STRUCTURAL DESIGN USING ADAPT-ABI SOFTWARE

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF ENGINEERING WITH HONOUR (CIVIL)

SCHOOL OF ENGINEERING AND INFORMATION TECHNOLOGY
UNIVERSITI MALAYSIA SABAH

2007

PUMS99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS@

JUDUL: STRUCTURAL DESIGN USING ADAPT-ABI SOFTWARE

IJAZAH: IJAZAH SARJANA KEJURUTERAAN DENGAN KEPUJIAN (CIVIL)

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ACKNOWLEDGEMENT

A very special thanks to Prof Madya Dr. S. Narayanan, my project supervisor who had supervised me and given lots of advice, guidance and help. Thank you for guidance, patience and tolerance.

My sincere thanks to Universiti Malaysia Sabah for providing me with all the necessary equipment and facilities. I would also like to thank Dr. TM Indra Mahlia from Department of Mechanical Engineering, Universiti Malaya for helping in getting some journal related to my studies.

Last but not least, I would like to thank my parents, siblings for their never ending support and motivation as well as encouragement. My sincere thanks for my friends who has been there by my side all the time during the project. Thanking God Almighty His blessings in making my task interesting and successful.

ABSTRAK

ADAPT ABI adalah direka khas untuk membuat analisis pembinaan jambatan secara bersegmen, seperti pembinaan kantilevel keseimbangan. Ia telah digunakan secara berleluasa serata dunia oleh jurutera-jurutera dari 60 negara. ABI menggunakan analisis elemen finite untuk menganalisis jambatan konkrit dan rangka bangunan semasa pembinaan dijalankan serta selepas struktur siap dibina. ABI boleh meramal sifat konkrit yang baru sahaja dituang, penjalaran, pengecutan, pengenduran semasa prategasan, pemantapan konkrit dan variasi dengan suhu. Ia juga dapat menunjukan momen, daya ricih, ketegangan dan kecacatan struktur semasa peringkat pembinaan. Selain pembinaan kantilevel keseimbangan, ia juga dapat digunakan untuk pembinaan secara berperingkat. Aplikasi lain seperti kerja-kerja pembaikan rangka konkrit dengan penampalan konkrit, penambahan struktur baru ataupun pengubahsuaian dan pemusnahan rangka struktur. Perisian ini juga dapat menganalisis pembinaan komposit dan jambatan berkabel besi. Oleh itu, ADAPT ABI merupakan sebuah perisian anlisis yang canggih dan lengkap.

ABSTRACT

ADAPT-ABI has been specifically developed for the analysis and design of segmentally constructed bridges, such as balanced cantilever construction. It has been serving the bridge engineers in over sixty countries across the globe. DAPTAB has been used in design of many notable bridges worldwide. ADAPT-ABI is a finite element program which is tailored to perform time dependent analysis of concrete bridges and frames, during the construction phase and after the structure is complete. ABI can investigate the effects of newly placed concrete, creep, shrinkage, relaxation in prestressing over time, aging of concrete, and variation in temperature. Its powerful graphical interface can display moments, shears, stresses and deformations for various stages of construction. The software can handle non prestressed concrete, precast, cast-in place, pre-tensioned or post-tensioned frames and is specifically suited for the design and analysis of balanced cantilever construction, incrementally launched bridges, span-by-span construction, and other segmentally built bridges. Other applications include retrofit of concrete frames where new concrete is added, new members are added or existing members are modified; and demolition (reverse construction) of frames. The software also handles composite construction and cable-stayed bridges. The basic module of the software ADAPT-ABI Basic is self-contained and complete.

