

AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING

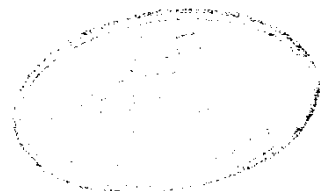
EFFECT OF THE DEGREE OF CONNECTION  
ON THE ULTIMATE CAPACITY OF  
COMPOSITE SIMPLE BEAMS

BY

NADIA ABD EL ZAHER WAHIDAN

B.Sc. CIVIL ENGINEERING

AIN SHAMS UNIVERSITY , 1985



624-17723  
M.A.

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT FOR THE  
REQUIREMENTS OF THE DEGREE OF  
MASTER OF SCIENCE  
IN  
STRUCTURAL ENGINEERING

12391

SUPERVISORS

PROF. MOSTAFA KAMEL M. ZIDAN  
STRUCTURAL ENGINEERING DEPT.  
FACULTY OF ENGINEERING  
AIN SHAMS UNIVERSITY

Dr. IBRAHIM SHAWKY MOHARRAM  
STRUCTURAL ENGINEERING DEPT.  
FACULTY OF ENGINEERING  
AIN SHAMS UNIVERSITY

Dr. KAMAL SAID ABDEL-AZZIZ  
STRUCTURAL ENGINEERING DEPT.  
FACULTY OF ENGINEERING  
AIN SHAMS UNIVERSITY

### Acknowledgements

The author wishes to express her sincere appreciation and deep gratitude to Dr. Mostafa Kamel M. Zidan , Professor of theory of structures , Faculty of Engineering , Ain Shams University , Dr. Kamal Said Abdel-Aziz , lecturer, structural Engineering Department , Faculty of Engineering , Ain Shams University and Dr. Ibrahim Shawky moharram , lecturer, structural Engineering Department , Faculty of Engineering , Ain Shams University for their kind supervision , unlimited help , guidance , valuable suggestions and generous support during all phases of this research work.

The author is indebted to Dr. Adeeb Gohneimy professor of Computer Engineering , Faculty of Engineering , Ain Shams University for allowing the use of the computer facilities available at the faculty . The author also extends her appreciation to all members of the staff of the department of computer for their assistance and endless co-operation .

The author is indebted to Dr. Mohamed Sameh Ibrahim , Professor of Computer Engineering ,for allowing the use of the computer facilities available at the company .

The author is indebted to Dr. Abd El-Monhem Wahdan professor of Computer Engineering , Faculty of Engineering , Ain Shams University for his continuous encouragement , his useful advices and his unlimited help .

Finally the author dedicates this thesis to her family especially her mother and father , for their continuous encouragement , sacrifice and fruitful care.



### STATEMENT

-----

This dissertaion is submitted to Ain Shams University for the degree of Master of science in Structural Engineering .

The work included in this thesis was carried out by the author in the Department of Structural Engineering , Ain Shams University , from November 1986 to March 1992 .

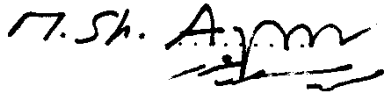
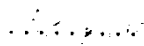
No part of this thesis has been submitted for a degree or a qualification at any other university or institution .

Date :

Signature : 

Name : Nadia Wahdan

Examiners committee

| Name , Titel and affiliation                                                              | Signature                                                                             |
|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1 Shaffik Aggour<br>Professor<br>Faculty of engineering<br>Cairo university .             |     |
| 2 Gamal El Din Nassar<br>Professor<br>Faculty of engineering<br>Ain Shams university .    |     |
| 3 Mostafa Kamel M. Zidan<br>Professor<br>Faculty of engineering<br>Ain Shams university . |  |

Ain Shams University  
Faculty of Engineering  
-----

Dept of : Structural Engineering

Abstract of the M.Sc. Thesis submitted by : Nadia Abd El Zaher Wahdan

Title of Thesis "Effect of degree of connection on the ultimate capacity of composite simple beams".

Supervisors : ( 1 ) Prof Mostafa Kamel M. Zidan

( 2 ) Dr. Ibrahim Shawky Moharram

( 3 ) Dr. Kamal Said Abdel-Aziz

Registration Date : 12/1/1996

Examination Date : 23 / 5 / 1992

Abstract :

A proposed calculation model is adopted for the analysis of the composite simple steel-concrete beams , valid up to collapse , which takes into account the effects of different parameters such as : Material non-linearity , the effect of slip at the interface between concrete slab and the steel girder , load-slip curve , spacing and the type of connectors , type of loading , geometrical configuration of the cross section .....etc . The resolution of the model is made easier in adopting the formulation by transfer matrix method , the unknown vector containing some internal forces and generalized displacements .

