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MODELLING OF REINFORCED CONCRETE BEAM FOR FLEXURAL BEHAVIOUR

Lydia Kristen Binti Edward Mongudal

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ALAMAT TETAP:
P.O. Box 125,
Kg. Tingkalanon,
Kota Marudu,
Sabah, Malaysia.

Dr. Ng Chee Khoon
Nama Penyelia

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Title : Modelling of Reinforced Concrete Beam for Flexural Behaviour

Author's name: Lydia Kristen Binti Edward Mongudal

Matrix number: 6765

Has been read and approved by

______________________	10/5/2015
Prof. Madya. Dr. Ng Chee Khoon	Date
Supervisor	

MODELLING OF REINFORCED CONCRETE BEAM FOR FLEXURAL BEHAVIOUR

LYDIA KRISTEN BINTI EDWARD MONGUDAL

This Report is Submitted to Faculty of Engineering, Universiti Malaysia Sarawak in Partial Fulfillment of the Requirements for the Degree of Bachelor of Engineering with Honours (Civil Engineering) 2005

Dedicated to beloved Mom and Dad,

Roy, Eva, Becca and Ronn.

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ABSTRACT

A FORTRAN program for the non-linear analysis of reinforced concrete beam has been developed in this study. This program is able to produce the complete load-deflection behaviour and moment-curvature relationship for the whole flexural response of the beams. The computational results have been verified by manual calculations, indicating that any error in the calculation has been avoided. However, this program is only applicable to simply-supported T-beams with both compression and tension reinforcements.

ABSTRAK

Satu program FOTRAN bagi analisa ketidak linearan rasuk konkrit bertetulang telah dibina dalam kajian ini. Program ini mampu menghasilkan tindakan beban-pemesongan dan hubungan daya-kelengkungan yang lengkap bagi kesemua respons kelenturan rasuk tersebut. Hasil pengiraan telah disahkan melalui pengiraan manual, menunjukkan sebarang kesilapan dalam kiraan telah dielakkan. Walaubagaimanapun, program ini hanya boleh digunakan untuk rasuk-T sokongan-mudah bersama kedua-dua tetulang kemampatan dan ketegangan.

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As	-	area of nonprestressed tension reinforcement
A's	-	area of compression reinforcement
B_F	-	flange width
B_W	-	web width
Cc	-	concrete compressive force in cross section
Cs	-	steel compressive force in cross section
C_I	-	distance from extreme compression fiber to neutral axis
Ds	-	effective depth, that is, distance from extreme compression fiber to centroid of tension reinforcement
D's	-	distance from extreme compression fiber to centroid of compression reinforcement
Ec	-	modulus of elasticity of concrete
Es	-	modulus of elasticity of reinforcement
H	-	overall thickness of member
HF	-	flange thickness
Fn	-	the initial force
fct	-	splitting tensile strength of concrete
fcu	-	specified compressive strength of concrete
fr	-	modulus of rupture of concrete
fs	-	calculated stress in reinforcement at service loads

fy	-	specified yield strength of nonprestressed reinforcement
$f'c$	-	cylinder compressive strength of concrete
Icr	-	moment if inertia of cracked section transformed to concrete
Ie	-	effective moment of inertia for computation of deflection
I_{EC}	-	the effective moment of inertia for computation of deflection of cracked T-section
I_{EUC}	-	the effective moment of inertia for computation of deflection of uncracked T-section
Ig	-	moment of inertia of gross concrete section, neglecting reinforcement
Igt	-	moment of inertia of gross transformed uncracked section
LAM	-	the lever arm of the compression force from top fibre
LB	-	the centre of level of each section
Ma	-	applied moment in member
Mcr	-	cracking moment
Mn	-	the initial moment
n	-	modular ratio
P	-	the axial load
YB	-	the level of each section
Y_C	-	the centroid for cracked transform of doubly reinforced T-section
Y_{UC}	-	the distance from centroid to extreme fiber of the transformed section
y_b	-	distance from the centroidal axis to the extreme fibre in tension

y_t	-	distance from the centroidal axis to the extreme fibre in compression
ϵc	-	the strain in concrete
ϵct	-	the strain
ϵs	-	the strain in steel
Φ	-	the curvature of each cross section
Φ_C	-	the curvature for cracked T-section
Φ_{UC}	-	the curvature for uncracked T-section
Δ_C	-	the deflection for cracked T-section
Δ_{UC}	-	the deflection for uncracked T-section
ΣFn	-	total of the initial force
ΣMn	-	total of the initial moment