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CHAPTER 1

INTRODUCTION

1.1 Overview

With the fast advancement of science and technologies in the 21st challenging century, the nature of construction and building technology is changing rapidly and the market is demanding more. At the same time, the economics of the industry are being challenged with the goal of controlling the costs of construction. These external changes are having a fundamental impact on how the industry operates, approaches construction processes and a dynamic structural analysis is required. It is critical for the researchers and engineers to continually create new innovative products and solutions to meet the needs of expanding market. Once a very conservative industry, where innovation was measured incrementally over many years, construction is quickly becoming a technology-driven, specialized and sophisticated business that is demanding a highly knowledge of structural analysis and skills of time-and-cost-saving to meet these challenges.

ADAPT-ABI Version 4.04 is a special-purpose program developed for the design and analysis of prestressed concrete bridges built either segmentally or conventionally. It provides information for geometry and stress control during construction, as well as design values for service load. ADAPT-ABI has been serving bridge design engineers worldwide for over fifteen years, and has provided the foundation for analysis of many notable bridges.

1.2 Objective

The objectives of this project are:

I. To model simple structure (simple supported beam, truss and simple prestressed beam) using Adapt-ABI and validate the results.

II. To model a bridge girder for analysis.

III. To determine the different spans of the girder based on the permissible stresses.

1.3 Scope of Study

The primary objective of the study was to develop a comprehensive understanding design of prestressed concrete bridge using ADAPT-ABI software. It was intended that this understanding would then form the basis for structural analysis design.

The work will be limited to the objectives mentioned. It includes parametric studies of different spans.

1.4 Organization of Chapters

Some basic knowledge on this thesis title will be discussed in Chapter 2. It includes different kind of loadings will be generally considered in structural analysis, methods of prestressing, prestressing steel and the advantages of the prestressed concrete. Besides, Adapt ABI will be also discussed based on some literatures available.

Chapter 3 will illustrates some command syntax of the ABI software and the methodology to accomplish the objective of the project. The outcome of the analysis and discussion will be detailed in the Chapter 4 and the conclusion will be presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a basic knowledge of structural analysis will be discussed. Therefore different kind of loading to be used in analysis will be discussed as well. Since major part of the ABI software is dealing with prestressed concrete girder, different method and advantages of prestressing will be discussed. Adapt ABI software will be studied through some literature available.

2.1 Introduction

Structural engineering is the art of planning, designing and constructing to produce a safe and economic structure which suit to the intended purposes. Structural analysis is an important part of structural engineering project to estimate the loading and ensure the performance of the proposed structure having adequate safety against the limit states.

There are consisting of two principal limit states: ultimate limit state and the serviceable limit state. The ultimate limit state is reached when the structure collapses. An adequate factor of safety is used to design purposes so that the structure can withstand the loading condition without collapse.

The serviceability limit states are those for deflection and cracking. Therefore in design state, it is required that the appearance, durability and the performance of the structure must not be affected by the deflection and cracking. Some of the serviceability limit states such as durability, fire resistant, excessive vibration and fatigue are also be considered to suit the structure's intended purposes.

In a designing project, there are several steps that are regularly followed. A flowchart showing the various phases of a typical structural engineering project is presented in Fig. 2.1. In the diagram indicated, the process is an iterative, and it generally consists of the following steps:

1. Planning phase
2. Preliminary structure design
3. Estimation of loads
4. Structural analysis
5. Safety and serviceability checks
6. Revised structural design

1. Planning Phase

The planning phase usually involves the establishment of the functional requirements of the proposed structure, the general layout and dimensions of the structure, consideration of the possible types of structures (e.g., rigid frame or truss) that may be feasible and the types of materials to be used (e.g., structural steel or reinforced concrete). Besides, this phase may also involve consideration of nonstructural factors, such as aesthetics, environmental impact of the structure, and so on.

The purpose of this phase is making sure that the structural system complies with the functional requirements and the most economic design. This phase is the most crucial part of the entire project and requires experience and knowledge of construction practices in order to having a good understanding of the behavior of structures.

2. Preliminary Structural Design

In the preliminary structural design phase, the sizes of the various members of the structural system selected in the planning phase are estimated based on approximate analysis, past experience, and code requirements. The member sizes thus selected are used in the next phase to estimate the weight of the structure.