A computer programme is developed to deal with this mathematical model . After checking the efficiency and accuracy of the proposed model and the computer programme with the available experimental test results , a versatile parametric study is performed to investigate the effects of the degree of connection , the geometrical dimensions of composite section and the type of loading on the overall behaviour of the composite beams.

Key words :

Composite beam and transfer matrix .

## TABLE OF CONTENTS

|                                                                                         |     |
|-----------------------------------------------------------------------------------------|-----|
| Acknowledgements .....                                                                  | i   |
| Statement .....                                                                         | ii  |
| Examiners committee .....                                                               | iii |
| Abstract .....                                                                          | iv  |
| Table of contents .....                                                                 | v   |
| Introduction .....                                                                      | 1   |
|                                                                                         |     |
| Chapter I                                                                               |     |
| Review of composite beams analysis                                                      |     |
| I-1 Introduction .....                                                                  | 5   |
| I-2 Construction components of composite beams .....                                    | 6   |
| I-2-1 Steel beam .....                                                                  | 6   |
| I-2-2 Reinforced concrete slab .....                                                    | 6   |
| I-2-3 Shear connectors .....                                                            | 6   |
| I-3 Properties of materials used for composite beams .                                  | 12  |
| I-3-1 Stress-Strain curves of steel .....                                               | 12  |
| I-3-2 Stress-Strain curves of concrete .....                                            | 17  |
| I-4 Construction methods .....                                                          | 19  |
| I-5 Effective breadth of concrete slab used in the<br>analysis of composite beams ..... | 21  |
| I-6 Limiting deflections and the use of span-depth<br>ratios .....                      | 24  |
| I-7 Methods of analysis and design .....                                                | 26  |
| I-7-1 Elastic full interaction analysis .....                                           | 31  |

|                               |                                                                                |    |
|-------------------------------|--------------------------------------------------------------------------------|----|
| 1-7-2                         | Ultimate full interaction analysis .....                                       | 35 |
| 1-7-3                         | Elastic and ultimate partial<br>interaction theories .....                     | 41 |
| Chapter II                    |                                                                                |    |
| Theoretical Model of Analysis |                                                                                |    |
| II-1                          | Introduction .....                                                             | 49 |
| II-2                          | Notations .....                                                                | 50 |
| II-3                          | Assumptions .....                                                              | 54 |
| II-4                          | Proposed mathematical model .....                                              | 57 |
| II-4-1                        | Relations between internal forces and<br>deformations .....                    | 57 |
| II-4-2                        | Compatibility equation of deformation at<br>the concrete-steel interface ..... | 58 |
| II-4-3                        | Equilibrium equation for the composite<br>section .....                        | 60 |
| II-4-4                        | Equilibrium Equation at a connector<br>position .....                          | 61 |
| II-5                          | Discrete Analysis of the problem .....                                         | 63 |
| II-6                          | Equations of the problem for the interval $\delta x_1$ ....                    | 66 |
| II-7                          | Solution of the problem                                                        |    |
| II-7-1                        | Transfer-matrix method .....                                                   | 69 |
| II-7-2                        | Boundary conditions of the unknowns<br>of the problem .....                    | 73 |



|                 |                                                                                     |     |
|-----------------|-------------------------------------------------------------------------------------|-----|
| II-7-3          | Determination of the unknowns<br>of vector .....                                    | 73  |
| II-7-4          | Non linear inelastic iteration<br>procedure .....                                   | 81  |
| II-7-5          | Convergence of solution .....                                                       | 82  |
| II-7-6          | Failure modes .....                                                                 | 83  |
| II-8            | Equivalent axial and flexural rigidities<br>in elastic-plastic range .....          | 85  |
| II-9            | computer programme .....                                                            | 93  |
| <br>Chapter III |                                                                                     |     |
|                 | Comparison between experimental and<br>theoretical results .....                    | 99  |
| III-1           | Introduction .....                                                                  | 99  |
| III-2           | Geometry and properties of the tested beams ...                                     | 101 |
| III-2-1         | General .....                                                                       | 101 |
| III-2-2         | Simple composite beams loaded by<br>a single concentrated load<br>at mid-span ..... | 104 |
| III-2-3         | Simple composite beams loaded by<br>a uniformly distributed load .....              | 106 |
| III-3           | Comparison between the theoretical and<br>experimental results .....                | 108 |
| III-3-1         | Beams under point load at mid-span .....                                            | 108 |

