COMPARISON ON STRUCTURAL DESIGN USING THREE (3) STRUCTURAL SOFTWARES

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Comparison on Structural Design Using Three (3) Structural Softwares

by

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CERTIFICATION OF APPROVAL

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Approved by,

____

(AP Dr. Madzlan bin Napiah)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NOORFAKHRIAH BINTI YAAKUB

ABSTRACT

A rapid development within the field of civil engineering structural design methods and techniques and software designs that has taken place over the last years offers new possibilities for designers of structural design through the use of Building Information Modeling (BIM) concept. The concept of generating computable data set of building and modeling in the construction industry is very definite. With a lot of softwares available in the market for structural consulting firms to choose, there is a need to find the software that produce optimum results. For this approach, a same structural design is done using three different softwares, namely Esteem, Orion, and STAAD Pro Structural Software, with fixed parameters to see the difference in the design output. In this case, a water tank structure architectural design is obtained and roughly designed before being transferred into the softwares. The designs include beam, column, slabs, and foundation where certain parameters such as element size and density are fixed in order to find the most powerful output.

This Final Year Project thesis is a theoretical work extracted from study material, ranges of codes of practice documents, and web-source referenced. The work was aimed towards giving a state-of-the-art introduction to software technology of structural design as well as comparing the use of the softwares in industry.

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The author wishes to take this opportunity to express her utmost gratitude to the individuals that have taken the time and effort to assist her in completing the Final Year Project throughout her final year. Without the cooperation of these individuals, no doubt the author would have faced some complications both major and minor throughout the course.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Structural design engineers have been using various structural softwares in aiding the design for their projects. The engineering softwares provide applicability for the structural engineers. These softwares are expected to produce analysis and design for certain structure and detect faults as well as failure so that the design engineer can improvise the design.

One of commonly used structural software is the Esteem Structural Design Software. The Esteem Structural Design is widely used in the consulting engineer offices as well as the developers. The software provides 2-D and 3D analysis design for the beams, columns, slabs, as well as the reinforced concrete wall. Most structural software now has BIM or Building Information Modeling where, not only that the user can observe the designed structure in 3-D view, he or she can also experience getting into the simulated structure and see information about the structure or where failure may occur.

Other famous structural software for consulting engineer in Malaysia would be the CSC Orion. CSC Orion is more complicated than the Esteem Structural Design software as it provides more detailed features when analyzing the structural design. This explains why CSC Orion is preferred for tall building design and for designing a complicated grid arrangement. Besides that, Orion software can be modeled initially in Autodesk Revit Structure. It means that, architectural drawing from Autodesk software can be directly transferred to Orion for editing by the design engineer, thus enhancing and speeding up the design process.

STAAD Pro is said to be the best method for the construction steel structure. No detail rebar needed, therefore the software produced results that are required only. Besides, this software provide broad range of design codes to be as reference, therefore, user can use this one software for various type of design. This means user don't have to use one software for modeling, another one for steel design, and yet another software to design the concrete beams, slabs, and foundation.

The use of software aid has been benefiting companies in term of time saving as well as increasing profitability where money is saved when high quality product is produced. Engineering software provides accurate measurement and come in various dimensions that are important in rendering of the designs.

1.2 PROBLEM STATEMENT

There are a lot of softwares in the market for structural engineers to choose depending on the quality and cost they are willing to spend. The structural design softwares create a functional, economic, and safe structure for public to reside, and are widely used to do the repetitive, lengthy and complicated calculations. However, the design engineer should not become too dependent on the softwares as they are merely tools to aid in designing structures.

The software calculations might be different from one another. For example, the Esteem Structural Design is using elastic method to obtain the reaction, not the area method students usually learnt in Structural Analysis course. The results might be a little different as two different methods are used, if the software user calculates manually using the area method. The results will then be different from other software's result of calculation, which should be the starting point of various resulting design produced by various softwares.

1.3 OBJECTIVE

At the end of this project, the comparison of the analysis and result of a water tank structural design using three (3) different structural softwares will be obtained. The results consist of difference in terms of:

1. Engineering Specification/Applicability
2. Structural Design and Detailing
3. User-friendliness of softwares

1.4 SCOPE OF WORK

The softwares involved in this project are:

1. Esteem Structural Software
2. CSC Orion
3. STAAD Pro

The softwares are expected to analyze the structural design of a water tank structure and come out with differing results in terms of engineering details. These will later on affect other factors such as quality, safety, cost, and others. The output of the software will be represented in drawings, detailing, and calculations.

1.5 RELEVANCY AND FEASIBILITY

This project is relevant to the structural design engineering field because it involves the usage of softwares which are being used in the industry. By comparing the results of the three softwares analysis and design, the findings would be one of a tool for the engineering firms to choose which software is the best for their business.

Besides, when doing the structural design, the author is also applying her theoretical knowledge learnt for the past few years in civil engineering courses.

This project is also feasible in terms of simplicity and availability of tools needed for the research. The author has to deal with the industry before getting hold of the softwares as well as the soft copies of architectural drawings, which is a good skill to practice.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 STRUCTURAL ENGINEERING AND DESIGN

Structural engineering, a specialty within civil engineering, is a field dealing with the design and analysis of structures that support or resist loads. Structural engineers are most commonly involved in the design of large modern buildings and similar structures and often specialize in particular fields, such as building engineering, bridge engineering, geotechnical engineering and highway engineering. Structural design of a reinforced concrete structure is a combination of beams, columns, slabs, walls, staircase, and foundations rigidly connected together to form a monolithic and indivisible frame. Each individual member must have the ability to resist the forces acting on it, so that the ascertainment of these forces is an essential component of the design process. The full design and analysis of a rigid concrete frame is mostly complicated, but simplified calculations of adequate accuracy can often be made if the basic action of the structure is understood.

The analysis must be performed with an evaluation of all the loads carried by the structure, such as roof load, floor load, and wall load for a typical structure including its own weight (beams, column, etc). The loads are usually not consistent in value and position, and the consideration must include all possible critical arrangement. First, the structure itself is rationalized into simplified forms that represent the load carrying action of the prototype.

According to Mosley (1999)

The forces in each member can be determined by one of the following methods:

1. Applying moment and shear coefficient;

2. Manual calculations;

3. Computer method

Tabulated coefficients are suitable for use only with simple, regular structures such as equal-span continuous beams carrying uniform loads. Manual calculations are possible for the vast majority if structures, but may be tedious for large or complicated ones. The computer can be an invaluable help in the analysis of even quite small frames, and for some calculations it is almost indispensable. However, the amount of output from a computer analysis is sometimes almost overwhelming; and then the results are most readily interpreted when they are presented diagrammatically by means of a graph plotter or other visual device.

2.2 BRIEF DESIGN CONSIDERATION

Basically, a simple and typical structural design consists of beams, columns, slabs, walls, staircase, and foundations design. The design specifications are listed in the BS8110 – Structural Use of Concrete and BS6399 – Loadings for Buildings.

Beam strength is more affected by its depth than its breadth. A suitable breadth may be a third or half of the beam depth; besides, if a beam is less than 150 mm wide, there may be difficulty in providing adequate side cover and space for the reinforcing bars. Figure 2.1 shows the typical dimension of beam design consisting of beam depth, breadth, as well as the concrete cover. Beam depth can be calculated using Equation 2.1:

[Beam depth, h = d + cover + t] Equation 2.1

where d is the effective depth

and t is the distance from the outside of the link to the centre of the tension bars

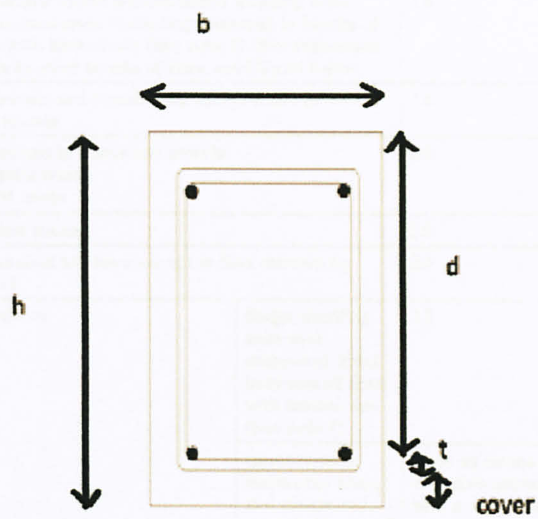

Figure 2.1: Beam Dimensions

Beam first live load is always considered zero. However, beam first dead load is taken as the beam self-weight and the Uniformly Distributed Load (UDL) from the floor and wall. Beams are considered fail if one or more of these criteria occur:

i) If tension reinforcement exceeds 4.0
ii) If compression reinforcement exceeds 2.0
iii) If deflection ratio is less than 1.0

Reinforced concrete slabs are used in floors, roofs, and building walls as well as the bridges decks. Slabs may span in one way or two way direction and are supported by beams, walls, or directly by the structure's columns. Slab imposed load is taken from Table 1 – Minimum Imposed Floor Loads of BS6399 – Part 1 (see Table 2.1). The loadings are distributed to the beams and columns using mesh properties as specified in the structural design softwares.

Table 2.1: Minimum Imposed Floor Loads

Table 1. Minimum imposed floor loads

Type of activity/occupancy for part of the building or structure	Examples of specific use		Uniformity distributed load kN/m²	Concentrated load kN
A Domestic and residential activities (Also see category C)	All usages within self-contained dwelling units Communal areas (including kitchens) in blocks of flats with limited use (See note 1) (For communal areas in other blocks of flats, see C3 and below)		1.5	1.4
	Bedrooms and dormitories except those in hotels and motels		1.5	1.8
	Bedrooms in hotels and motels Hospital wards Toilet areas		2.0	1.8
	Billiard rooms		2.0	2.7
	Communal kitchens except in flats covered by note 1		3.0	4.5
	Balconies	Single dwelling units and communal areas in blocks of flats with limited use (See note 1)	1.5	1.4
		Guest houses, residential clubs and communal areas in blocks of flats except as covered by note 1	Same as rooms to which they give access but with a minimum of 3.0	1.5/m run concentrated at the outer edge
		Hotels and motels	Same as rooms to which they give access but with a minimum of 4.0	1.5/m run concentrated at the outer edge
B Offices and work areas not covered elsewhere	Operating theatres, X-ray rooms, utility rooms		2.0	4.5
	Work rooms (light industrial) without storage		2.5	1.8
	Offices for general use		2.5	2.7
	Banking halls		3.0	2.7
	Kitchens, laundries, laboratories		3.0	4.5
	Rooms with mainframe computers or similar equipment		3.5	4.5
	Machinery halls, circulation spaces therein		4.0	4.5
	Projection rooms		5.0	To be determined for specific use
	Factories, workshops and similar buildings (general industrial)		5.0	4.5

Columns transfer the load from the beams and slabs down to the foundation and eventually to the ground. Although they may have to resist bending force due to structure continuity, columns are primarily considered as compression members of the structure. A braced and an unbraced column is differentiated by the lateral load resisted, which are walls or other bracing form restriction and column bending action restriction of lateral loads respectively. A structure is considered fail if the steel percent in the columns exceeds 6.0%.

Staircase designs consist of rise, going, waist, and steel detailing design (see Figure 2.2). It includes the analysis of moment reinforcement, shear resistance check and deflection check.

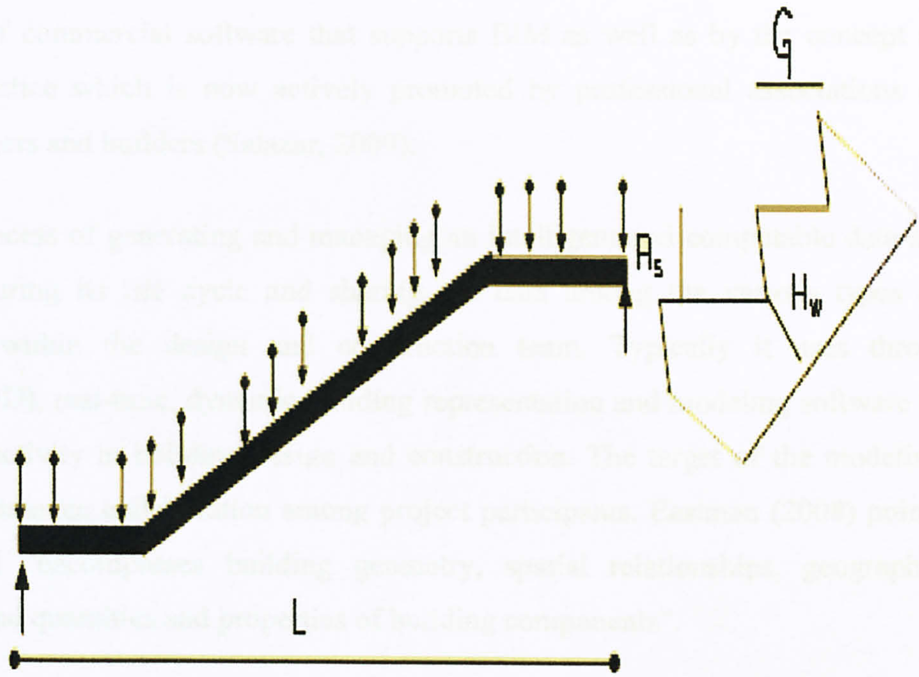

Figure 2.2: Rise (R), Going (G), and Waist (H) Length

For foundation design, the design engineer has to specify which type of foundation to be used, whether pad foundation, pile foundation, raft foundation or so on. Other method is to design all types of foundation and choose the most suitable one for the real construction, depending on the availability and cost factor.

Basically, a design engineer only has to roughly design a structure according to the specification, and export the input into structural design softwares. The softwares will then calculate and analyze the design, specify the failing criteria and list parts of structure that need modification. With this, the task of a design engineer is much more reduced, where cost and time consumed will be proportionally decreased as well.

2.3 BUILDING INFORMATION MODELING

The Architecture/Engineering/Construction (AEC) industry is showing an increasing interest in the concept of Building Information Modeling (BIM) and its applications (Fauerbach, 2007; Strafaci, 2008). This interest has been fuelled by the maturity and applicability of commercial software that supports BIM as well as by the concept of Integrated Practice which is now actively promoted by professional associations of owners, designers and builders (Salazar, 2009).