3. Estimation of Loads

Estimation of loads involves determination of all the loads that can be expected to act on the structure such as imposed load, dead load, wind load and impact load.

4. Structural Analysis

After identified all the loading condition and the size of the members of the structural system, the values of the loads are used to carry out an analysis of the structure in order to determine the stresses or stress resultants in the members and the deflections at various points of the structure in structural analysis.

5. Safety and Serviceability Checks

The results of the analysis are then used to determine whether the structure is satisfying the safety and serviceability requirements of the design codes. If these requirements are satisfied, then the design drawings and the construction specifications are prepared, and the construction phase begins.

6. Revised Structural Design

If the code requirements are not satisfied, then the member sizes are revised, and phases 3 through 5 are repeated until all the safety and serviceability requirements are satisfied.

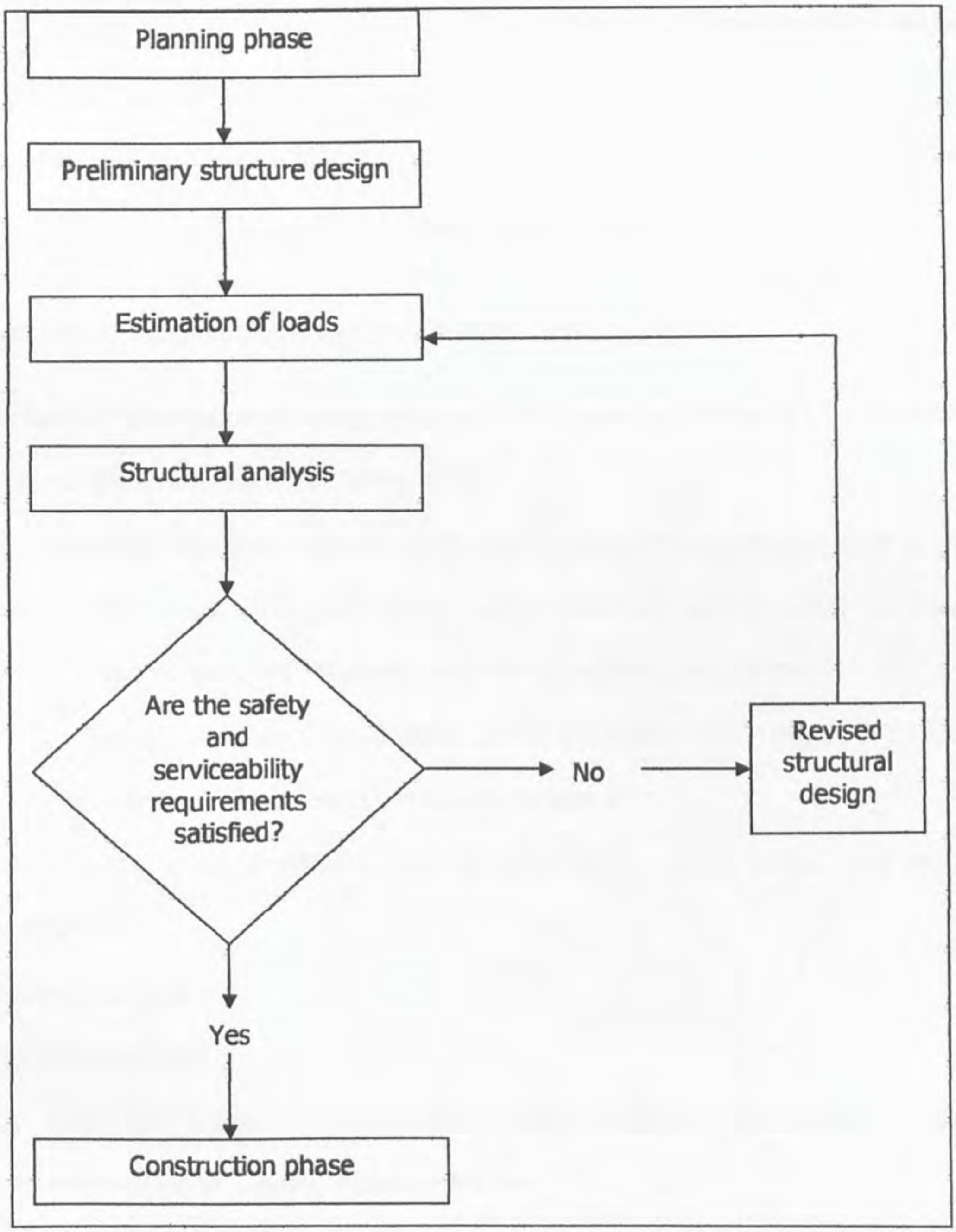

Figure 2.1 Phases of a Typical Structural Engineering Project (Kassimali. 2005)

2.1.1 Load

Design loads shall consist of dead load, live load, impact, and in addition, loads due to water table, and any other loads which may be imposed upon the structure.

In the design of bridge structure components, the engineer should consider all loads which the component must resist.

The load considered for design for each limit state known as design load is a combination of characteristic load and partial factor of safety (γ_f).

Design load = Characteristic load x Partial factor of safety (γ_f).

The value of partial factor of safety is based on the importance of the limit state and the accuracy of the predicting load. (Sinha, 2002)

Therefore structural analysis is the prediction of the performance of a given structure under prescribed loads and/or other external effects, such as support movements and temperature changes, using the appropriate load factor.

The performance characteristics due to strength of the material and load on a structure commonly of interest in the design analysis are:

(1) stresses or stress resultants, such as axial forces, shear forces, and bending moments;

(2) deflections; and

(3) support reactions.

Thus, the analysis of a structure usually involves determination of these elements as caused by a given loading condition.

