ANALYSIS AND DESIGN OF STRUCTURAL ELEMENTS FOR A 5- STOREY RESIDENTIAL BUILDING

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ANALYSIS AND DESIGN OF STRUCTURAL ELEMENTS FOR A 5-STOREY RESIDENTIAL BUILDING

by
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APPROVAL SHEET

This project report attached here to, entitled "Analysis and Design of Structural Elements for a 5-storey Residential Building" prepared and submitted by Cheng Hock Tian in partial fulfillment of the requirements for the degree of Bachelor of Engineering (Civil) is hereby accepted.

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ABSTRACT

The project presented herein is the design of main structural elements for a 5-storey residential building namely beams, slabs and columns using various softwares for design and comparison purposes. In reinforced concrete beam design, 3 critical beams had been chosen amongst approximate 450 beams for structural analysis and design. Similarly, a critical continuous 5-span slab with different cross sections at interval was selected for reinforced concrete slab design. Eventually, one critical external column and one critical internal column were selected as typical columns for reinforced concrete column design.

At fourth floor, a 9-span continuous beam marked as '4B26' to '4B34' was chosen as one of the critical beam. This was followed by an overhanging 2-span continuous beam marked as 'TB55' and 'TB56' with both spans of different cross sections. Finally, the last continuous beam marked as '4B80' to '4B81' was selected which comprised of two spans where each span supported a stiffener.

For the analysis and design purposes, 3 structural softwares were adopted for beam design to BS 8110 (1985) code of practices. Two of them are *Cbeam* and *AxisVm Ver.5.0*. Output results from these two softwares were studied and compared. Since these two softwares had no design function, another software, Reinforced Concrete Council, RCC spreadsheet (*RCC11 Element Design*) was selected as an alternative software for the beam design.

Another two different softwares were used to design reinforced concrete slabs. They are Reinforced Concrete Council, RCC spreadsheet [*RCC94 Two-Way Slabs*

(Tables)] and Staad III *Iteractive Design Rel. 22.3W 32-bit*. The latter software designs slabs to ACI 318 (1995) code requirements while RCC spreadsheet designs slabs to BS 8110 (1985) code. A continuous slab marked as 'S3' to 'S7' located at typical floor was designed using both softwares. Likewise, comparison of output results yielded by these two softwares was carried out thereafter.

Similarly, two spreadsheets were used in the design of reinforced concrete columns. The first one is the Reinforced Concrete Council, RCC spreadsheet (*RCC54 Column Design*) which designs columns to BS 8110 (1985) standard while the other spreadsheet known as *ShortCol* designs column to ACI 318 (1995) code requirement. The output results from both spreadsheets were analyzed and commented accordingly.

ABSTRAK

Projek ini merekabentuk 3 elemen struktur utama bagi 5 tingkat pangsapuri 'Class G' iaitu rasuk, papak dan tiang dengan menggunakan pelbagai perisian komputer untuk tujuan rekabentuk dan perbandingan keputusan. Dalam merekabentuk rasuk konkrit bertetulang, 3 rasuk kritikal telah dipilih antara kira-kira 450 rasuk unutk tujuan analisa struktur. Selain itu, satu papak ala-berterusan 5 rentang yang mempunyai keratan rentas berbeza-beza di antara satu sama lain telah dipilih untuk merekabentuk papak konkrit bertetulang. Akhir sekali, satu tiang bahagian luar dan satu tiang bahagian dalam bangunan akan dijadikan tiang tipikal untuk merekabentuk tiang konkrit bertetulang.

Di tingkat keempat bangunan tersebut, rasuk ala-berterusan yang terdiri daripada 9 rentang ditanda dari '4B26' ke '4B34' telah dipilih sebagai salah satu rasuk kritikal. Ia diikuti oleh rasuk separuh sokong tepi ditanda 'TB55' dan 'TB56' di mana keratan rentas kedua-dua rentang tersebut adalah berlainan. Akhir sekali, rasuk ala-berterusan ditanda '4B80' dan '4B81' telah dipilih di mana ia terdiri daripada 2 rentang dengan setiap rentang menyokong satu tiang rentas tingkat.

Selain itu, 3 perisian struktur telah digunakan dalam rekabentuk rasuk mengikut piawai kode BS 8110 (1985). 2 daripada perisian struktur itu ialah Cbeam dan AxisVm Ver.5.0 . Keputusan keluaran daripada kedua-dua perisian ini akan dikaji dan kerja-kerja perbandingan keputusan akan dijalankan sejurus selepas itu. Oleh kerana kedua-dua perisian ini tidak membekalkan sebarang rekabantuk tetulang bagi rasuk, maka Reinforced Concrete Council, RCC spreadsheet (RCC 11 Element Design) telah dipilih

sebagai perisian alternatif bagi mengira bilangan besi tetulang untuk rasuk-rasuk tersebut supaya dapat menghabiskan seluruh rekabentuk rasuk dengan lebih sempurna.