BIM is the process of generating and managing an intelligent and computable data set of building during its life cycle and sharing the data among the various types of professionals within the design and construction team. Typically it uses three-dimensional (3D), real-time, dynamic building representation and modeling software to increase productivity in building design and construction. The target of the modeling process is to enhance collaboration among project participants. Eastman (2008) points out that BIM "encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components".

Typically, architects and engineers create a 3-D model of a building or structure that is used for analysis and design. As stated by Fauerbach (2007), the model is shared among the various disciplines to improve design and avoid conflicts. (p. 2) For example, the mechanical engineer can use the model to design the Heating, Ventilating, and Air-Conditioning (HVAC) system and avoid interference with the structural system, and the architect and interior designer can use the model to adhere to *Leadership in Energy and Environmental Design (LEED)* standards for daylight.

In civil engineering, 3-D data is being shared and applied to various stages of project's lifecycle (see Figure 2.3). As a result, professionals from different fields are collaborating more and project data and information is being used in ways that benefit all parties involved in certain project. For example, for a highway construction project, a GIS is used for site planning and preliminary design which provide information such as soil classifications, locations of power line, nearby businesses, and traffic flow. The data is processed and shared with the civil engineer so that 3-D modeling detailed design can be produced. The design is then shared with the contractors for GPS machine control as well as the cost of construction. Next, the client will use these data for system integration so that it can be used for asset management and as data for planning future projects nearby.

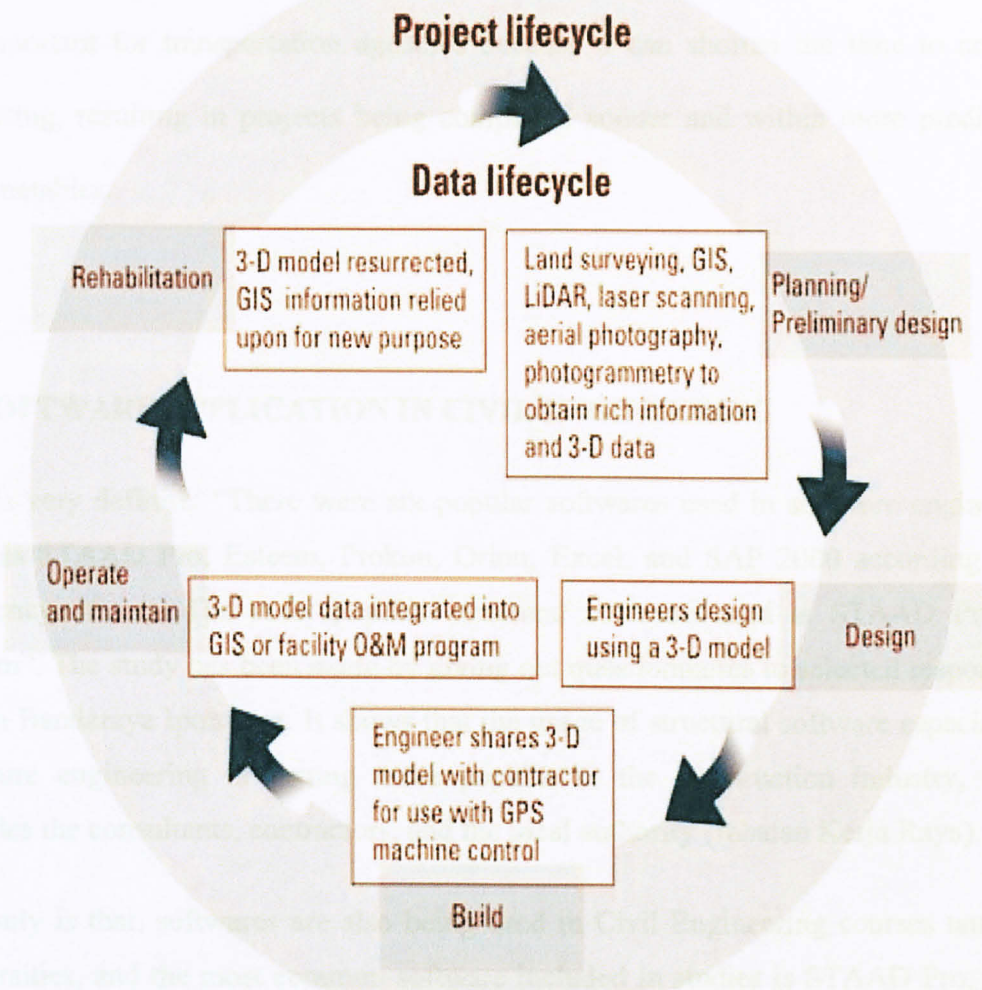

Figure 2.3: BIM Project Life Cycle, Fauerbach

Not all the steps in the Figure 2.3 project lifecycles are applied in civil engineering projects and the process of data sharing is not as simple. However, projects increasingly are applying some of the elements of this scenario, and keep on improving.

According to Strafaci (2008)

> The most immediate benefits of BIM are better designs and increased efficiency and productivity. Because design and construction documentation are dynamically linked, the time needed to evaluate more alternatives, execute design changes, and produce construction documentation is reduced significantly. This is particularly important for transportation agencies because it can shorten the time to contract letting, resulting in projects being completed sooner and within more predictable timetables.

2.4 SOFTWARE APPLICATION IN CIVIL ENGINEERING

Noh is very definite: "There were six popular softwares used in structure engineering such as STAAD Pro, Esteem, Prokon, Orion, Excel, and SAP 2000 according to its frequency of use. The most popular structural software used is STAAD Pro and Esteem". The study has been made by giving out questionnaires to selected respondents within Bandaraya Ipoh area. It shows that the usage of structural software especially in structure engineering is getting more popular in the construction industry, which includes the consultants, contractors, and the local authority (Jabatan Kerja Raya).

Not only is that, softwares are also being used in Civil Engineering courses taught in universities, and the most common software included in studies is STAAD Pro, which is said to be the most powerful software. "Research Engineers International (REI), a division of netGuru Inc. (Nasdaq:NGRU), providers of world class engineering software for structural design and analysis, announced that more than 300 licenses of its market-leading STAAD Pro structural design and analysis software has been purchased by leading engineering universities in Asia and the Middle East" (Yorba, 2002)

The universities that have designated STAAD.Pro as a standard teaching tool in their course within civil engineering departments since 2002 include University of the East and St. Luis College in the Philippines; Universiti Teknologi Malaysia (Johor), Universiti Tun Hussein Onn and Universiti Malaya (Sabah) in Malaysia; King Faisal University (Dammam) in Saudi Arabia; Sharjah University in Dubai; National Pintung University, National Chung Hshing University, Kaohsiung University (NKUAC), China Culture University and Ming Hsin Institute of Technology (MHIT) in Taiwan; and the Vocational Training Council in Hong Kong.

CHAPTER 3

METHODOLOGY

Procedures are developed as in Figure 3.1: Flow Chart of Project Methodology in order for this project to run smoothly and within the specified time.

3.1 RESEARCH

Firstly, research is done on the project title to see if the project is feasible for studies. Reading materials and reference are also acquired in subject of related softwares and their usage in the industry. Research includes internet research and going through publications (journals, symposium papers etc). The information is also used for literature review and discussion part in this paper.

Apart from having been used to Esteem Structural Software, the author has to learn on how to use the other two softwares before this project can proceed.

3.2 DATA GATHERING

Before proceeding with the use of structural software itself, an architectural design of a water tank structure must first be obtained. In this case, the author modified a design from a residential project during her internship in a consulting engineer firm. The modification includes editing the length of beams so that they are smaller and simpler in design.

Figure 3.2 shows the three dimensional view of proposed water tank structure.

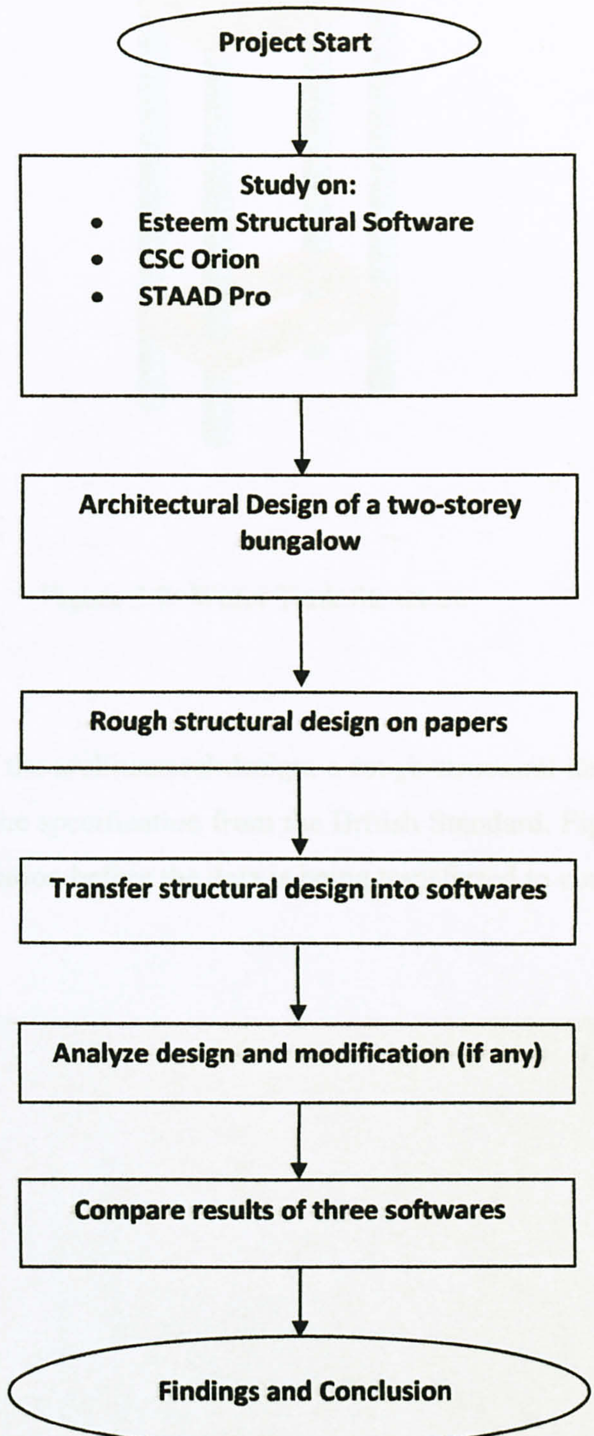

Figure 3.1: Flow Chart of Project Methodology

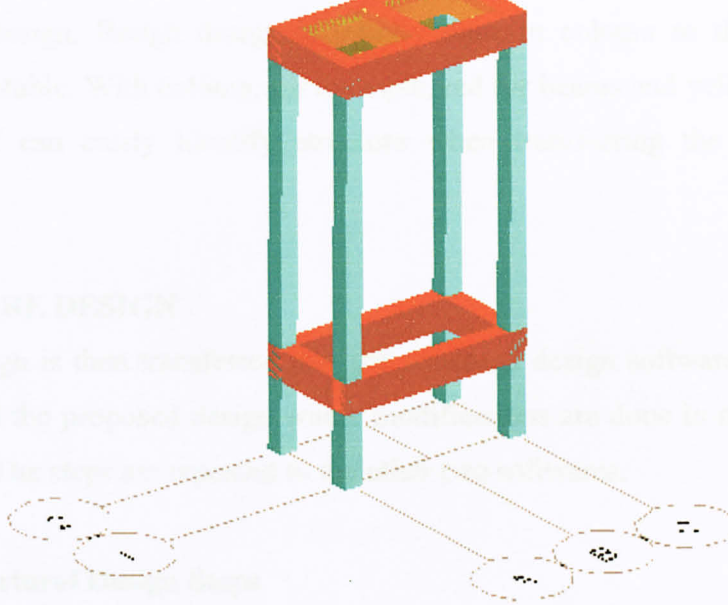

Figure 3.2: Water Tank Structure

3.3 ROUGH DESIGN

After familiarizing with the architectural design, a rough structural design is drafted on paper in accordance to the specification from the British Standard. Figure 3.3 shows an example of rough calculation before the data is being transferred to computer software.

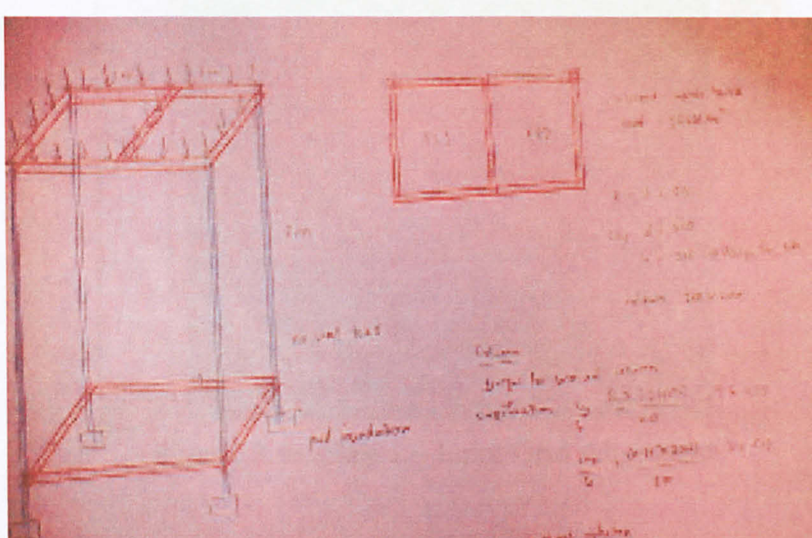

Figure 3.3: Rough Design on Paper

Grid alignments, beams, columns and slabs are proposed accordingly with the architectural design. Rough design is usually done in colours so that the drawings become presentable. With colours, for example, red for beams and yellow for slabs, the author herself can easily identify structure when transferring the details into the softwares.

3.4 SOFTWARE DESIGN

The draft design is then transferred into the structural design software which analyzed and calculated the proposed design where modifications are done in necessary parts of the structure. The steps are repeated to the other two softwares.

3.4.1 Structural Design Steps

Designs on Esteem include grids, beams, columns and slabs input in accordance to the architecture drawing. The author also has to input the parameters of each element before doing the analyzing part of the design. The steps of doing the structural design of water tank structure are shown in Figures 3.4a – 3.4d.