CHAPTER 1

INTRODUCTION

1.1 General

Beam is one of thc most common elements in design of reinforced concrete. Concrete beam in nature has a character which is strong in compression and weak in tension. In order to resist the tension, embedded materials, usually in the form steel bars, are provided in the concrete beam. Such combination create reinforced concrete beam. Reinforced concrete beam has the ability to resist both compressive and tensile stresses. If a reinforced concrete beam is designed properly, it can perform well to resist the bending moment due to subjected load applied to the member. Thus, it is essential to study the load-deformation response of a reinforced concrete beam to provide the designer the principles required to apply in the design consideration.

1.2 Historical Development of Reinforced Concrete

Reinforced concrete has been used as building material since last decades and still preferable nowadays. It is widely used in most countries because of the wide availability of reinforcing bars and economy of concrete constituents such as cement, aggregate and water.

In 1801, Frenchman, F. Coignet has published his statement of principles of construction, recognising the weakness of concrete in tension. He then, published a book illustrating the uses of reinforced concrete in 1861. For the first time, in 1848, another Frenchman, J.L. Lambot construct a rowboat of concrete reinforced with wire for exhibition in the 1855 World's Fair in Paris. His model included drawings of a reinforced concrete beam and a column reinforced with four round iron bars (MacGregor, 1992).

In 1850s, an American lawyer and engineer, Thaddeus Hyatt has carried out an experiment of reinforced concrete beams. He provides longitudinal bars in tension zone and vertical stirrups for shear in his beams. Unfortunately, Hyatt's work was not known until he privately published a book describing his tests and building system in 1877(MacGregor, 1992).

In 1867, J. Monier, owner of French nursery garden, has patented concrete containers reinforced with metal frames for planting trees. His same patent then was used to patent another reinforced concrete structure such as reinforced pipes and tanks (1868), flat plates (1869), bridges (1873), and stairs (1875) (MacGregor, 1992).

Professors Mörsch and Bach of the University Of Stuttgart has carried out an experiment to test the strength of reinforced concrete and the method of computing the strength of reinforced concrete was developed Mr. Koenen, chief building inspector for Prussia. He published the first manuscript on the theory and design of concrete structures in 1886. In his book, he presented an analysis which assumed that the neutral axis was at the midheight of the member (MacGregor, 1992).

W.E. Ward, a mechanical engineer built the first reinforced concrete building in the United States in 1875. It was a house built on Long Island. In 1988, E.L. Ransome constructed a building having cast-iron columns and a reinforced concrete floor system consisting beams and slab made from flat metal arches covered with concrete. In 1890, Ransome built the Leland Stanford, Jr. Museum in San Francisco. This two-story building used discarded cable car rope as beam reinforcement. In 1903, he built the first building in the United States completely framed with reinforced concrete in Pennsylvania. In 1906, C.A.P. Turner developed the first flat slab without beams (MacGregor, 1992).

In the last two decades, many books, technical articles, and codes present the theories of mechanical behaviour of reinforced concrete and help the engineer came to understand the principles applied in design procedures. As in 1894, Coignet (son of the earlier Coignet) and de Tedeskko extended Koenen's theories to develop the working stress design method for flexure (MacGregor, 1992).

1.3 Problem Statement

Understanding on the behaviour of the reinforced concrete beams has become more important as it is a basis of ideas for designing a reinforced concrete member. Before proceeding to design process, a section should be analyzed to determine if its nominal resisting strength is adequate to carry the load applied to the member. However, because of a large numbers of parameters that should be considered in analysis, such as geometrical width, depth, area of reinforcement, steel strain, concrete strain, steel stress, and so on, computer programs are required to assist the analysis.

