. Hany Ahmed Abdalla **Internal Examiner**
Professor of Reinforced Concrete structures, Cairo University

Prof. Dr. Gouda Mohamed Ghaniem **External Examiner**
Professor of Properties and Strength of Materials, Helwan University

‘

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

Engineer: Mahmoud Mostafa Mohamed El-Hawary
Date of Birth: 5 / 5 /1986
Nationality: Egyptian
E-mail: mahmoud.alhawary@must.edu.eg
Phone.: 01005681426
Address: 15 Mohamed Mahmoud El badry Madint Nasser - Cairo

Registration Date: 1 / 10 / 2013
Awarding Date: / / 2020
Degree: Doctor of Philosophy
Department: Structural Engineering

Supervisors: Prof. Dr. Mohamed Rabie Mahmoud
Dr. Wael Salah El-Dein Zaki

Examiners: **Prof. Dr. Mohamed Rabie Mahmoud** (Thesis main advisor)
Prof. Dr. Hany Ahmed Abdalla (Internal examiner)
Prof. Dr. Gouda Mohamed Ghaniem (External examiner)
(Faculty of Engineering – Helwan University)

Title of Thesis: "**Effect of shear connectors distribution and concrete compressive strength on the shear transfer of one-way composite pre-slabs**"

Key Words: (Shear Transfer; Shear Connectors; Pre-slabs; Interface roughness)

Summary:

The aim of this research is to study the influnce of concrete compressive strength, percentage, distribution of shear connectors and interface roughness on shear transfer of one-way composite pre-slabs, composed of two concrete layers with various concrete compressive strengths.A comprehensive literature review has been performed on almost all aspects concerning the behavior of reinforced concrete pre-slabs.

An expermental program has been performed to explore the research point, so that fourteen pre-slabs specimens were tested under the case of uniformly distributed loads, one-concentrated and two-concentrated line loads. Specimens were grouped into four groups to study the influence of dowel distribution, percentage and surface condition between two slab layers. It was concluded that increasing of shear connectors ratio and roughening the interface surface lead to increase in ultimate load, horizontal shear strength and ductility, also decrease in dowels' strain, horizontal slippage and deflection of pre-slabs.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute. I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Mahmoud Mostafa Mohamed El-Hawary Date: 25 /3/2020

Signature:

ACKNOWLEDGEMENT

It is my pleasure to express my deepest gratitude to **Prof. Dr. Mohamed Rabie Mahmoud**, who, very kindly, and generously, devoted much of his time and experience in helping, guiding and advising me. Indeed, this work is the outcome of his great continuous efforts and wide experience in the field of structural engineering.

I'm especially grateful and especially indebted to **Dr. Wael Salah El-Din Zaki** for his constructive keen supervision, fruitful criticism continuous support and encouragement to complete this work. I express my thanks for his efforts and help to me.

In addition, I would like to express my deepest respect to the Concrete Research Lab staff for their great help in the preparation and testing process.