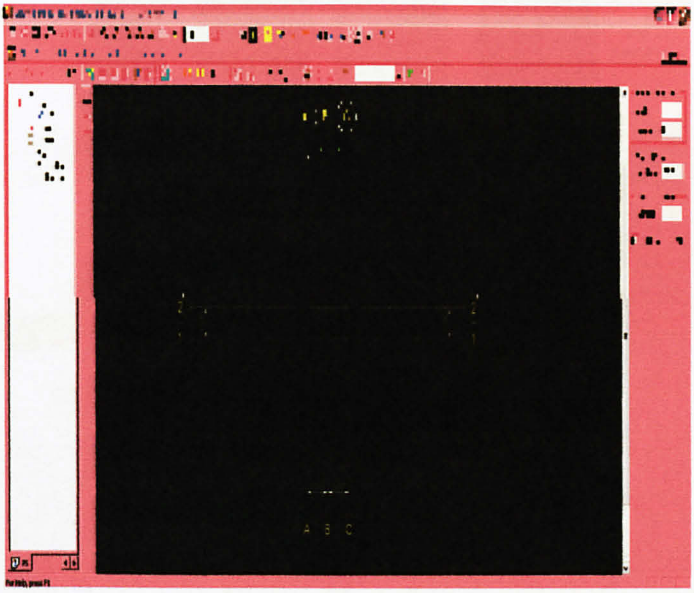

Figure 3.4a: Step 1 – Input Grid Alignment

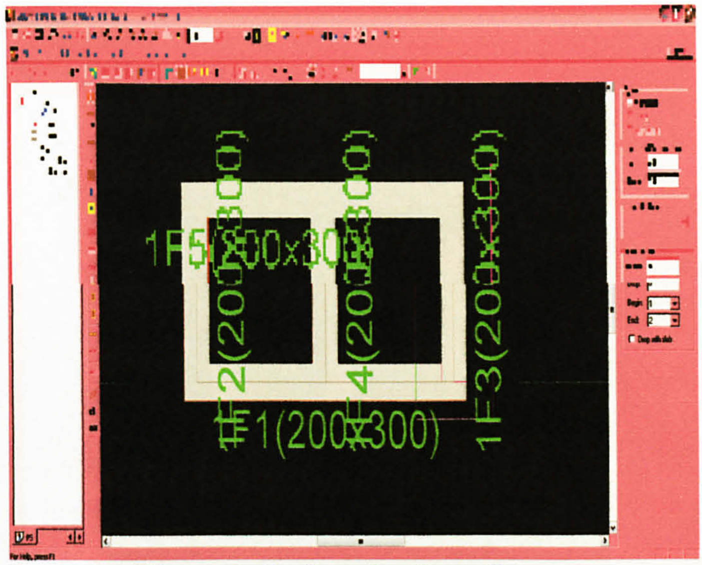

Figure 3.4b: Step 2 – Input Beam

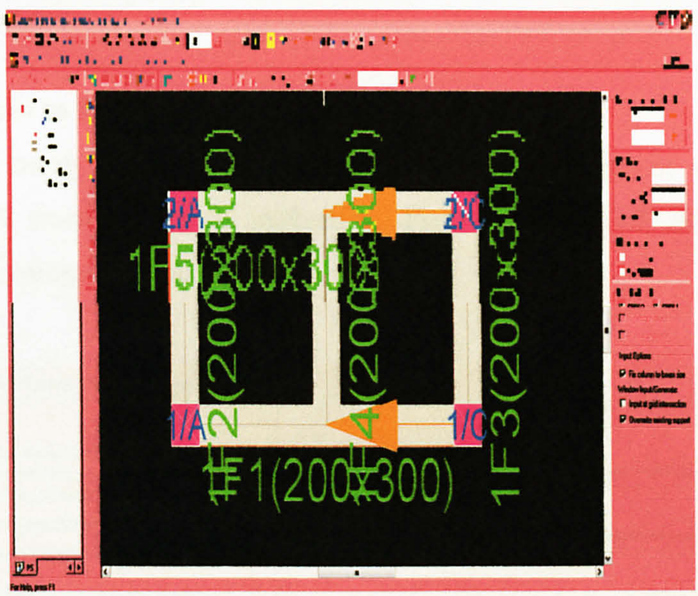

Figure 3.4c: Step 3 – Input Column

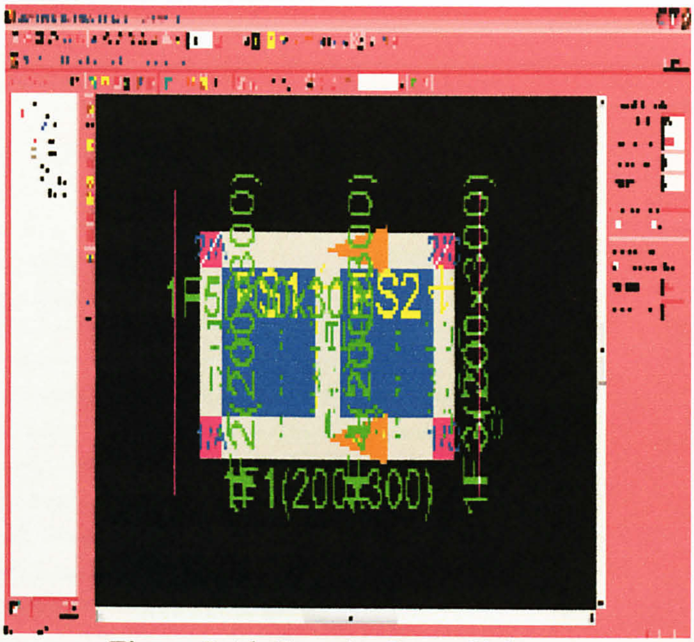

Figure 3.4d: Step 4 – Input Slab

3.4.2 Parameters in Design

Parameters are being fixed for the water tank structural design in order to get the optimum result from the three softwares. Figure 3.5 to 3.7 shows the fixed parameters for column and beam design.

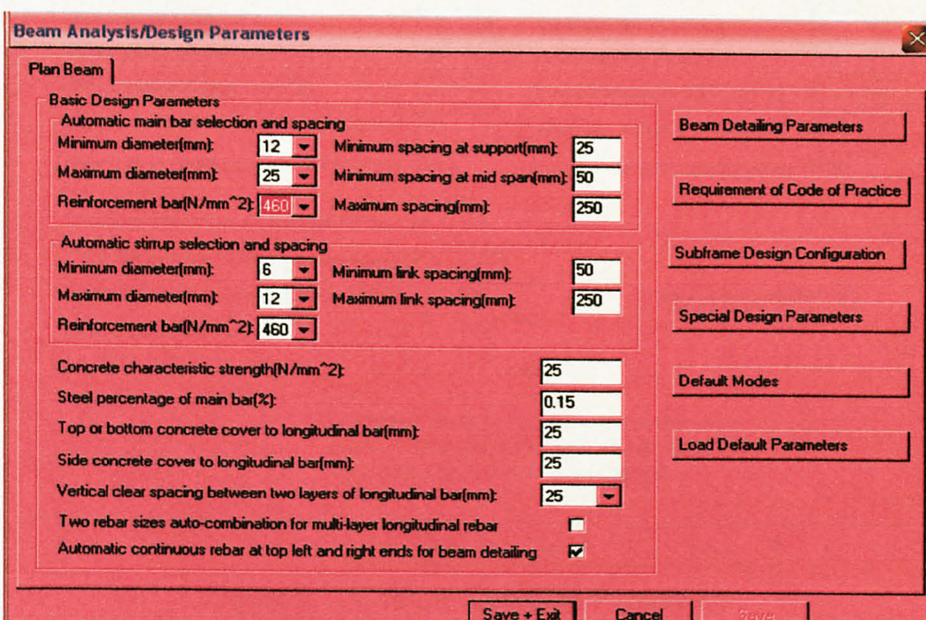

Figure 3.5: Beam Analysis and Design Parameters

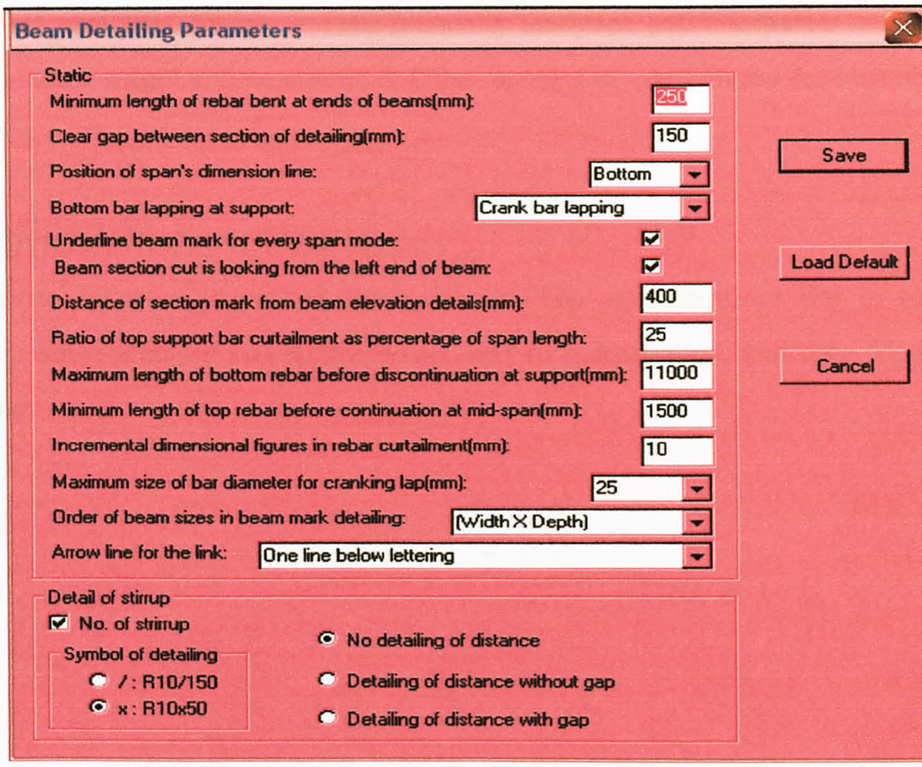

Figure 3.6: Beam Detailing Parameters

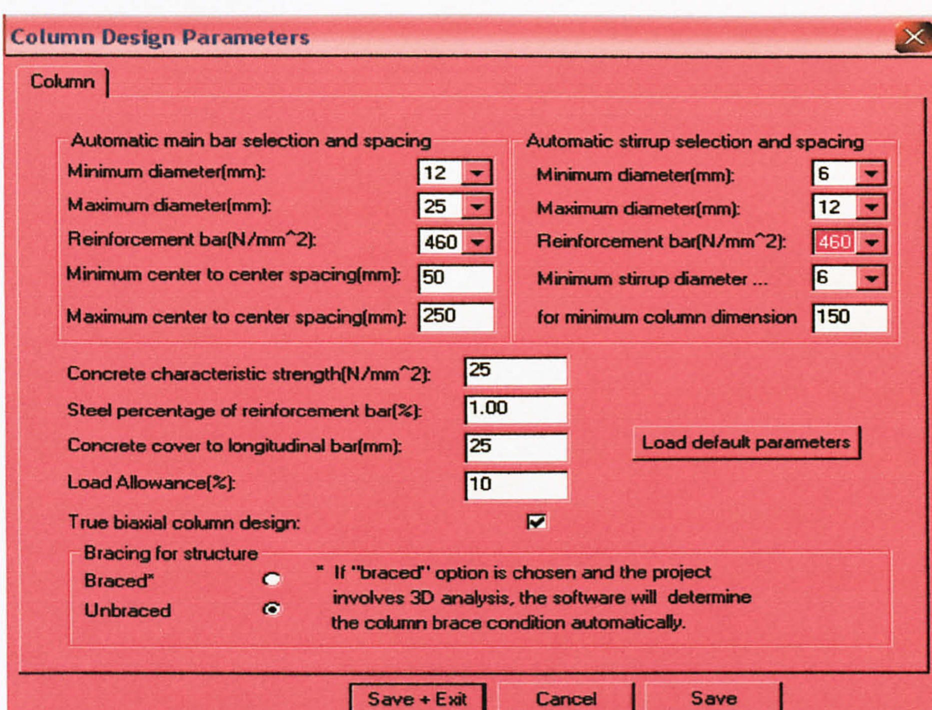

Figure 3.7: Column Detailing Parameters

3.5 COMPARISON OF SOFTWARE

The resulting structural design is then manually analyzed and compared to see which result is the most sound and economical. Other aspects of comparison are also observed and reported.

3.6 FINDINGS AND CONCLUSION

The optimum software is picked among three. The considerations are in terms of engineering specifications and applicability, cost of construction, and user-friendliness of softwares.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 STRUCTURAL DESIGN PARAMETERS

Parameters are being fixed in the process of structural design of the water tank structure using the Esteem, Orion, and STAAD Pro software. This is due to the mean of comparison, where the compared elements in the design should be equivalent, to produce fair and square results. The only variable in the research is the software design itself.

4.1.1 Beam Parameters

Beam parameters are being fixed as in Figure 3.5: Beam Analysis and Design Parameters and Figure 3.6: Beam Detailing Parameters. The parameters are as followings:

Beam size: 200 mm x 300 mm
Concrete characteristic strength: 25 N/mm^2
Concrete cover: 25 mm
<u>Main bar selection:</u>
Minimum diameter: 12 mm
Maximum diameter: 25 mm
Reinforcement bar: 460 N/mm^2
Minimum spacing: 25 mm
Maximum spacing: 200 mm
<u>Stirrup selection:</u>
Minimum diameter: 6 mm
Maximum diameter: 12 mm
Reinforcement bar: 460 N/mm^2
Minimum spacing: 100 mm
Maximum spacing: 250 mm

4.1.2 Column Parameters

Column parameters are being fixed as in Figure 3.7: Column Detailing Parameters, and as followings:

Column size: 200 mm x 200 mm
Concrete characteristic strength: 25 N/mm^2
Braced column
Main bar selection:
Minimum diameter: 12 mm
Maximum diameter: 25 mm
Reinforcement bar: 460 N/mm^2
Minimum spacing: 25 mm
Maximum spacing: 200 mm
Stirrup selection:
Minimum diameter: 6 mm
Maximum diameter: 12 mm
Reinforcement bar: 460 N/mm^2

4.2 RESULTS AND REPORTS

After analysis and design using the three softwares, namely Esteem, Orion, and STAAD Pro Structural Software, the results are printed out and compared to see if there is any difference in the design. The key plan for the water tank structure is as Figure 4.1: Key plan for the water tank upper floor (1F) and ground floor (GF). 3D view can be seen in Figure 3.2: Water Tank Structure.