This project studies on the flexural behaviour of reinforced concrete beam with a computer model based on section analysis. Non-linear behaviour of materials are seldom considered in computer models, but it will be considered in this study.

1.4 Aim and Objectives

The main aim of this project is to model the flexural behaviour of reinforced concrete beams. Development of this model is made using Fortran 90 program. The flexural resistance will be calculated by using cross section analysis based on force equilibrium and compatibility. Deflection of the beam will be calculated by conjugate beam method based on curvature. Therefore, the load-deflection response is obtained. All calculation will be based on ACI Building Code (1999).

1.5 Chapter Overview

This project is divided into two parts. The first part consists of three chapters. Chapter 1 gives a brief introduction of reinforced concrete beam. Historical development of reinforced concrete, problem statement, aim and objectives, and chapter overviews are included. Chapter 2 presents computer programming background and reason argument about flexural behaviour of reinforced concrete beam. The method of analysis used in determining the flexural resistance and deflection are discussed in Chapter 3.

In the second part of this project, Chapter 4 gives the case scenario and based on this, the data given will be used in Fortran computation to get the flexural response. After the completion of the computational program, the results both from manual and Fortran computations are discussed. Chapter 5 presents the conclusions indicating the achievement of the aim and objectives of this project and some recommendations for future use.

CHAPTER 2

LITERATURE REVIEW

2.1 Computer Program and Engineering

The computer is the most important invention of the 20th century. A computer is a special type of machine that stores information and can perform mathematical calculations on that information at speeds much faster than human beings can think (Mayo and Martin, 1991). A program, which is stored in the computer's memory, tells the computer what sequence of calculations are required and which information to perform the calculations on.

Engineers and scientists were among the first large-scale computer users dating back to the earliest back of the invention of computers. Engineers use computers in many ways, but the software that they used usually falls into two broad categories. The first contains utilities, such as word processing and graphics programs, that are low-cost packages and require no programming. The second category includes programs devoted specifically to engineering applications. This requires that the engineers to write their own program. Sometimes it is possible to modify an existing program, but some programming is unavoidable. There are five major uses of computers in engineering such as modelling and simulations, data acquisition, data analysis, process control, and design.

There are various programming languages of interest to engineers. Table 2.1 list some of the programming languages and its strong points (Mayo and Martin, 1991).

Table 2.1: Partial list of programming languages of interest to engineers

Programming Languages	**Description**
a) FORTRAN	A compiled language widely used for engineering applications. Contains a full range of structured commands and uses of subroutines which promote good style. Periodic revisions update the language to include new advances.
b) BASIC`	An interpreted language primarily used for its simplicity. The lack of structured commands tends to produce the problematic spaghetti code. The structure of a subroutine using the GOSUB statement prevents development of long programs. Proprietary dialects, such as QuickBASIC eliminate some of these problems.
c) Pascal	A compiled language which utilizes structured constructs. Promotes good programming practice. Very good for handling nonnumeric data, but somewhat limited for computational work.
d) C	Very powerful compiled language which combines system level and high-level commands. Requires an advanced level of programming experience and can be somewhat difficult to debug. Debugging problems are most severe for lengthy programs.

2.2 Application of FORTRAN Programming Language in Civil Engineering

Programming language has been used in Civil Engineering in a variety of application. Computer program such as ABAQUS, ANSR, and FEAP were written in the FORTRAN computer language for the structural analysis (Austin et al. 1995). These programs offered a restricted, but well implemented, set of numerical linear/nonlinear time-history response calculations.

The LSTRLP algorithm is implemented by an optimization code written in Fortran 90 (Lamberti and Pappalettere, 2003). The optimization code is tested in eight cases of weight minimization of bar truss and frame structures. The Gauss–Legendre method was used for the numerical integration of each of the integrals. The system of non-linear equations (including contributions from all elements) was solved using FORTRAN. A good agreement between experimental and predicted data was obtained (Yamsaengsung and Moreira, 2001). In 2004, ESDU 90002 introduces a FORTRAN program, provided in both compiled and uncompiled forms as ESDUpac A9002, for calculating the flexural buckling strength, and the local and inter-rivet buckling stresses, of uniform section struts.