Table of Contents

Acknowledgment .... **II**

Table of Contents .... **III**

List of Tables .... **IX**

List of Figures .... **X**

Abstract .... **XVIII**

CHAPTER ONE: Introduction **1**

1.1 General 1

1.2 Research range and aims 1

1.3 Research significance 1

1.4 Thesis arrangement 2

CHAPTER TWO: Literature Review **3**

2.1 Introduction 3

2.2 Factors affecting shear strength 3

2.2.1 Position of casting 3

2.2.2 Slippage 4

2.2.3 Layers Concrete compressive strength 4

2.2.3.1 Characteristics of high Strength Concrete 4

2.2.3.1.1 Stress – Strain Relationship in Uni-axial Compression 4

2.2.3.1.2 Modulus of elasticity 5

2.2.3.1.3 Poisson's ratio 6

2.2.3.1.4 Behavior of Concrete in tension 6

2.2.3.1.5 Tensile strength 6

2.2.3.1.6 Tensile splitting strength 6

2.2.4 The influence of the shape and size of the aggregate 7

2.2.5 The location of interface surface with assessment of neutral axis 7

2.2.6 Curing types and concrete age 7

2.2.7 The tested specimen's dimensions and reinforcement 8

2.2.8 Kind of stress affect parallel to the shear plane surface 8

2.2.9 Differential shrinkage 8

2.2.10 Loading type 9

2.2.11 Shear length to effective depth ratio 9

2.2.12 Method of concrete placement 10
2.3 Composite section 10
2.3.1 Manner of composite flexure members 10
2.3.1.a Fully interaction surface 10
2.3.1.b Partially interaction surface 10
2.3.1.c No interaction 10
2.4 Types of shear transfer tests 10
2.4.1 Composite slab or beam experiments 10
2.4.2 Direct shear tests 11
2.5 Mechanism of shear transfer in composite sections 11
2.5.1 The Theory of Shear Friction 11
2.5.2 General theory of shear transfer 12
2.5.2.a Members included shear reinforcement (high) 12
2.5.2.b Members included reasonable shear reinforcement 13
2.5.2.c Members has no shear reinforcement 13
2.5.3 Shear transfer truss action model 13
2.5.3.1 Behavior of shear transfer at initially cracked concrete 13
2.5.3.2 Behavior of shear transfer at initially uncracked concrete 14
2.6 Composite slab types 15
2.6.1 Deck slab system with standard steel 15
2.6.2 Composite slab with manufactured beams specimens 15
2.6.3 Composite slab (concrete-concrete) specimens 15
2.7 Various types of shear connection between concrete surfaces in one section 15
2.7.1 Surface connection “Rough” 15
2.7.2 Steel doweled connection 19
2.7.2.1 Influence of steel strength, bar size and spacing 19
2.7.2.2 Steel dowels distribution and shapes over the span 19
2.7.2.3 The influence of the embedded length of dowels and percentage area .20
2.7.3 Shear keyed connection 21
2.7.4 Binding materials (Epoxy) 23
2.8 Composite concrete members using theoretical analysis 23
2.9 Shear transfer capacity prediction 24
2.9.1 Semi- empirical equations 24

2.9.2 Empirical equations 25
2.10 Requirements of code 25
2.10.1 ACI committee 318-2019 25
2.10.1.a Horizontal shear strength art 17.4 25
2.10.1.b Vertical shear strength art 17.4 27
2.10.1.c Horizontal shear ties art 117.6 27
2.10.2 BS 8110 28
2.10.2.a Average design horizontal shear stress 28
2.10.2.b Nominal links 28
2.10.2.c Excess of minimum links 28
2.10.3 DIN 1045(1978) 28
2.10.4 ECP 203-2018 29

CHAPTER THREE: Experimental Program 66

3.1 Introduction 66
3.2 Test specimens 66
3.2.1 Fabrication of Specimens 66
3.2.2 Materials used in specimen's preparation 66
3.2.2.1 Coarse Aggregate 66
3.2.2.2 Fine Aggregate 66
3.2.2.3 Cement 66
3.2.2.4 Water 66
3.2.2.5 Super Plasticizers 67
3.2.2.6 Silica Fume 67
3.2.2.7 Reinforcement 67
3.3 Details of Test Specimens 67
3.3.1 Shuttering 67
3.3.2 Concrete mix design 67
3.3.3 Specimens preparation 68
3.3.4 Reinforced concrete casting and curing 68
3.3.5 Evaluation of concrete strength 68
3.3.6 Monolithic slab specimens 68
3.3.7 Composite pre-Slab specimens 68
3.3.8 Interface of pre- slab Specimens 68

3.3.9 Shear connectors 69
3.4 Test set-up and loading arrangement 69
3.5 Measured variables 70
3.5.1 Strain in reinforcement 70
3.5.2 Instantaneous mid-span deflection 71
3.5.3 Applied loads 71
3.5.4 Concrete strain 71
3.5.5 Slippage 71
3.5.6 Crack pattern 71
3.5.7 Data collection 71