Determination of various loads that will impose to a structure is based on the dimensional requirements of a structure defined. For instant, high-rise structures must be able to resist large lateral loadings due to wind, and therefore shear walls and tubular frame systems are provided, whereas buildings located in earthquake zone must be designed for ductile frames and connections.

Once the structural form has been determined, the actual design begins with those elements that are subjected to the primary loads the structure is intended to carry, and proceeds in sequence to the various supporting members until the foundation is reached. Thus, a building floor slab would be designed first, followed by the supporting beams, columns, and last, the foundation footings. In order to design a structure, it is therefore necessary to first specify the loads that act on it.

2.1.2 Dead Load

Dead load usually categorized as permanent load due to its weight of the various structural members such as beam, column, floor slab, roofing, girder, wall, window, electrical fixtures, plumbing and other miscellaneous attachments are permanently attached to the structure.

In some of the cases, a structural dead load can be estimated satisfactorily from simple formulas based on the weights and sizes of similar structures. Sometimes the dead load may also be determined through the experience of previous work done. For example, the average weight for timber buildings is 1.9-2.4 kN/m^2, for steel framed buildings it is 2.9-3.6 kN/m^2, and for reinforced concrete buildings it is 110-130 lb/ft^2 5.3-6.2 kN/m^2. Once the materials and sizes of the various components of the structure are determined, their weights can also be found from tables that list their densities.

2.1.3 Live Load

Live load of a structure is caused by the weight of object temporarily placed on it, moving vehicles, or natural forces. The minimum live loads for various types of building are specified in codes which have additional protection against excessive deflection or sudden overload.

Design live loadings for highway and railway bridges are specified in the code of the BS5400: Part 2. This code specifies wheel loadings and spacing for different types of trucks and trains. For the design purposes, the maximum value of the live load stress in the bridge member is calculated by placing a series of vehicle loads back to back within critical regions of the bridge.

2.2 Prestressed Concrete

Professor Magnel's explanation of the principle of prestressing.