From Figure 4.1, items marked as A, B, C, and 1, 2 are the grid lines for the structure. A, B, and C are the x-direction of axis while 1 and 2 are the y-axis direction and the value 1000 refers to the distance of each grid line, which is 1000 mm. 1F and GF refers to the location of the beams for upper floor (or first floor) and the ground floor, while the value in the brackets mean the size of the beams in millimeters. As for columns, the width and breadth size is the same as the beam width, which means the column size is 200 mm x 200 mm.

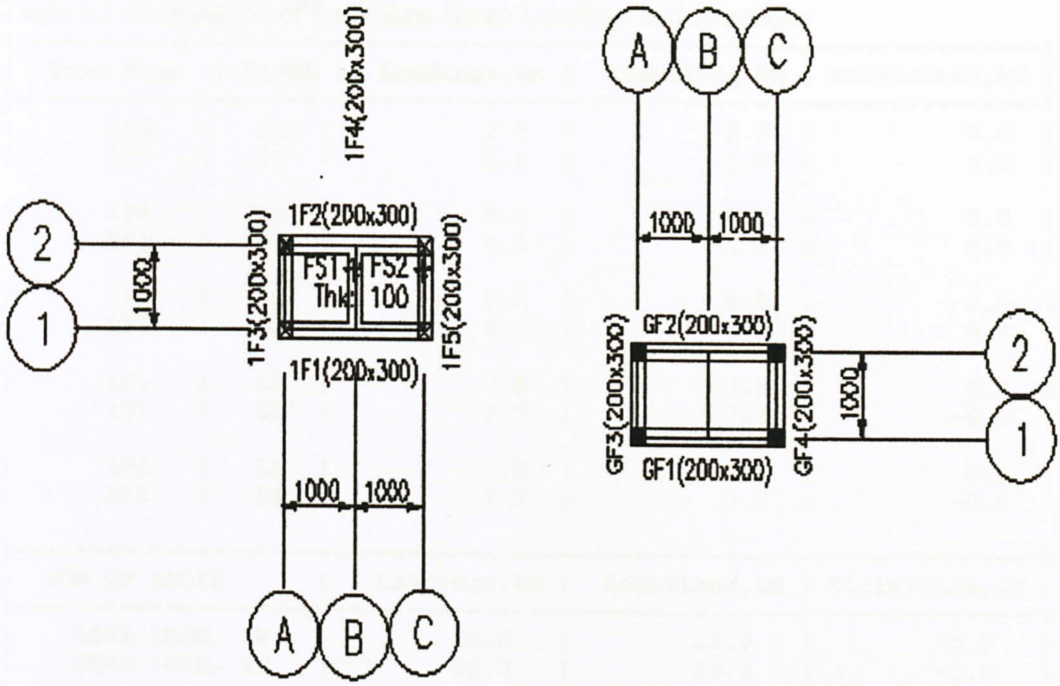

Figure 4.1: Key plan for the Water Tank Upper Floor (1F) and Ground Floor (GF)

4.2.1 Beam Design

For beam design, the reports are at the appendix part of this report. The resulting outputs from the Structural Softwares are as followings:

Ground Beam (GB); First Floor Beam (1B)
For GB1 = GB2 = 1B1 = 1B2
Proposed size: 2T12 top and bottom bar
3 x R6 – 175 link
For GB3 = GB4 = 1B4 = 1B5
Proposed size: 2T12 top and bottom bar
3 x R6 – 175 link

Table 4.1 and 4.2 shows the Summation of Individual Beam Loadings and Reactions for the upper floor of the water tank structure, and the calculation for Beam 4 in Floor 1 (1B4) from the Esteem Structural Software:

Table 4.1: Summation of Individual Beam Loadings and Reactions

Beam Name	LL/DL	Loadings,kN	Reactions,kN	Difference,kN
1F3	LL	2.5	2.5	0.0
1F3	DL	2.8	2.8	0.0
1F4	LL	5.0	5.0	0.0
1F4	DL	4.1	4.1	0.0
1F5	LL	2.5	2.5	0.0
1F5	DL	2.8	2.8	0.0
1F1	LL	7.5	7.5	0.0
1F1	DL	7.7	7.7	-0.0
1F2	LL	7.5	7.5	0.0
1F2	DL	7.7	7.7	-0.0

SUM OF ABOVE	Loadings,kN	Reactions,kN	Difference,kN
LIVE LOAD, kN	25.0	25.0	0.0
DEAD LOAD, kN	25.0	25.0	-0.0

Table 4.2: Summation of Key Plan Load Input

Element	Load Type	Dead Load,kN	Live Load,kN
Slab	Area load	10.8	20.0
Slab	Internal UDL	0.0	0.0
Slab	Edge UDL	0.0	0.0
Slab	Point load	0.0	0.0
Slab	SUM of Above	10.8	20.0
Beam	SelfWeight	10.1	0.0
Beam	UDL	0.0	0.0
Beam	Point load	0.0	0.0
Beam	VariableLoad	0.0	0.0
Beam	SUM of Above	10.1	0.0
S: SUM of KEYPLAN INPUT		**20.9**	**20.0**
Column	Point load	0.0	0.0
Wall	Point load	0.0	0.0
T: SUM of ALL THE ABOVE		**20.9**	**20.0**

A: SUM BEAM TAKE-OFF	20.9	20.0
B: SUM COLUMN TAKE-OFF	0.0	0.0
C: SUM LOAD TAKE-OFF	20.9	20.0
D: SUM COLUMN REACTIONS	20.9	20.0
DIFFERENCE: T - C	**0.0**	**0.0**
DIFFERENCE: T - D	**-0.0**	**0.0****
**** The difference is due to Live Load pattern is OFF**		

BEAM MARK: 1F4

DESIGN THE SUPPORT MOMENT FOR MOST CRITICAL LIVE LOAD PATTERN

DESIGN FOR CONTINUOUS BEAM

ALONG GRID : B;

CodeOfPractice	fcu	fys	fyv	cover	span
BS8110:1985	25	460	460	25	1

Span No	Span-m	Width-mm	Depth-mm	F-width	F-depth
1	1.00	200	300	200	0

Span No	Load Type	D.L. kN;kN/m	L.L. kN;kN/m
1	udl	1.44	0.00
1	symm. tri-lar	5.40	10.00

DESIGN FOR DEAD LOAD AND LIVE LOAD:

Design for the following load factors:-
Dead Load = 1.40; Live Load = 1.60 Wind Load = 0.00

1.40*DEAD LOAD & 1.60*LIVE LOAD FACTORED MOMENT-kNm

Span No	Left	LFace	Span	RFace	Right	CutSpan
1	-0.0	-0.7	2.3	-0.7	-0.0	-0.0

Moment & Shear Curtailment, CutSpan is at 25 percent of Span
Design for Moment at support centre

1.40*DEAD LOAD & 1.60*LIVE LOAD FACTORED SHEAR-kN

Span No	Left	LFace	CutSpan	RFace	Right
1	6.9	6.5	5.0	6.5	6.9

Design for Shear at support centre

Span No.	**AREA OF REBAR-mm2 Left**	**Span**	**Right**	**REBAR ARRANGEMENT -Top/Bottom Left**	**Span**	**Right**	**Side Bar**
1	90	90	90	2T12= 2x1	2T12= 2x1	2T12= 2x1	Top
	78	90	78	2T12= 2x1	2T12= 2x1	2T12= 2x1	Bot

Support No	**Support Reaction-kN D.L.**	**L.L.**
1	2.1	2.5
2	2.1	2.5

Span No	**Stress-N/mm2 L**	**CutSpan**	**R**	**Vc-N/mm2 L**	**CutSpan**	**R**	**Link L**	**S**	**R**	**Defl'n ratio**
1	0.14	0.10	0.14	0.53	0.53	0.53	6-125	6-125	6-125	12.09

==

DEFLECTION CHECK FOR SPAN NO. 1:

Refer to Table 3.10, Table 3.11 & Table 3.12 of BS8110:1985
(As in Table 4.3, 4.4 and 4.5)

Eqn. 8,
fs = 5fy*As,reqd/(8As,prov) = 5*460*90/(8*226) = 114.4 N/mm^2

Eqn. 7, Tension Modification Factor,
TMF = 0.55 + (477-fs)/(120*(0.9+M/bd^2))
= 0.55 + (477-114.4)/(120*(0.9+2215333/(200*269.0^2)))
= 3.42

Actual Beam span/depth ratio = 1000/269.0 = 3.7

Eqn. 9, Compression Modification Factor,
MF1 = 1+As/(3+As/) = 1+0.42/(3+0.42) = 1.12

Allowable span/depth ratio = TMF*MF1*BasicRatio
= 2.00*1.12*20 = 44.9

Modification fac = 2.25; Deflection ratio = 12.08; Steel = 0.42 percent

Actual Beam span/depth ratio < Allowable span/depth ratio, i.e. 3.7 < 44.9 --> Deflection O.K.

Table 4.3: Modification Factor for Tension Reinforcement

Service stress		M/bd^2								
		0.50	0.75	1.00	1.50	2.00	3.00	4.00	5.00	6.00
	100	2.00	2.00	2.00	1.86	1.63	1.36	1.19	1.08	1.01
	150	2.00	2.00	1.98	1.69	1.49	1.25	1.11	1.01	0.94
($f_y = 250$)	167	2.00	2.00	1.91	1.63	1.44	1.21	1.08	0.99	0.92
	200	2.00	1.95	1.76	1.51	1.35	1.14	1.02	0.94	0.88
	250	1.90	1.70	1.55	1.34	1.20	1.04	0.94	0.87	0.82
	300	1.60	1.44	1.33	1.16	1.06	0.93	0.85	0.80	0.76
($f_y = 460$)	307	1.56	1.41	1.30	1.14	1.04	0.91	0.84	0.79	0.76

NOTE 1 The values in the table derive from the equation:

$$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \frac{M}{bd^2}\right)} \leq 2.0 \qquad \text{equation 7}$$

where

M is the design ultimate moment at the centre of the span or, for a cantilever, at the support.

NOTE 2 The design service stress in the tension reinforcement in a member may be estimated from the equation:

$$f_s = \frac{2 f_y A_{s\,req}}{3 A_{s\,prov}} \times \frac{1}{\beta_b} \qquad \text{equation 8}$$

NOTE 3 For a continuous beam, if the percentage of redistribution is not known but the design ultimate moment at mid-span is obviously the same as or greater than the elastic ultimate moment, the stress f_s in this table may be taken as $2/3 f_y$.

Table 4.4: Modification Factor for Compression Reinforcement

$100\frac{A'_{s\,prov}}{bd}$	Factor
0.00	1.00
0.15	1.05
0.25	1.08
0.35	1.10
0.50	1.14
0.75	1.20
1.0	1.25
1.5	1.33
2.0	1.40
2.5	1.45
≥ 3.0	1.50

NOTE 1 The values in this table are derived from the following equation:
Modification factor for compression reinforcement =

$$1 + \frac{100A'_{s\,prov}}{bd} \Big/ \left(3 + \frac{100A'_{s\,prov}}{bd}\right) \leq 1.5 \qquad \text{equation 9}$$

NOTE 2 The area of compression reinforcement A used in this table may include all bars in the compression zone, even those not effectively tied with links.

Table 4.5: Ultimate Bending Moment and Shear Forces in One-Way Spanning Slabs

	End support/slab connection				At first interior support	Middle interior spans	Interior supports
	Simple		Continuous				
	At outer support	Near middle of end span	At outer support	Near middle of end span			
Moment	0	$0.086Fl$	$-0.04Fl$	$0.075Fl$	$-0.086Fl$	$0.063Fl$	$-0.063Fl$
Shear	$0.4F$	—	$0.46F$	—	$0.6F$	—	$0.5F$

NOTE F is the total design ultimate load ($1.4G_k + 1.6Q_k$);
l is the effective span.

SHEAR CHECK:

```
Span No 1 at Left Support ; Shear, V = 6.9 kN

Shear Stress, v = V/bd = 6.9*1000/(200*263) = 0.131 N/mm^2


Shear Capacity,
vc = 0.79*((100As/(bd))^1/3)*(400/d)^1/4)*((fcu/25)^1/3)/1.25

Effective depth ratio = max(1,400/d) = max(1,400/263) = 1.524

Concrete Grade ratio  = min(40,fcu)/25 = min(40,25)/25 = 1.000

Steel Percentage, 100As/(bd) = min(3,0.43) = 0.43

vc = ( 0.79*(0.43)^1/3*(1.524)^1/4*(1.000)^1/3 )/1.25 = 0.530 N/mm^2

Shear Stress - Shear Capacity = v - vc = vd
                              = 0.131 - 0.530 = -0.399 N/mm^2

vd < 0.40 N/mm^2 --> Design for vd = 0.40 N/mm^2

Steel area provided by Link size 6 = 2*pie*dia*dia/4
                                   = 2*3.1416*6*6/4 = 56.5 mm^2


Link spacing required = 135
Shear Capacity provided by Link = 0.87*220*56.5/(135*200)
                                = 0.400 N/mm^2
```

Link provided = R-6-125

Similar reports from Orion Structural Software are attached in Appendix: Beam Design.

4.2.2 Column Design

The output for column design is summarized in tables consisting of main bar and ties size as well as the detail drawing for each column. Table 4.6 shows the output from Esteem Structural Software while Table 4.7 shows the output from Orion Structural Software.