2 lagi perisian telah diperoleh daripada tapak jaringan komputer untuk merekabentuk konkrit bertetulang bagi papak. Kedua-dua perisian ini adalah Reinforced Concrete council, RCC spreadsheet [RCC94 Two-way slabs (Tables)] dan Staad III Iteractive Design Rel. 22.3 w 32-bit. Perisian yang kedua disebut itu merekabentuk papak berdasarkan keperluan kode ACI 318 (1995) manakala Reinforced Concrete Council, RCC spreadsheet [RCC94 Two-way slabs (Tables)] merekabentukl papak mengikuti piawai kode BS 8110 (1985). Satu papak ala-berterusan ditanda dari 'S3' ke 'S7' yang berada di tingkat tipikal akan direkabantuk menggunakan kedua-dua perisian tersebut. Sama seperti rekabentuk rasuk, perbandingan keputusan keluaran akan dilaksanakan selepas itu.

Tambahan pula, 2 perisian akan terlibat dalam merekabentuk konkrit bertetulang untuk tiang. Perisian pertama adalah Reinforced Concrete Council, RCC spreadsheet (RCC54 Column Design) di mana ia merekabentuk tiang mengikut piawai kod BS 8110 (1985) manakala perisian kedua yang dikenali ShortCol merekabentuk tiang berdasarkan keperluan kod ACI 318 (1995). Keputusan keluaran daripada kedua-dua perisian akan dianalisa dan diberi komen selepas kerja-kerja perbandingan dilakukan.

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CHAPTER 1

INTRODUCTION

1.1 General

There are many softwares developed by firms, organizations, group of software developers as well as individuals. Some of them are user-friendly and the output results are reliable as well. Most the softwares developers provide trial Demo version but these softwares may contain analysis limitation. However, freewares for structural concrete design also available for public distribution on internet. Normally, these softwares are developed by non-profit organization with financial support from both government and private agencies.

A total of seven softwares are downloaded from engineering freewares website except *AxisVM Ver.5.0* and *Staad III* where all of them play an important role in this design project. Amongst them, three softwares were used in reinforced concrete beams design, two softwares for reinforced concrete slabs design and the remaining two softwares run the reinforced concrete columns design. All output results generated by these softwares would be studied and the differences, if available, would be figured out and comparison between output results were to be done accordingly thereafter. Two widely practiced codes namely BS 8110 (1985) and ACI 318 (1995) which incorporated in these softwares would become the main reference sources particularly during output results comparison and discussion tasks. Reasons and causes contributed to output differences would be identified and generalized conclusion would be drawn eventually.

1.2 Project Review

The proposed Royal Malaysia Naval Base at Teluk Sepangar, Kota Kinabalu, Sabah will become the biggest naval base throughout Malaysia. There are eight phases of building construction works where it will take approximately five years to complete. The 8 packages of design projects are residentials (15 buildings), workshops & stores (11 buildings), offices (7 buildings), community buildings (7 buildings), recreations (5 buildings), trainings (7 buildings), naval air station (4 buildings) and hospital (1 building).

Defence Ministry is recruiting more and more amateur naval armed forces troops yearly. The authority faces shortage of accommodation facilities in Sabah. In order to temporary eradicates this residential problem, expenses have been allotted in building residential flats.

The design project namely 5-storey residential building is one of the highest buildings in package 1 (Residential phase). The building which consists of three apartments in each storey making a total of twelve apartments for the whole block is 17.5m in height. The height of each storey including the car park basement (also known as ground floor) is 3.2 m. The length and the width of the building is 37m and 14.1m respectively hence the total area of the whole building is 521.7m^2 on ground surface. An apartment which takes up a total area of 173.9m^2 has three bedrooms, two toilets, one living/dining room, one kitchen, one utility room, one store room and one balcony. The residential building which takes approximate eight months to complete can accommodate seventy-two people for the whole block.

1.3 Softwares Overview

There were altogether seven softwares used in designing this 5-storey residential building. Most of them are freewares downloaded from websites. Brief descriptions on these softwares are as follows.

Reinforced Concrete Council was founded in 1988 to promote knowledge and understanding of efficient reinforced concrete design and construction. Publications from the council include design guides, newsletters, videos, articles and many reading materials in electronics forms. The council offers a CD with twenty-six Excel spreadsheets files for design structural elements to BS 8110 (1985) code. This CD can be obtained free of charge from the council. As far as this project was concerned, *RCC11 Element Design*, *RCC94 Two-way Slabs (Tables)* and *RCC53 Column Design* were used for structural elements design of this 5-storey residential building.