Professor Magnel teaching prestressed concrete.

Figure 2.2 Professor Gustave Magnel (1885-1955) of Belgium gave lectures to engineers in the US and Canada in the mid 1940's to the early 1950's.

The design of the bridge was based on European prestressing technology and design methods introduced to North America after the Second World War. Professor Gustave

Magnel (1885-1955) of Belgium gave lectures to engineers in the US and Canada in the mid 1940's to the early 1950's. Magnel's book "Prestressed Concrete" attracted considerable interest in North America of the potential for prestressed concrete. (http://www.cpci.ca)

Nowadays prestressed concrete is one of the most reliable, durable, and widely used construction materials in building and bridge projects. It has made significant contributions to the construction industry, the precast manufacturing industry, and the cement industry.

Prestressed concrete is good in bending force compare to ordinary reinforced concrete. Loads which are carried in a member by bending are effectively transferred through it as compressive and tensile forces, as illustrated in Fig. 2.3. Because of the low tensile strength of concrete, steel reinforcement must be provided in all structural concrete members subjected to such bending forces to control tensile cracking and, ultimately, to prevent failure.

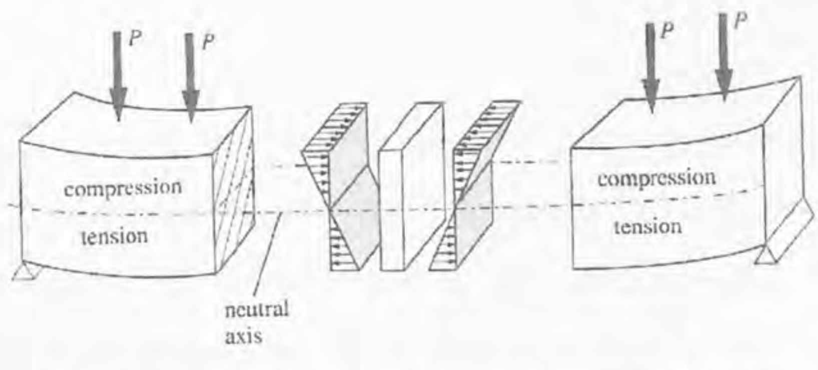

Fig. 2.3 Stresses due to bending in a beam (O'Brien,1995)

In ordinary reinforced concrete, steel bars are placed within the tension zones of concrete members to carry internal tensile forces across flexural cracks to the supports.

Therefore in such a member, the applied moment is resisted by compression of the uncracked portion of the concrete section and by tension in the reinforcing bars.

A common problem encountered by the ordinary reinforced concrete is corrosion which is due to the exposure of reinforcement bar to water and chemical substances through the cracks occur on the concrete surface. However this problem is generally only important for structures with aggressive exterior environments such as bridges, marine structures, and so on. It is not critical in the majority of buildings.

Furthermore, cracking of ordinary reinforced members may also contribute to substantial loss in stiffness. The second moment of area of the cracked section is far less than the second moment of area before cracking. Thus, allowing cracks to develop and may cause greater deformation of the member.

To overcome this matter, prestressed concrete is an alternative form of reinforced concrete. In prestressed concrete, compressive stresses are introduced into a member to reduce the tensile stresses which result from bending due to the applied loads. The tensioned steel is anchored at the ends of the members and/or bonded to the concrete.

A simply supported beam illustrated in the Fig. 2.4(a) is encountered an applied load at a given section of the member which has generate a bending stress distribution illustrated in the figure. Cracking will forms in the particular section when the maximum tensile stress, $\sigma_{app,t}$ exceeds the tensile strength of the concrete. If there is no reinforcement, the crack will propagate until the failure of concrete is reached.

By introducing a steel tendon running along the centroid of the member, tensioned to a force of *P* and anchored at its ends (Fig. 2.4(b)), it will creates a stress distribution illustrated. When the stress is combined with the stress due to applied

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