From the tables, it is shown that the design for column for Esteem, Orion, and STAAD Pro Structural software gives the same result (see also: Appendix: Column Design and Slab Design). The output is as following:

Main bars: 4T12
Ties: R6 – 125

Table 4.6: Esteem – Column Reinforcement Schedule

FLOOR \ COLUMN MARK		C1(1/A)	C2(2/A)	C3(1/C)	C4(2/C)
Floor GF–1F					
	MAIN BAR	4T12	4T12	4T12	4T12
	TIES	R6–125	R6–125	R6–125	R6–125
	COL. SIZE	200 X 200	200 X 200	200 X 200	200 X 200
Stump					
	MAIN BAR	4T12	4T12	4T12	4T12
	TIES	R6–125	R6–125	R6–125	R6–125
	COL. SIZE	200 X 200	200 X 200	200 X 200	200 X 200

Table 4.7: Orion – Column Reinforcement Schedule

	A–1	B–1	B–3	A–3
2. STOREY	200 / 200	200 / 200	200 / 200	200 / 200
	200x200	200x200	200x200	200x200
	4T12	4T12	4T12	4T12
	Links: 1T6-125	Links: 1T6-125	Links: 1T6-125	Links: 1T6-125
1. STOREY	200 / 200	200 / 200	200 / 200	200 / 200
	200x200	200x200	200x200	200x200
	4T12	4T12	4T12	4T12
	Links: 1T6-125	Links: 1T6-125	Links: 1T6-125	Links: 1T6-125
	1C1	1C2	1C3	1C4

4.3 COMPARISON AND DISCUSSION

4.3.1 Engineering Specification/Applicability

When designing using Esteem and Orion Structural Software, users are given choices of which specification or code of practice to be used. As for Esteem, the choices consist of British Standard (BS) 8110 – Structural Use of Concrete, CP65, ACI-318, and AS-3600.

Orion choices of code or practice range from BS8110, CP65, BS6399 – Loadings for Buildings, and BS8666 – Scheduling, Dimensioning, Bending, and Cutting of Steel Reinforcement for Concrete.

However, for STAAD Pro, the applicability is highest as the users do not have to choose which code they prefer, but the software will analyze the design in accordance to all code of practice available, and compare them to produce the most optimum results. Among codes used by the software are BS8110, BS5950 – Structural Use of Steelwork in Building, BS5400 – Steel, Concrete, and Composite Bridges, BS8007 - Design of Concrete Structures for Retaining Aqueous Liquids, IS:800, AASHTO, ASCE, AISC, and API. As an example, for beam design only, the software considers the following codes:

1. German Codes – Concrete Design Per DIN 1045
2. French Codes – Concrete Design Per B.A.E.L.
3. Japanese Codes – Concrete Design Per AIJ
4. Australian Codes – Concrete Design Per AS3600
5. Canadian Codes – Concrete Design Per CSA Standard A23.3-94
6. Chinese Codes – Concrete Design Per GBJ 10-89
7. Indian Codes – Concrete Design Per IS456
8. British Codes – Concrete Design Per BS8110
9. Indian Codes – Concrete Design Per IS13920
10. European Codes – Concrete Design Per Eurocode EC2

By default, the Esteem and Orion softwares design was analyzed using the British Standard 8110 code. However, STAAD Pro analysis should be the most powerful as it compares many codes of practice before concluding its result.

4.3.2 Structural Design

As for structural design, from the reports and output of the softwares, it is safe to conclude that the design and analysis of the specific water tank structure in this project are the same. This can be seen from beam and column results which show the same detailing for the structure. Therefore, the steel weight and concrete weight would be the same through all three software analysis. Table 4.8 to 4.14 shows an example of how quantity take off are made for columns.

QUANTITY TAKE-OFF FOR COLUMN

Column Height= 3000 mm; Concrete Grade= G25; Steel = T460 N/mm^2

Table 4.8: Concrete Volume and Formwork Area

Grid	Column		Concrete,m3	Formwork,m2	Nos	Concrete,m3	Formwork,m2
1/A	200	200	0.1200	2.400	1	0.1200	2.400
2/A	200	200	0.1200	2.400	1	0.1200	2.400
1/C	200	200	0.1200	2.400	1	0.1200	2.400
2/C	200	200	0.1200	2.400	1	0.1200	2.400
Total Concrete Volume & Formwork Area						**0.4800**	**9.600**

Total Column Plane Formwork = 9.600 m^3

Table 4.9: Total Lower Column Concrete for Floor Plan : 1F

Grade	Volume,m3	Raw Cost	Placement Cost
G25	0.48000	RM 72.0	RM 120.0

Table 4.10: Total Lower Column Formwork for Floor Plan : 1F

Location	Area,m2	Raw Cost	Placement Cost
Bottom	**9.600**	**RM 240.0**	**RM 288.0**

Table 4.11: Main Rebar Steel and Link Weight

Grid	Rebar Weight	kg	Link Weight	kg	Nos	Rebar,kg	Link,kg
1/A	4T12	12.1	24R6-125	3.6	1	12.1	3.6
2/A	4T12	12.1	24R6-125	3.6	1	12.1	3.6
1/C	4T12	12.1	24R6-125	3.6	1	12.1	3.6
2/C	4T12	12.1	24R6-125	3.6	1	12.1	3.6
Total Main Rebar Steel and Link Weight						**48.2**	**14.4**

Table 4.12: Lower Column Main Rebar for Key Plan: 1F

Diameter	Weight,kg	Raw Cost	Placement Cost
12	48.1	RM 57.8	RM 91.4
Total	**48.1**	**RM 57.8**	**RM 91.4**

Table 4.13: Lower Column Link for Key Plan: 1F

Diameter	Weight,kg	Raw Cost	Placement Cost
6	**14.3**	**RM 15.8**	**RM 25.8**
Total	**14.3**	**RM 15.8**	**RM 25.8**

Table 4.14: Summation of All of the Above Cost

Item	Quantity	Material	Cost	Placement	Cost
Concrete	0.5 m^3	RM 150.0	RM 72	RM 250.0	RM 120
FlatFormwork	9.6 m^2	RM 25.0	RM 240	RM 30.0	RM 288
CircularForm	0.0 m^2	RM 25.0	RM 0	RM 30.0	RM 0
Main Bar T12	48.1 kg	RM 1.20	RM 58	RM 1.90	RM 91
Link Bar R 6	14.3 kg	RM 1.10	RM 16	RM 1.80	RM 26
SUMMATION OF ABOVE			**RM 386**		**RM 525**

The costings are due to default Esteem project quantity parameters as in Figure 4.2:

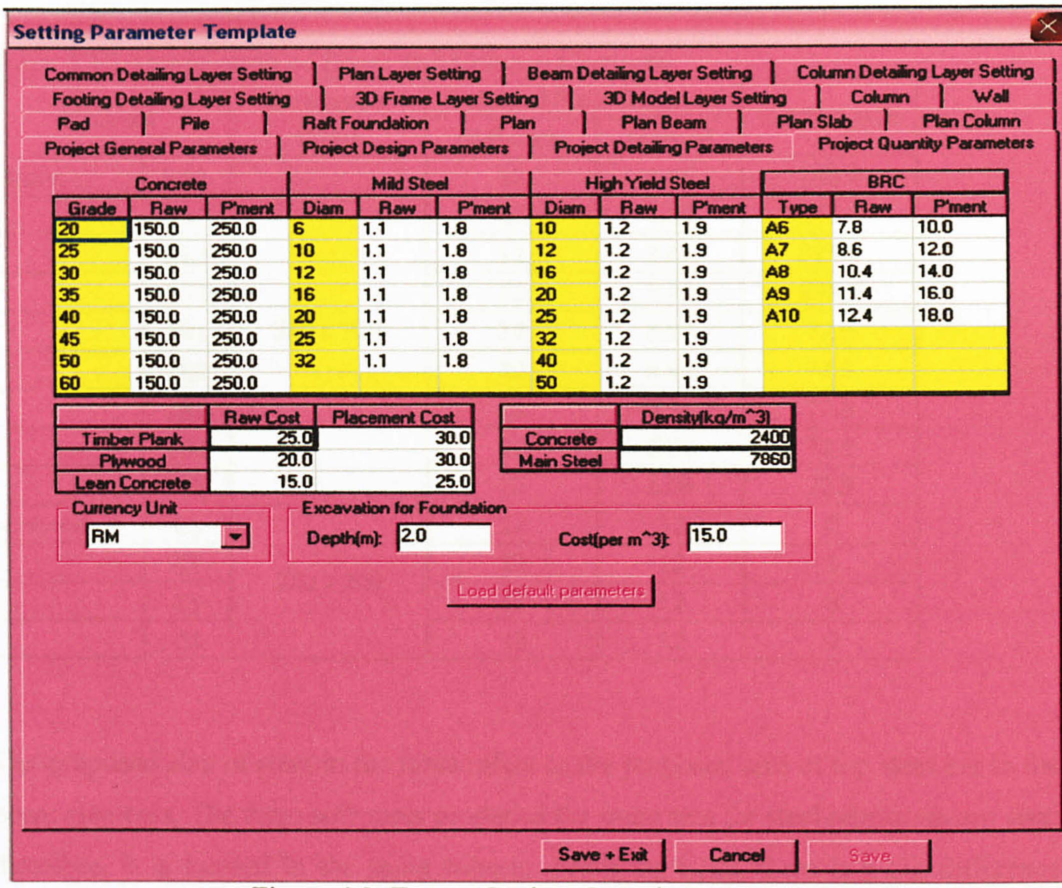

Figure 4.2: Esteem Project Quantity Parameters

The justification for the same resulting output from Esteem, Orion, and STAAD Pro structural software might be due to the structural design of the water tank itself. The design is considered too safe because the beam and column size are large. Therefore, if the beam and column size are decreased to an extent that the structure is about to fail, the resulting output from the softwares might differ. This is discussed more in the recommendation part of the report.

Manual calculation is done as attached in the Appendix: Manual Calculation for Water Tank Structure. Using the results from Esteem Structural Software, CSC Orion, STAAD Pro, as well as the manual calculation, a comparison has been made as in Table 4.15.

Table 4.15: Comparison of Beam and Column Elements

Element		Dimension (mm)	Proposed Steel Size (mm)		% Difference
			Software	Manual	
Beam	GB1	200 x 300	12	4.86	146.9
	GB2		12	4.86	146.9
	GB3		12	2.42	395.9
	GB4		12	2.42	395.9
	1B1		12	6.94	72.9
	1B2		12	6.94	72.9
	1B3		12	6.94	72.9
	1B4		12	6.94	72.9
	1B5		12	6.94	72.9
Column	C1	200 x 200	12	12	0
	C2		12	12	0
	C3		12	12	0
	C4		12	12	0

The proposed size of steel in the table refers to the proposed size of top steel bar in the beam elements. The three softwares produced the same size for steel reinforcement size; therefore, it is located in the same column. From the table, there is a big difference between proposed steel size of beams from the softwares and the manually calculated. The percentage difference is shown on the % difference column. As for column design, the percentage difference is zero.

It is safe to assume that the softwares provided a very safe design to the water tank structure. This is due to the parameters in the design, that the author has to fix the minimum available steel bar size in the market is 12 mm. Therefore, even though the software calculated for smaller size of steel bar, it still has to propose the steel size according to the minimum diameter available from the fixed parameters in the software.

4.3.3 User-Friendliness of Software

The author has been used to Esteem Structural Software during her internship, therefore Esteem is the most easy to handle software among three. The parameters are already a default according to the code of practice that the user has already chosen in the early stage of design. The author took 1 month to master the usage of Esteem under the supervision of her colleague engineers. However, Esteem structural software gets hanged or unexpectedly come to a state which no further operations can be carried out when designing multistorey structures, especially more than five storeys. In this case, Orion is better when designing high rise structures, however for this project; the water tank structure is only 2 storey height thus there is no problem designing it using Esteem Structural Software.

For Orion Structural Software, the parameters are almost the same as Esteem, only a little more complicated. Users have to edit manually any modification to each element of beam and column. For example, if the user wants to change the size of beam for the whole floor, he or she must do it manually one by one, while using Esteem, user can easily select all floor beams and modify once and for all.

Other minus for Orion is that the software automatically default the height of column for each floor. In the early stage of software design, user is prompted with a screen to choose the height of floors. By default, the height of floor will be the height of column and stump as well. As for Esteem, the height of also default for each floor, but user can still edit manually for certain situations. This includes the stump height. Stump height for this water tank structure is 1000 mm; therefore the author has to modify the stump height in the Ground Floor elements. In Orion, the stump height has to be designed as default floor height, which is 3000 mm.

However, Orion parameters and features are more advance. The detailing includes the bar reinforcement bending and cutting which is a plus compared to Esteem. Users can also choose the steel size needed for each beam according to their needs and immediately see the failure notification even before analyzing the design. This ease users a lot as analyzing process took a long time and wore out the computer as well.

As for STAAD Pro, at first, the parameters are difficult to understand. However, after training and lessons from persons and tutorials, the author managed to use the softwares successfully. At first, the author finds it difficult to use the grid alignment parameters in STAAD because the software does not provide easy grid alignment as in Esteem and Orion. In STAAD Pro, users have to fix the dimension of each grid lines in a certain A times A (A x A) boxes. This is a problem because the first water tank design is in awkward values (say, 2440 mm). Therefore, the author has to modify the water tank architecture design so that it can satisfy the requirements of STAAD Pro software.

Using STAAD Pro needs much effort or skill because users have to input all data themselves and not just choose from certain range. Therefore, STAAD Pro is the most difficult software to handle among all three softwares. Only experienced users manage to use STAAD Pro as default software for structural design. New users are recommended to use Esteem Structural Software.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, there is no difference in the design output from the three softwares for this particular structural design, therefore the costing for the water tank structure is the same. All three softwares are applicable and can be used even by new users, as long as there are sufficient training and lessons. The findings of this project are simplified into following table:

Table 5.1: Comparison on Esteem, Orion, and STAAD Pro.

Comparison	**Esteem**	**Orion**	**STAAD**
Applicability Code of Practice	**High** BS8110 CP65 ACI-318 AS-3600	**High** BS8110 CP65 BS6399 BS8666	**Highest** BS8110 BS5950 BS5400 BS8007 IS:800 AASHTO ASCE AISC API
Structural Design Steel Weight Concrete Weight Cost	Same	Same	Same
User Rate Usage in Industry	**Easy** Low-Rise	**Intermediate** High-Rise	**Difficult** Power User

5.2 RECOMMENDATION

For future research, the structural design should be more complicated in order to get different output from the softwares, for example, a two-storey bungalow or a multistorey apartment building. These complicated designs might results in different output from different softwares as it involves a lot more calculation and arrangements.