CHAPTER FOUR: Analysis and Discussion of Experimental Results 91

4.1 Introduction 91
4.2 Results of tested slabs 91
4.2.1 Crack pattern and mode of failure 91
4.2.1.1 Monolithic slab (R-N-U) 91
4.2.1.2 Monolithic slab (R-H-U) 91
4.2.1.3 Monolithic slab (R-N-O) 92
4.2.1.4 Monolithic slab (R-H-O) 92
4.2.1.5 Monolithic slab (R-N-T) 92
4.2.1.6 Monolithic slab (R-H-T) 92
4.2.1.7 Composite slab (0.06%-U) 93
4.2.1.8 Composite slab (0.1%- U) 93
4.2.1.9 Composite slab (0.06%- O) 93
4.2.1.10 Composite slab (0.06%-O-R) 93
4.2.1.11 Composite slab (0.1%- O) 94
4.2.1.12 Composite slab (0.1%- O-R) 94
4.2.1.13 Composite slab (0.06%- T) 94
4.2.1.14 Composite slab (0.1%- T 95
4.2.2 Cracking loads 95
4.2.3 Failure loads 95
4.2.4 Shear transfer along the interface 96
4.2.4.a Comparing with monolithic specimens 96

4.2.4.b Effect of shear connectors ratio 97
4.2.4.c Effect of interface roughness 97
4.2.5 Load-deflection curves 98
4.2.6 Concrete tensile strain 99
4.2.7 Strain in shear connectors 99
4.2.8 Slippage 100
CHAPTER FIVE: Numerical Analysis with Finite Element Idealization 157
5.1 Introduction 157
5.2 ANSYS (finite Element Program) 157
5.3 ANSYS (non- linear analysis) 157
5.3.1 Geometric non-linearity 157
5.3.2 Material nonlinearity 158
5.4 Finite element modeling by “ANSYS” program 158
5.4.1 Element type 158
5.4.1.1 Concrete element 158
5.4.1.2 Shear connectors 158
5.4.1.3 Interface element 158
5.4.2 Real constant 159
5.4.2.1 SOLID 65 159
5.4.2.2 BEAM4 159
5.4.2.3 CONTA174 159
5.4.3 Materials 159
5.4.3.1 concrete 159
5.4.3.2 Reinforcement rebar 159
5.4.4 Geometry and dimensions 159
5.4.5 Constrains 159
5.4.6 Load Stepping and failure definition 160
5.4.7 Non-linear solution 160
CHAPTER 6: Correlation Between Theoretical and Experimental Results 171
6.1 General 171
6.2 Failure load 171
6.3 Ultimate shear strength 171
6.4 Load-deflection 172

6.5 Flexure and shear cracks 173
6.6 Parametric study 173
6.6.a Case study A 173
6.6.a.1 Shear transfer strength 174
6.6.a.2 Vertical deflection 174
6.6.b Case study B 174
6.6.b.1 Effect of compressive strength of the top layer 174
6.6.b.2 Effect of compressive strength of the bottom layer 174
6.6.b.3 Calculation of horizontal shear stress 174
6.6.b.3.1 ACI (2019) code 175
6.6.b.3.2 ECP (2018) code 175
6.6.b.3.3 JSCE (2007) code 175
6.6.b.3.4 Euro code (2004) 175
6.6.b.3.5 Mattock and Niel 176
6.6.b.3.6 Kahn and Mitchell 176
6.6. b.3.7 M.Rabie 176
6.6.b.3.8 El-Rakib T 176
6.6. b.3.9 Zhuangcheng Fang and j.Haibo 176
6.6.b.3.10 Proposed equation 177
CHAPTER 7: Conclusions and Recommendations 229
7.1 General 229
7.2 Conclusions 229
7.3 Research proposed equation 230
7.4 Recommendations for future research 230
REFERENCES 231