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ANALYSIS OF 2-D FRAMES USING THE STIFFNESS METHOD

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by

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Acknowledgments

I would like to thank Dr. Christis Chrysostomou, my diploma project supervisor, for his guidance and most valuable help.

I would like to dedicate this project to my parents.

Finally, I dedicate it to good friends.

Thank you all,

Orestis Marangos

PREFACE

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The object of the project was the development of a computer program for the analysis of two-dimensional frames using the stiffness method. In this report, the stiffness method formulation is presented in detail, providing all the relevant derivations from first principles. This report, follows a sequence that the author considered to be the most appropriate. Each chapter is connected with the previous chapters through a logical sequence, presenting new definitions every time, which finally lead to the stiffness method formulation.

The program presented in this report demonstrates how the stiffness method for two-dimensional frames can be implemented on a computer. It is not a commercial program. The program was developed on an IBM Personal Computer using the Microsoft Visual Basic 4.0 compiler. The program should run on most IBM PC-compatible systems under Windows 95 operating system. A user's manual of the program is included in the report as well as the program itself on floppy disk. Also, the listing of the program is available at the end of the report.

The author would like to emphasize that this report is not a computer-programming guide. Therefore, greatest weight was given to the formulation of the stiffness method and less in the presentation of the aspects of Visual Basic 4.0 as a programming language and as a compiler. Finally, anything that has been left out of the report, was considered by the author as out of scope.

INTRODUCTION

COMPUTERS AND STRUCTURAL ANALYSIS

Man from the beginning of time had the need to invent devices with which to perform calculations.

In the early ages, these counting devices were simple. The first such device is considered to be the *abacus*, originating from ancient Greece and Rome.

Throughout the centuries, these devices were improved. In 1623, *Wilhelm Schickard* (1592-1635) had designed and built a machine that would automatically add and subtract, multiply and divide with a minimum of manual intervention.

In the eighteenth century, *Charles Babbage* (1791-1871) developed *the Difference Engine*, a major advance in automatic machines. Later he conceived the *Analytic Engine* which he did not manage to materialize.

A century later, in the mid-1950s, major changes began to occur in computer technology with the introduction of a new tool called *digital computer*, otherwise known as a *von Neumann Machine*. John Louis Neumann (1903-1957) was the one who in 1945 described the logical design that would lead to simpler yet more powerful machines. Computers at that time, compared with present day computers were very slow and big in size.

Today, computers have become far more powerful, with large memories and fast processors. They are now used in almost every aspect of our lives, from guiding aircraft to word processing.

One of the pioneer areas in which computers are utilized is the field of Civil Engineering and particularly the area of structural analysis and design.

Many programs have been developed to assist the civil engineer to carry out his work efficiently and with minimal error.

Several structural analysis procedures have been developed which are well suited for application on digital computers. One of the early pioneers in forming structural analysis procedures was *J.H Argyris*, who showed that if structural analysis equations were expressed in matrix form, the entire computation process could be carried out by a series of simple matrix operations. Since then, most analysis procedures developed were based on the application of matrix operations and thus they are referred to *as matrix methods.*

The two most common matrix methods are the *stiffness or displacement method* and the *flexibility or force method.*

The stiffness method can be formulated in many different ways. The *direct stiffness method* seems to be the easiest for both programming and hand calculations. For this reason it has become the most common method of structural analysis. The analysis is carried out by first determining the force-displacement relations for each member. Then, equilibrium of the forces of each joint and compatibility of the joint displacements lead to equilibrium equations with the displacements as the unknowns. The joint displacements are found by solution of the equilibrium equations. The member end forces are then recovered from the member force-displacement relations.

It should be mentioned that for structures with a large number of members, analysis by hand calculations using the direct stiffness method proves to be a tedious procedure but when solved by a computer, becomes an easy task.

Programming the stiffness method, if done with some planning and with a little knowledge of the subtle aspects of bookkeeping does not present any particular difficulty.