In terms of sizing, the member size for beams and columns for example, should be minimized so that the load distribution is designed to be in critical condition. When member size is minimized, the software will design for larger steel reinforcement size, therefore this may be the starting point for differing output from various softwares.

The structural design should also includes staircase design, concrete wall, and pile foundation so that the project becomes more applicable and trustworthy. Raft foundation can also be considered as the new elements for comparison.

In terms of software, future research can be done with more softwares that are used in the industry. This includes PROKON, SAAP 2000 and so on.

It is hoped that with more elements to compare and more softwares used, the comparison of the respective structural design will be more complicated and therefore, will have more findings and discussion parts.

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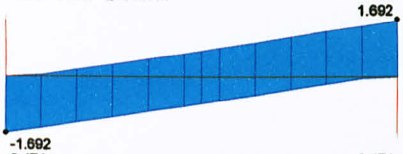
APPENDIX

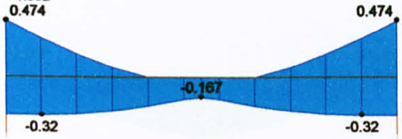
1 Storey: 1

Material: C25 / Grade 460 (Type 2) (Links: Grac

	1B3 L=1000mm
(mm)	200 x 300
؛ BfxHf	—

UDL G=1.5 Q=0 kN/m





nt

ıg (Top Edge) ...

٧.m)	0.47	0.06	0.47
ım)	263.0	263.0	263.0
	0.01	0.00	0.01
ım)	2.92	2.92	2.92
٦m2)	4.7	0.6	4.7
nm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

ıg (Lower Edge) ...

٧.m)	0.32	0.27	0.32
ım)	266.0	266.0	266.0
	0.01	0.00	0.01
ım)	2.96	2.96	2.96
٦m2)	3.2	2.7	3.1
nm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

Design ...

‹N)	1.692		1.692
٦m2)	0.03		0.03
	0.53	0.38	0.53
x		4.00	
ו (kN)		54.550	
n)	0.0		0.0
з	**T6-175**	**T6-175**	**T6-175**

ion Check ...

3.76 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ו Edge	84.8	84.8	84.8

ars ...

ar 2T12
op Bar

op Bar

ו Bar 3T6
ו Bar
ot Bar

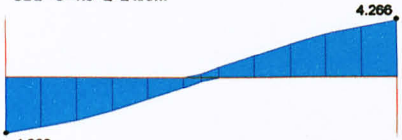
ars

1 Storey: 2

Material: C25 / Grade 460 (Type 2) (Links: Grac

	2B6 L=1000mm
(mm)	200 x 300
ɜ BfxHf	—

UDL G=1.5 Q=2 kN/m



nt

ıg (Top Edge) ...

ʌ.m)	0.26		0.26
ım)	263.0		263.0
	0.00		0.00
ım)	2.92		2.92
ım2)	2.6		2.6
ım2)	0.0		0.0
ıin	78.0	78.0	78.0

ıg (Lower Edge) ...

ʌ.m)	0.66	1.12	0.66
ım)	266.0	266.0	266.0
	0.01	0.02	0.01
ım)	2.96	2.96	2.96
ım2)	6.5	11.1	6.5
ım2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

Design ...

‹N)	4.266		4.266
ım2)	0.08		0.08
	0.38	0.38	0.38
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
ɜ	T6-175	T6-175	T6-175

ion Check ...

3.76 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ars ...

ar 2T12
ɔp Bar

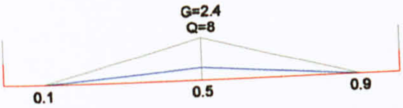
ɔp Bar

ı Bar 3T6
ı Bar
ot Bar

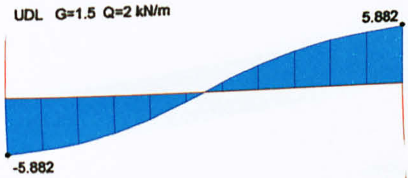
ars

2 Storey: 2

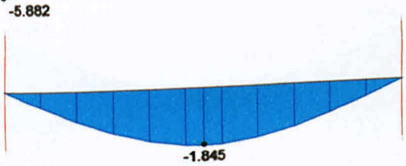
	2B7	L=1000mm
(mm)	200 x 300	
› BfxHf	—	



UDL G=1.5 Q=2 kN/m



nt



ıg (Top Edge) ...

√.m)	0.00		0.00
ım)	263.0		263.0
	0.00		0.00
ım)	2.92		2.92
·nm2)	0.0		0.0
·nm2)	0.0		0.0
ıin	78.0	78.0	78.0

ıg (Lower Edge) ...

√.m)	1.14	1.85	1.14
ım)	266.0	266.0	266.0
	0.02	0.03	0.02
ım)	2.96	2.96	2.96
·nm2)	11.3	18.3	11.3
·nm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

Design ...

‹N)	5.882		5.882
·nm2)	0.11		0.11
	0.38	0.38	0.38
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
;	T6-175	T6-175	T6-175

ion Check ...

3.76 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ars ...

ar — 2T12
op Bar

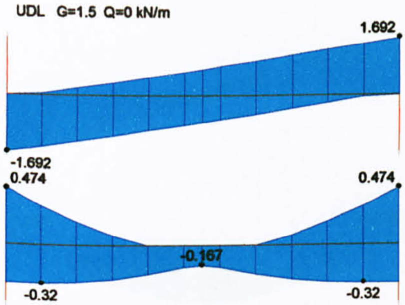
op Bar

ı Bar — 3T6
ı Bar
ot Bar

ars

3 Storey: 1 Material: C25 / Grade 460 (Type 2) (Links: Grac

	1B4		L=1000mm
(mm)		200 x 300	
ɜ BfxHf		—	



ɪg (Top Edge) ...

ɴ.m)	0.47	0.06	0.47
ım)	263.0	263.0	263.0
	0.01	0.00	0.01
ım)	2.92	2.92	2.92
ɱm2)	4.7	0.6	4.7
ɱm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

ɪg (Lower Edge) ...

ɴ.m)	0.32	0.27	0.32
ım)	266.0	266.0	266.0
	0.01	0.00	0.01
ım)	2.96	2.96	2.96
ɱm2)	3.2	2.7	3.1
ɱm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

Ɔesign ...

ᴋN)	1.692		1.692
ɱm2)	0.03		0.03
	0.53	0.38	0.53
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
ɜ	T6-175	T6-175	T6-175

ion Check ...

3.76 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ars ...

ar 2T12
ɔp Bar

ɔp Bar

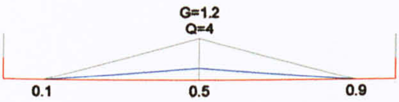
ı Bar 3T6
ı Bar
ot Bar

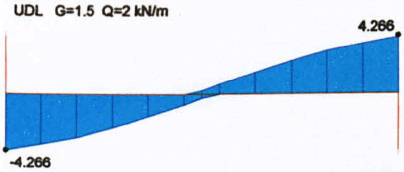
ars

3 Storey: 2

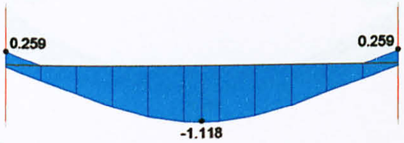
Material: C25 / Grade 460 (Type 2) (Links: Grac

	2B8 L=1000mm
(mm)	200 x 300
ɜ BfxHf	---





nt



ıg (Top Edge) ...

ɴ.m)	0.26		0.26
ım)	263.0		263.0
	0.00		0.00
ım)	2.92		2.92
nm2)	2.6		2.6
nm2)	0.0		0.0
ıin	78.0	78.0	78.0

ıg (Lower Edge) ...

ɴ.m)	0.66	1.12	0.66
ım)	266.0	266.0	266.0
	0.01	0.02	0.01
ım)	2.96	2.96	2.96
nm2)	6.5	11.1	6.5
nm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

ɔesign ...

‹N)	4.266		4.266
nm2)	0.08		0.08
	0.38	0.38	0.38
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
s	T6-175	T6-175	T6-175

ion Check ...

	3.76 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ɜars ...

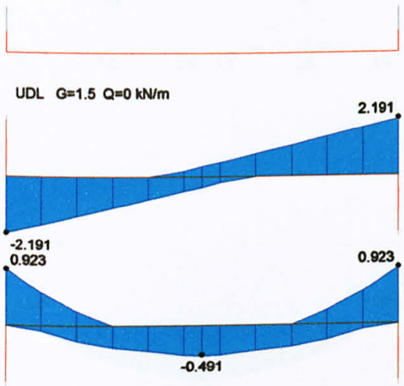
ar	2T12
ɔp Bar	
ɔp Bar	
ı Bar	3T6
ı Bar	
ot Bar	

ɜars

A **Storey: 1**

Material: C25 / Grade 460 (Type 2) (Links: Grac

	1B1		L=2000mm
(mm)		200 x 300	
BfxHf		—	



nt

ıg (Top Edge) ...

ν.m)	0.92	0.00	0.92
ım)	263.0	263.0	263.0
	0.02	0.00	0.02
ım)	2.92	2.92	2.92
nm2)	9.2	0.0	9.2
nm2)	0.0	0.0	0.0
in	78.0	78.0	78.0

ıg (Lower Edge) ...

ν.m)	0.25	0.49	0.27
ım)	266.0	266.0	266.0
	0.00	0.01	0.00
ım)	2.96	2.96	2.96
nm2)	2.5	4.9	2.7
nm2)	0.0	0.0	0.0
in	78.0	78.0	78.0

Design ...

κN)	2.191		2.191
nm2)	0.04		0.04
	0.53	0.38	0.53
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
s	T6-175	T6-175	T6-175

ion Check ...

7.52 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ars ...

ar 2T12

op Bar

op Bar

ı Bar 3T6

ı Bar

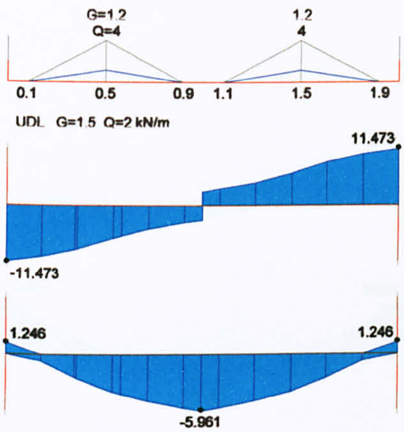
ot Bar

ars

A Storey: 2

Material: C25 / Grade 460 (Type 2) (Links: Grac

	2B4	L=2000mm
(mm)	200 x 300	
› BfxHf	—	



ıg (Top Edge) ...

٧.m)	1.25		1.25
ım)	263.0		263.0
	0.02		0.02
ım)	2.92		2.92
ՠm2)	12.5		12.5
ոm2)	0.0		0.0
ıin	78.0	78.0	78.0

ıg (Lower Edge) ...

٧.m)	2.56	5.96	2.56
ım)	266.0	266.0	266.0
	0.05	0.11	0.05
ım)	2.96	2.96	2.96
ՠm2)	25.4	59.0	25.4
ոm2)	0.0	0.0	0.0
ıin	78.0	78.0	78.0

Design ...

‹N)	11.473		11.473
ՠm2)	0.22		0.22
	0.38	0.38	0.38
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
s	**T6-175**	**T6-175**	**T6-175**

ːion Check ...

7.52 < 44.97 OK

ed Steel Areas (mm2)

ɖge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ːars ...

ar 2T12
ɔp Bar

ɔp Bar

ı Bar 3T6
ı Bar
ot Bar

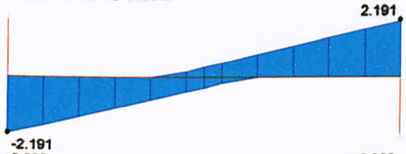
ːars

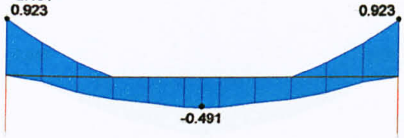
B Storey: 1

Material: C25 / Grade 460 (Type 2) (Links: Grac

	1B2	L=2000mm
(mm)	200 x 300	
› BfxHf	—	

UDL G=1.5 Q=0 kN/m





nt

ıg (Top Edge) ...

N.m)	0.92	0.00	0.92
ım)	263.0	263.0	263.0
	0.02	0.00	0.02
ım)	2.92	2.92	2.92
nm2)	9.2	0.0	9.2
nm2)	0.0	0.0	0.0
iin	78.0	78.0	78.0

ıg (Lower Edge) ...

N.m)	0.25	0.49	0.27
ım)	266.0	266.0	266.0
	0.00	0.01	0.00
ım)	2.96	2.96	2.96
nm2)	2.5	4.9	2.7
nm2)	0.0	0.0	0.0
iin	78.0	78.0	78.0

Design ...

kN)	2.191		2.191
nm2)	0.04		0.04
	0.53	0.38	0.53
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
s	T6-175	T6-175	T6-175

ion Check ...

7.52 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

ars ...

ar 2T12
op Bar

op Bar

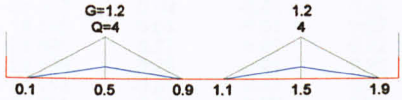
ı Bar 3T6
ı Bar
ot Bar

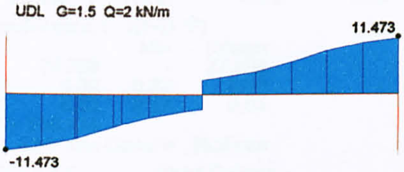
ars

B **Storey: 2**

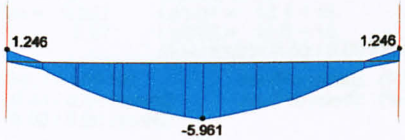
Material: C25 / Grade 460 (Type 2) (Links: Grac

	2B5		L=2000mm
(mm)		200 x 300	
፥ BfxHf		—	





nt



ıg (Top Edge) ...

\.m)	1.25		1.25
ım)	263.0		263.0
	0.02		0.02
ım)	2.92		2.92
nm2)	12.5		12.5
nm2)	0.0		0.0
in	78.0	78.0	78.0

ıg (Lower Edge) ...