ShortCol is a spreadsheet written by Yakov Polyakov, P.E. and it is distributed free of charge in website entitled "Spreadsheet Solution For Structural Engineer". It is an Excel template used to generate iteraction diagram for short reinforced concrete column of rectangular cross section. This spreadsheet design is based on ACI 318 (1995) code requirements and AASHTO codes of practices. Both SI and English units are adopted for the design. In this design project, *ShortCol* was used to generate iteraction diagrams for two critical columns.

Staad III is a structural analysis software developed by Research Engineer, a netGuru company incorporated in 1981. Currently, the headquarter is situated in Yorba Linda, California. Staad III provides 2D/3D graphical model generation using Finite

Element Analysis method. In this project, Staad III *Iteractive Design VER 22.3 w* was used for slabs design to ACI 318 (1995) code requirements.

Cbeam is a software used for structural analysis of continuous beams operating under MS DOS environment. It was developed by BenArit Ltd and the author is Eli Ben-Ari. The software can run analysis up to nine spanning beam with different cross sections at interval. However, the software can only generate bending moment envelopes and shear force envelopes using moment distribution method without computation of reinforcements. It was used to generate both above-mentioned envelopes for three critical beams in this design project.

AxisVm Ver.5.0 is a high productivity Finite Element Analysis software tool for civil engineers. It had been applied in design for international airports, steel microwave towers, mega-shopping complexes, fire stations and many other construction projects in European countries. The software was designed by a team of civil engineers under registered trademark of Inter-CAD Kft. since 1991. In this design project, *AxisVm Ver. 5.0* was used to obtain the shear force envelopes and bending moment envelopes of three critical beams.

1.4 Objectives

The main objective of this design project is to carry out structural analysis and reinforced concrete design for beams, slabs and columns using various softwares. Output results generated by these softwares will be compared and general conclusion pertaining this design project will be drawn subsequently.

CHAPTER 2

DESIGN OF STRUCTURAL ELEMENTS

2.1 Structural Elements Design Considerations for 5-Storey Residential Building

The economical design was to be carried out with consideration for architectural esthetical aspects. In order to fully utilize the available budget, there were a mutual agreement between the developer and client on some design matters by imposing some design restriction on beams, slabs, and columns on the building.

There were about 90 beams in each floor which make a total of approximate 450 beams for the whole block. Beam sizes for the design was kept at maximum 200mm x 500mm except for ground floor beam which may reach until 200mm x 600mm maximum. The maximum length for beam span was 6m. The type of reinforcements used during construction was high yield tensile hot rolled steels (Y type steels). A maximum of three layers of 2Y16 were restricted for beam 150mm in width regardless of beam height.

Furthermore, the maximum number and size of bars to be used were 3Y25 for beam width of 200mm and 250mm but could be provided into layers. The shear link was always kept at R8 size where it might reach 2R8-75 in some critical cases. If there was a drop of slab from higher level to lower level, staggered design was expected on beam underneath with beam soffits remained at the same level throughout the whole continuous beam.

For slab design, the maximum depth of each slab was 115mm (for economical purpose). Slab reinforcements were to be kept at size of Y10-200 and Y10-200 for top and bottom steel respectively.

There were nine stiffeners supporting the roof excluding additional supports from columns. The stiffeners were sat on fourth floor beams. The maximum cross-sectional area for each stiffener was 150mm x 150mm. Staggered columns were to be designed as well where their sizes gradually increased from roof to ground floor. As far as possible, column width was to be kept at maximum 200mm from first floor onwards until 4th floor. This was to enhance the esthetical aspect for interior renovation later on since the kicker cause by the width of a column was only 50mm.

2.2 Reinforced Concrete Slabs and Beams Design Procedures

2.2.1 Slabs Design Method

For this particular project, slabs were analyzed one after another by two softwares although they were continuously connected. Lets take a 3-span slab as an example as shown in Fig. 2.1. The design in this project was different as what was conventionally done whereby these types of continuous joined slabs were supposed to be designed continuous on a 3-span basis as shown in Fig. 2.1(a). Contrary, as far as this project was concerned, all slabs were treated individually where every single slab was to be designed simply supported as shown in Fig. 2.1(b). This kind of design was adopted to save time and design efforts since less tedious design jobs were to be done. Moreover, restriction on reinforcements that had been discussed earlier in which top steels and bottom steels for all slabs were set at Y10-200 and Y10-200 respectively also accounted for this type of design.

Referring to Fig. 2.1, the continuous edge between slab marked as 'S1' and 'S2' needed less reinforcements since reinforcements here could be reduced according to code requirements. In this case, the design still adhered to the type of reinforcements stated above for top steels and bottom steels.

However, it was to be noted that some big heavy slabs might need more reinforcements. In this case, such a slab was supposed to be split into two small slabs in between by adding an extra beam underneath. Such amendment was carried out in order to fit the above-mentioned reinforcements into all slabs of the building eventually.