|                                                         |     |
|---------------------------------------------------------|-----|
| III-3-2 Beams under uniformly distributed               |     |
| load .....                                              | 132 |
|                                                         |     |
| Chapter IV                                              |     |
| Partial interaction analysis of composite simple        |     |
| beams .....                                             | 151 |
| IV-1 Introduction .....                                 | 151 |
| IV-2 Effect of degree of connection (r) .....           | 154 |
| IV-3 Influence of the dimensions of composite sections. | 168 |
| IV-3-1 Effect of concrete slab thickness .....          | 168 |
| IV-3-2 Effect of concrete slab breadth .....            | 173 |
| IV-3-3 Effect of concrete slab reinforcement .....      | 176 |
| IV-3-4 Effect of steel beam cross section .....         | 181 |
| IV-3-5 Influence of the type of loading .....           | 189 |
|                                                         |     |
| Chapter V                                               |     |
| Summary and Conclusion                                  |     |
| V-1 Summary .....                                       | 195 |
| V-2 Conclusions .....                                   | 196 |
| V-3 Recommendations for further studies .....           | 199 |
| References .....                                        | 200 |

|                                                                                         |     |
|-----------------------------------------------------------------------------------------|-----|
| Appendix A                                                                              |     |
| List of the computer programme .....                                                    | 203 |
| Appendix B                                                                              |     |
| Example Results                                                                         |     |
| Appendix C                                                                              |     |
| Equivalent axial and flexural rigidities of concrete<br>slab and steel I-beam section . |     |
| C-1 Case of the steel cross section .....                                               | 247 |
| C-2 Case of the concrete slab section .....                                             | 250 |
| Appendix D                                                                              |     |
| Full and partial interaction design for composite<br>simple beams .                     |     |
| D-1 Full interaction calculation for composite<br>simple beams with solid slab .....    | 257 |
| D-1-1 Ultimate capacity for beam B1<br>according to CP117 .....                         | 257 |
| D-1-2 Ultimate capacity for beam B1<br>according to E.C.4 .....                         | 260 |
| D-2 Partial interaction calculation for composite<br>simple beam with solid slab .....  | 263 |

|       |                                  |     |
|-------|----------------------------------|-----|
| D-2-1 | Ultimate capacity for beam B9    |     |
|       | according to CP117, [ 3 ] .....  | 263 |
| D-2-2 | Ultimate capacity for beam B9    |     |
|       | according to E.C.4, [ 12 ] ..... | 266 |

# **INTRODUCTION**

## INTRODUCTION

Composite construction has played a very important role in structural engineering . Its use has varied from small structures to large buildings and bridges . The basic principle underlying composite construction is that certain materials may be used more effectively in certain types of stressed conditions ; thus , the combination of a material strong in compression with one strong in tension makes a very economical union for its use in structures . With basic materials such as concrete , steel , masonry , wood and timber , a number of successful combinations can be used ; however , until now , such information has not been readily available to design for practicing engineers.

The most common composite construction in buildings and bridges is the composite steel-concrete wherein a steel beam and a reinforced concrete slab ( cast-in-situ or precast ) are so interconnected with shear connectors that they act together as a unit . In the common type of composite beam , there is some shear transfer by bond and friction at the interface between steel beam and concrete slab. It can not be depended upon if there is a single overload or pulsating load that will destroy such bond and cause a separation of the slab from the beam . Hence , shear connectors are needed to give reliable composite action with two objectives :

- 1- To transfer shear between the steel and concrete , thus limiting the slip at the interface so that the slab beam

system acts as a unit to resist longitudinal bending ( with one neutral axis for the composite section )

- 2- To prevent an uplift between the steel beam and concrete slab , i.e. , to prevent separation of the steel and concrete at right angles to the interface .

Various types of shear connectors have been used to resist longitudinal shear and uplift . In a broad sense , connectors may be divided into two categories , rigid and flexible connectors. It must be pointed out that slip must occur before they are utilized ; therefor , the terms are relative . Usually the interaction between steel beam and concrete slab is incomplete due to slip caused by flexibility of shear connectors and the compressibility of concrete . It produces a discontinuity in the strain distribution at the interface . Some researches developed a partial interaction theory in the elastic range assuming a linear load-slip relation for the connectors . They showed that fairly large variations in the value of the shear connector modulus ( defined as the ratio of load to slip ) affected the deformations only slightly ; however , such variations affected the deflection considerably and to a large degree the elastic strains and stresses . The partial interaction theory has been extended to take into account the nonlinear load-slip characteristics of shear connectors and also the inelastic behaviour of steel and concrete material .