\.m)	2.56	5.96	2.56
ım)	266.0	266.0	266.0
	0.05	0.11	0.05
ım)	2.96	2.96	2.96
nm2)	25.4	59.0	25.4
nm2)	0.0	0.0	0.0
in	78.0	78.0	78.0

Design ...

kN)	11.473		11.473
nm2)	0.22		0.22
	0.38	0.38	0.38
x		4.00	
ı (kN)		54.550	
n)	0.0		0.0
ɜ	T6-175	T6-175 .	T6-175

ion Check ...

7.52 < 44.97 OK

ed Steel Areas (mm2)

dge	226.2	226.2	226.2
ı Edge	84.8	84.8	84.8

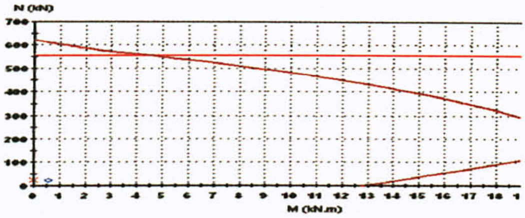
ars ...

ar 2T12
ɔp Bar
ɔp Bar
ı Bar 3T6
ı Bar
ot Bar
ars

l Storey: 1 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

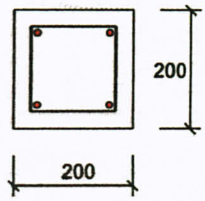
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	27.289	-0.01	-0.01	0.02	0.02
2	27.289	-0.01	-0.01	0.02	0.02
3	27.289	-0.01	-0.01	0.02	0.02
4	17.811	-0.04	-0.01	0.08	0.02
5	21.387	-0.03	-0.01	0.06	0.02
6	18.535	-0.01	-0.01	0.02	0.01
7	21.695	0.27	-0.01	-0.22	0.01
8	22.789	-0.29	-0.01	0.28	0.01
9	21.148	-0.01	0.27	0.03	-0.24
10	23.336	-0.01	-0.29	0.03	0.26



:ritical Combination:1 - (G+Q *F)

		Min	Design
l (kN)	27.289	-	27.289
11 (kN.m)	0.02	0.27	0.00
12 (kN.m)	0.02	0.27	0.54
l-max (kN)	556.074		

Concrete Cover = 25.0 mm



;S8110-Cl.3.8.4.5
N/bhFcu = 0.027
Beta = 0.97

Short Column...
Le1/b1 = 10.4 < 15
Le2/b2 = 10.3 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.040 / 0.008 kN
c'(x/y)= 0.44 / 0.44 N/mm2
(x/y)= 0.00 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2

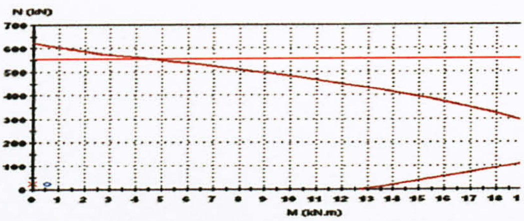
4T12

.inks = T6-125

2 Storey: 1 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

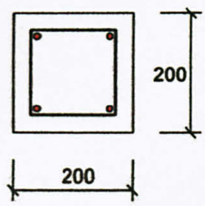
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	27.289	-0.01	0.01	0.02	-0.02
2	27.289	-0.01	0.01	0.02	-0.02
3	27.289	-0.01	0.01	0.02	-0.02
4	17.811	-0.04	0.01	0.08	-0.02
5	21.387	-0.03	0.01	0.06	-0.02
6	18.535	-0.01	0.01	0.02	-0.01
7	21.695	0.27	0.01	-0.22	-0.01
8	22.789	-0.29	0.01	0.28	-0.01
9	23.336	-0.01	0.29	0.03	-0.26
10	21.148	-0.01	-0.27	0.03	0.24



:ritical Combination:1 - (G+Q *F)

		Min	Design
l (kN)	27.289	-	27.289
11 (kN.m)	0.02	0.27	0.00
12 (kN.m)	-0.02	-0.27	-0.54
l-max (kN)	556.074		

Concrete Cover = 25.0 mm



;S8110-Cl.3.8.4.5
N/bhFcu = 0.027
Beta = 0.97

Short Column...
Le1/b1 = 10.4 < 15
Le2/b2 = 10.3 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.040 / 0.008 kN
c'(x/y)= 0.44 / 0.44 N/mm2
(x/y)= 0.00 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2

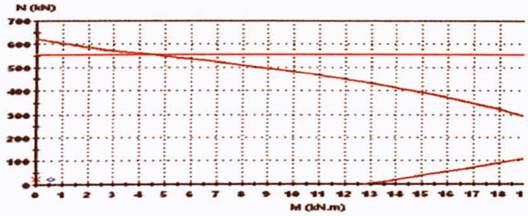
4T12

.inks = T6-125

3 Storey: 1 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

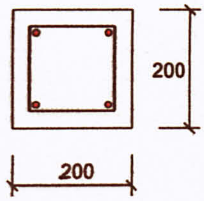
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	27.289	0.01	0.01	-0.02	-0.02
2	27.289	0.01	0.01	-0.02	-0.02
3	27.289	0.01	0.01	-0.02	-0.02
4	17.811	0.04	0.01	-0.08	-0.02
5	21.387	0.03	0.01	-0.06	-0.02
6	18.535	0.01	0.01	-0.02	-0.01
7	22.789	0.29	0.01	-0.28	-0.01
8	21.695	-0.27	0.01	0.22	-0.01
9	23.336	0.01	0.29	-0.03	-0.26
10	21.148	0.01	-0.27	-0.03	0.24



:ritical Combination:1 - (G+Q *F)

		Min	Design
I (kN)	27.289	-	27.289
/1 (kN.m)	-0.02	-0.27	0.00
/2 (kN.m)	-0.02	-0.27	-0.54
I-max (kN)	556.074		

Concrete Cover = 25.0 mm



iS8110-Cl.3.8.4.5
N/bhFcu = 0.027
Beta = 0.97

Short Column...
Le1/b1 = 10.4 < 15
Le2/b2 = 10.3 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.040 / 0.008 kN
c'(x/y)= 0.44 / 0.44 N/mm2
(x/y)= 0.00 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2

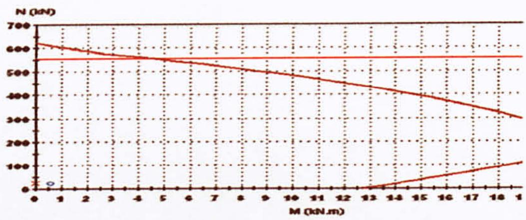
4T12

.inks = T6-125

4 Storey: 1 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

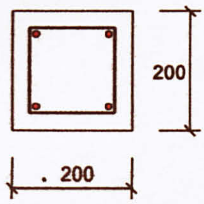
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	27.289	0.01	-0.01	-0.02	0.02
2	27.289	0.01	-0.01	-0.02	0.02
3	27.289	0.01	-0.01	-0.02	0.02
4	17.811	0.04	-0.01	-0.08	0.02
5	21.387	0.03	-0.01	-0.06	0.02
6	18.535	0.01	-0.01	-0.02	0.01
7	22.789	0.29	-0.01	-0.28	0.01
8	21.695	-0.27	-0.01	0.22	0.01
9	21.148	0.01	0.27	-0.03	-0.24
10	23.336	0.01	-0.29	-0.03	0.26



:ritical.Combination:1 - (G+Q *F)

		Min	Design
I (kN)	27.289	-	27.289
/1 (kN.m)	-0.02	-0.27	0.00
/2 (kN.m)	0.02	0.27	0.54
I-max (kN)	556.074		

Concrete Cover = 25.0 mm



iS8110-Cl.3.8.4.5
N/bhFcu = 0.027
Beta = 0.97

Short Column...
Le1/b1 = 10.4 < 15
Le2/b2 = 10.3 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.040 / 0.008 kN
c'(x/y)= 0.44 / 0.44 N/mm2
(x/y)= 0.00 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2

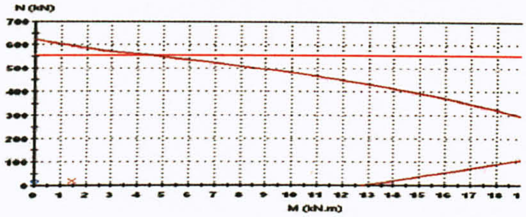
4T12

.inks = T6-125

ł Storey: 2 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

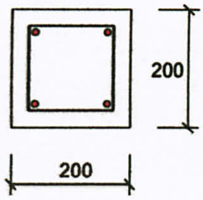
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	19.939	-0.63	0.08	1.25	-0.14
2	19.939	-0.63	0.08	1.25	-0.14
3	19.939	-0.63	0.08	1.25	-0.14
4	11.061	-0.21	0.08	0.30	-0.14
5	14.337	-0.50	0.03	0.93	-0.04
6	13.285	-0.42	0.05	0.82	-0.09
7	15.786	-0.37	0.06	0.82	-0.11
8	16.098	-0.65	0.06	1.14	-0.11
9	16.244	-0.51	0.21	0.98	-0.26
10	15.640	-0.51	-0.08	0.98	0.04



:ritical Combination:1 - (G+Q *F)

		Min	Design
I (kN)	19.939	-	19.939
/I1 (kN.m)	1.25	0.20	1.44
/I2 (kN.m)	-0.14	-0.20	0.00
I-max (kN)	556.074		

Concrete Cover = 25.0 mm



'S8110-Cl.3.8.4.5
N/bhFcu = 0.020
Beta = 0.98

Short Column...
Le1/b1 = 9.9 < 15
Le2/b2 = 9.6 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.478 / 0.073 kN
c'(x/y)= 0.44 / 0.43 N/mm2
(x/y)= 0.01 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2

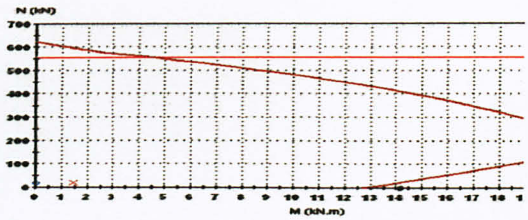
4T12

.inks = T6-125-

ƽ Storey: 2 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

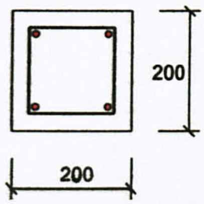
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	19.939	0.63	0.08	-1.25	-0.14
2	19.939	0.63	0.08	-1.25	-0.14
3	19.939	0.63	0.08	-1.25	-0.14
4	11.061	0.21	0.08	-0.30	-0.14
5	14.337	0.50	0.03	-0.93	-0.04
6	13.285	0.42	0.05	-0.82	-0.09
7	16.098	0.65	0.06	-1.14	-0.11
8	15.786	0.37	0.06	-0.82	-0.11
9	16.244	0.51	0.21	-0.98	-0.26
10	15.640	0.51	-0.08	-0.98	0.04



:ritical Combination:1 - (G+Q *F)

		Min	Design
I (kN)	19.939	-	19.939
/I1 (kN.m)	-1.25	-0.20	-1.44
/I2 (kN.m)	-0.14	-0.20	0.00
I-max (kN)	556.074		

Concrete Cover = 25.0 mm



'S8110-Cl.3.8.4.5
N/bhFcu = 0.020
Beta = 0.98

Short Column...
Le1/b1 = 9.9 < 15
Le2/b2 = 9.6 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.478 / 0.073 kN
c'(x/y)= 0.44 / 0.43 N/mm2
(x/y)= 0.01 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2

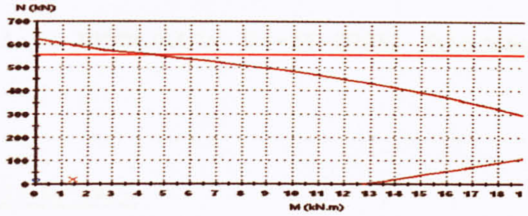
4T12

.inks = T6-125

5 Storey: 2 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

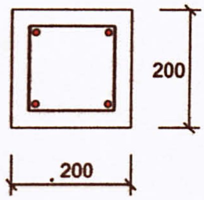
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	19.939	0.63	-0.08	-1.25	0.14
2	19.939	0.63	-0.08	-1.25	0.14
3	19.939	0.63	-0.08	-1.25	0.14
4	11.061	0.21	-0.08	-0.30	0.14
5	14.337	0.50	-0.03	-0.93	0.04
6	13.285	0.42	-0.05	-0.82	0.09
7	16.098	0.65	-0.06	-1.14	0.11
8	15.786	0.37	-0.06	-0.82	0.11
9	15.640	0.51	0.08	-0.98	-0.04
10	16.244	0.51	-0.21	-0.98	0.26



:ritical Combination:1 - (G+Q *F)

		Min	Design
I (kN)	19.939	-	19.939
11 (kN.m)	-1.25	-0.20	-1.44
12 (kN.m)	0.14	0.20	0.00
I-max (kN)	556.074		

Concrete Cover = 25.0 mm



iS8110-Cl.3.8.4.5
N/bhFcu = 0.020
Beta = 0.98

Short Column...
Le1/b1 = 9.9 < 15
Le2/b2 = 9.6 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.478 / 0.073 kN
c'(x/y)= 0.44 / 0.43 N/mm2
(x/y)= 0.01 / 0.00 N/mm2

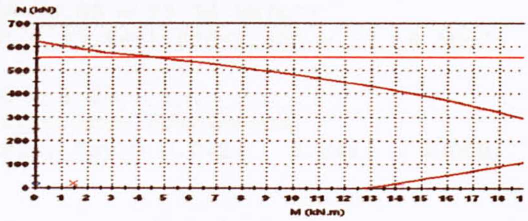
As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2
4T12

.inks = T6-125

7 Storey: 2 (Concrete: C25 / Steel: Grade 460 (Type 2

oadings (Combination):

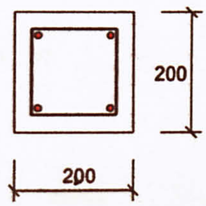
No	N	M1 (bot)	M2 (bot)	M1 (top)	M2 (top)
1	19.939	-0.63	-0.08	1.25	0.14
2	19.939	-0.63	-0.08	1.25	0.14
3	19.939	-0.63	-0.08	1.25	0.14
4	11.061	-0.21	-0.08	0.30	0.14
5	14.337	-0.50	-0.03	0.93	0.04
6	13.285	-0.42	-0.05	0.82	0.09
7	15.786	-0.37	-0.06	0.82	0.11
8	16.098	-0.65	-0.06	1.14	0.11
9	15.640	-0.51	0.08	0.98	-0.04
10	16.244	-0.51	-0.21	0.98	0.26



:ritical Combination:1 - (G+Q *F)

		Min	Design
I (kN)	19.939	-	19.939
11 (kN.m)	1.25	0.20	1.44
12 (kN.m)	0.14	0.20	0.00
I-max (kN)	556.074		

Concrete Cover = 25.0 mm



iS8110-Cl.3.8.4.5
N/bhFcu = 0.020
Beta = 0.98

Short Column...
Le1/b1 = 9.9 < 15
Le2/b2 = 9.6 < 15
M-add(1/2)= 0.00 / 0.00 kN.m

'd(x/y)=0.478 / 0.073 kN
c'(x/y)= 0.44 / 0.43 N/mm2
(x/y)= 0.01 / 0.00 N/mm2

As (Required): (% 0.10) 40.0 mm2
As (Provided): (% 1.13) 452.4 mm2
4T12

.inks = T6-125

Final Year Project, Universiti Teknologi PETRONAS; 24-10-2009, Saturday 4:20:47

Water Tank

Slab Detailed Design Calculation:

Code of Practice	D.L.	L.L.	fcu	fy	cover
BS8110:1985	1.4	1.6	25	460	25

Data of Slab Mark : FS1; Location: 1-2/A-B

Dimensions, X	Y	Thickness, Thk	ImposedLiveLoad, ILL	ImposedDeadLoad, IDL
1000 mm	1000 mm	100 mm	10.00 kN/m^2	3.00 kN/m^2

TotalDeadLoad = SelfWeight + ImposedDeadLoad
= Thk*ConcreteDensity/1000 + IDL = 100*24/1000 + 3.00 = 5.40
Total factored load, Wu = 1.40*5.40+1.60*10.00 = 23.56 kN/m^2
Total factored load*lx*lx, Wu*Lx*Lx = WL = 23.56*1.000*1.000 = 23.56 kNm/m

Long/Short span-ratio, ly/lx = 1000/1000 = 1.00
Case 8: Three edges discontinuous(one short edge continuous)
Span and support coefficients, Bx, By, Bsx, Bsy = 0.042; 0.044; 0.000; 0.058

Moment based on the above coefficients (before redistribution):
Short span moment, Mx = Bx*WL = 0.042 * 23.56 = 1.00
Long span moment, My = By*WL = 0.044 * 23.56 = 1.02
Support long span moment, Msy = Bsy*WL = 0.058 * 23.56 = 1.37

Summary of Moment, Steel Area Required, Rebar Provided:

	Mxx	Myy	Msy1	Msy2	Msx1	Msx2
Moment	1.02	1.00	0.00	1.37	0.00	0.00
Area	150	150	150	150	150	150
Rebar	T10-175	T10-225	T10-225	T10-225	T10-225	T10-225

Deflection Check:

Dimensions Y, 1000 < X, 1000 AND bottom of bottom(BB) rebar is spanning Y-direction:
So effective depth, d = Thickness - cover - YRebar/2 = 100-25-10/2 = 70.0 mm
Span/depth's ratio, Ar = l/d = 1000/70.0 = 14.3
Basic Span/depth's ratio, Br = 20.0
A = 5fyAs,req /(8As,prov) = 5*460*150/(8*349) = 123.5
B = 120*(0.9 + M/(b*d^2)) = 120*(0.9+1.00*1000/(7070)= 132.5

Modification Factor, MF = 0.55 + (477 - A)/B = 0.55+(477-123.5)/132.5 = 3.22
Modification Factor, MF = 3.22 > 2.0 ---> MF = 2.0
Slab deflection ratio = MF*Br/Ar = 2.00*20.0/14.29 = 2.80
Ratio >= 1.0 : Deflection check PASSED

Data of Slab Mark : FS2; Location: 1-2/B-C

Dimensions, X	Y	Thickness,Thk	ImposedLiveLoad,ILL	ImposedDeadLoad,IDL
1000 mm	1000 mm	100 mm	10.00 kN/m^2	3.00 kN/m^2

TotalDeadLoad = SelfWeight + ImposedDeadLoad
= Thk*ConcreteDensity/1000 + IDL = 100*24/1000 + 3.00 = 5.40
Total factored load, Wu = 1.40*5.40+1.60*10.00 = 23.56 kN/m^2
Total factored load*lx*lx, Wu*Lx*Lx = WL = 23.56*1.000*1.000 = 23.56 kNm/m

Long/Short span-ratio, ly/lx = 1000/1000 = 1.00
Case 8: Three edges discontinuous(one short edge continuous)
Span and support coefficients, Bx, By, Bsx, Bsy = 0.042; 0.044; 0.000; 0.058

Moment based on the above coefficients (before redistribution):
Short span moment, Mx = Bx*WL = 0.042 * 23.56 = 1.00
Long span moment, My = By*WL = 0.044 * 23.56 = 1.02
Support long span moment, Msy = Bsy*WL = 0.058 * 23.56 = 1.37

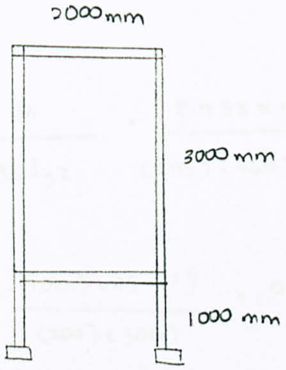
Summary of Moment, Steel Area Required, Rebar Provided:

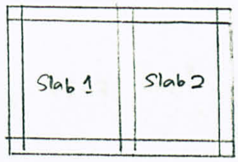
	Mxx	Myy	Msy1	Msy2	Msx1	Msx2
Moment	1.02	1.00	1.37	0.00	0.00	0.00
Area	150	150	150	150	150	150
Rebar	T10-175	T10-225	T10-225	T10-225	T10-225	T10-225

Deflection Check:

Dimensions Y, 1000 < X, 1000 AND bottom of bottom(BB) rebar is spanning Y-direction:
So effective depth, d = Thickness - cover - YRebar/2 = 100-25-10/2 = 70.0 mm
Span/depth's ratio, Ar = l/d = 1000/70.0 = 14.3
Basic Span/depth's ratio, Br = 20.0
A = 5fyAs,req /(8As,prov) = 5*460*150/(8*349) = 123.5
B = 120*(0.9 + M/(b*d^2)) = 120*(0.9+1.00*1000/(7070)= 132.5
Modification Factor, MF = 0.55 + (477 - A)/B = 0.55+(477-123.5)/132.5 = 3.22
Modification Factor, MF = 3.22 > 2.0 ---> MF = 2.0
Slab deflection ratio = MF*Br/Ar = 2.00*20.0/14.29 = 2.80
Ratio >= 1.0 : Deflection check PASSED

WATER TANK





1F

GF

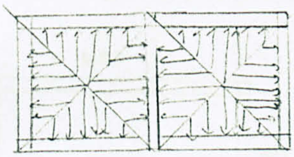
Proposed Size :

BEAM 200 mm × 300 mm

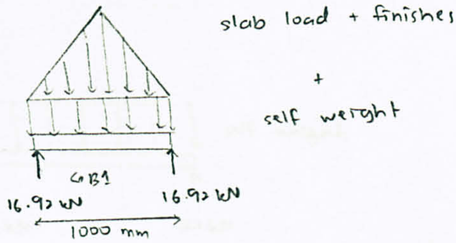
COLUMN 200mm × 200 mm

BEAM DESIGN

1F :



1F1



Self weight $= 0.2\,m \times 0.3\,m \times 25\,\frac{kN}{m^3} \times 1.0\,m = 1.5\,kN$

slab DL $= 1.0\,\frac{kN}{m^2} \times \frac{(1.0m)(0.5m)}{2} = 0.25\,kN$

assuming water tank height = 1.0m, volume of water when the tank is full

is $2m \times 1m \times 1m = 2\,m^3 = 2000L = 2000\,kg \times 9.80665 = 19\,613.3\,N$

$= 19.6133\,kN$

Slab LL $= 19.6133\,kN \div (2m)(1m) = 9.80665\,\frac{kN}{m^2}$

Total Load $= 1.4\,(1.5\,kN + 0.25\,kN) + 1.6\,(19.6133\,kN)$

$= 33.83\,kN$

$M\,max = \frac{33.83\,kN}{2} \times 0.5\,m = 8.458\,kN\cdot m$

$h = d + 25 + 6 + \frac{12}{2} = d + 37\,mm$

$d = 300 - 37 = 263\,mm$

$M_u = 0.156\,f_{cu}bd^2 = (0.156)(25)(200)(263)^2 = 53.952\,kN\cdot m > M.max$

$$K = \frac{M}{bd^2 f_{cu}} = \frac{8.458 \times 10^6}{(200)(263)^2(25)} = 0.0245 > 0.0156 \longrightarrow \text{doubly reinforced}$$

$$z = d\left[0.5 + \sqrt{0.25 - \left(\frac{K}{0.9}\right)}\right] = 263\left[0.5 + \sqrt{0.25 - \left(\frac{0.0245}{0.9}\right)}\right]$$

$$z = 255.63 \text{ mm}$$

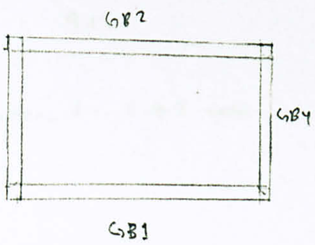
$$A_s = \frac{M}{0.95 f_y z} = \frac{8.458 \times 10^6}{(0.95)(460)(255.63)} = 75.71 \text{ mm}^2$$

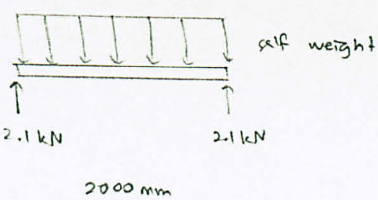
$$\frac{100 A_s}{bh} = \frac{(100)(75.71)}{(200)(300)} = 0.126\,\% < 0.2\,\% \longrightarrow \text{O.K.}$$

$$2\pi\left(\frac{d}{2}\right)^2 = 75.71 \text{ mm}^2$$

bar diameter, $d = 6.94$ mm

GF :





GB1 : self weight $= 0.2\text{ m} \times 0.3\text{ m} \times 25 \frac{\text{kN}}{\text{m}^3} \times 2.0\text{ m} = 3$ kN

Total Load $= 1.4\,(3\text{ kN}) = 4.2$ kN

$M_{max} = 4.2 \times 1.0 = 4.2$ kN·m

$M_u = 53.95$ kN·m $> M_{max}$

$$K = \frac{4.2 \times 10^6}{(200)(263)^2(25)} = 0.0121 < 0.0156 \longrightarrow \text{singly reinforced}$$

$$z = 263\left[0.5 + \sqrt{0.25 - \left(\frac{0.0121}{0.9}\right)}\right] = 259.4 \text{ mm}$$

$$A_s = \frac{4.2 \times 10^6}{(0.95)(460)(259.4)} = 37.05 \text{ mm}^2 \; ; \; \frac{100(37.05)}{(200)(300)} = 0.062\,\% < 0.2\,\% \longrightarrow \text{o.k.}$$

$$2\pi\left(\frac{d}{2}\right)^2 = 37.05 \text{ mm}^2$$

bar diameter, $d = 4.86$ mm

GB3 : self weight = $0.2\,m \times 0.3\,m \times 25\,\frac{kN}{m^3} \times 1.0\,m = 1.5\,kN$

Total Load = 1.4 (1.5) = 2.1 kN

$M_{max} = 2.1 \times 0.5 = 1.05\,kN \cdot m$

$M_u = 53.95\,kN \cdot m > M_{max}$

$$k = \frac{1.05 \times 10^6}{(200)(263)^2(25)} = 0.00304 < 0.0156 \longrightarrow \text{singly reinforced}$$

$$z = 263\left[0.5 + \sqrt{0.25 - \left(\frac{0.00304}{0.9}\right)}\right] = 262.11\,mm$$

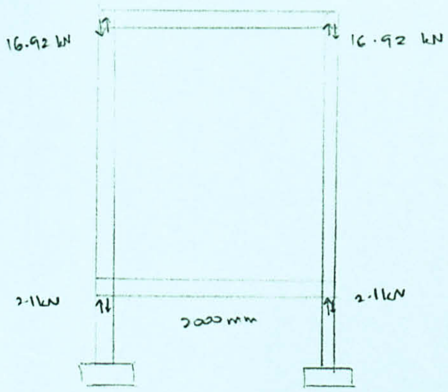
$$A_s = \frac{1.05 \times 10^6}{(0.95)(460)(262.11)} = 9.17\,mm^2$$

$$\frac{100\,(9.17)}{(200)(300)} = 0.0153\% < 0.2\% \longrightarrow \text{o.k.}$$

$$2\pi\left(\frac{d}{2}\right)^2 = 9.17$$

bar diameter, d = 2.42 mm

COLUMN DESIGN



$h = d + 25 + 6 + \frac{12}{2} = d + 37$ mm

$d = 200 - 37 = 163$ mm

$M_u = 0.156 f_{cu} b d^2$

$= (0.156)(25)(200)(163)^2$

$= 20.72 \times 10^6$ N.mm

$N = 16.92 + 2.1 = 19.02$ kN

$\frac{N}{bh} = \frac{19.02 \times 10^3}{(200)(200)} = 0.4755$ N/mm^2

$\frac{M}{bh^2} = \frac{20.72 \times 10^6}{(200)(200)^2} = 2.59$ N.mm^2

From BS8110 - Part 3 (Graph of $\frac{N}{bh}$ vs $\frac{M}{bh^2}$ for rectangular columns),

$\frac{100 A_s}{bh} = 1.5$; $A_s = 600$ mm^2 $= 4\pi(\frac{d}{2})^2$

$d = 13.82$ mm

Proposed bar = 4T12

even though required d is 13.82 mm, the $\frac{100 A_s}{bh}$ from graph is already overdesigned. Therefore, diameter of 12 mm reinforcement bar is adequate.

Proposed link size = $\frac{1}{4} \times 13.82 = 3.46$ mm < 6 mm

maximum spacing = $12 \times 12 = 144$ mm < 150 mm

Proposed Link = R6 – 150 mm