COMPARISON OF SLAB DESIGN BETWEEN BS 8110 AND EUROCODE 2 BY USING MICROSOFT EXCEL

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A thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Civil Engineering

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DECEMBER 2010

ABSTRACT

This project is to develop a program that able to analyze and design of reinforced concrete slabs using the application of spreadsheet Microsoft Excel. The analysis and design of slabs is in accordance with BS 8110 Part 1: 1997 and Eurocode 2 - Design of concrete structures. Thus, this research focuses on the application of those design codes in the form of spreadsheets from Microsoft Excel for the purpose of analyzing and designing of reinforced concrete slab. Basically, the procedures in designing this element require numerous calculations in order to reach the most desired and economical design. Spreadsheet in Microsoft Excel has the capability of solving problems related to equations and formulas in a short time which makes design calculations and procedures easier. Besides that, Microsoft Excel is easily available and also presented in a user-friendly manner. A software has been developed with design procedures based on BS 8110 and Eurocode 2, which is the design of concrete slabs. Necessary checking such as deflection and crack control is also calculated by the software which helps to improve the accuracy of the design. The calculation done by the software was compared to manual calculation to ensure the reliability of this software. Results and conclusions show that this software fulfills the research objectives which are to develop software to aid designers in the designing using BS 8110 and Eurocode 2.

ABSTRAK

Kajian yang dilakukan ini adalah untuk menyediakan satu program yang mampu menganalisis dan mereka bentuk papak konkrit bertetulang secara tepat dan cepat dengan menggunakan aplikasi program Microsoft Excel. Analisis dan reka bentuk papak adalah berpandukan kepada *BS 8110 Part 1: 1997* dan *Eurocode 2 - Design of concrete structures*. Oleh demikian, kajian ini memberi fokus kepada perlaksanaan kod-kod tersebut dalam bentuk *spreadsheet* perisian Microsoft Excel bagi tujuan menganalisis dan merekabentuk struktur papak konkrit bertetulang. Pada asasnya, prosedur untuk merekabentuk struktur tersebut memerlukan pengiraan berkali-kali bagi mencapai rekabentuk yang ekonomi dan diingini. *Spreadsheet* dalam Microsoft Excel dapat menyelesaikan masalah berkaitan dengan pengiraan persamaan dan formula dalam masa yang singkat, membuatkan rekabentuk prosedur dapat diselesaikan dengan lebih mudah. Selain itu, Microsoft Excel juga mudah diperolehi dan digunakan. Satu perisian telah dibangunkan berpandukan prosedur rekabentuk dalam *BS 8110* dan *Eurocode 2*, iaitu rekabentuk papak. Pemeriksaan yang perlu dalam rekabentuk seperti keretakan dan pesongan juga akan dikira oleh perisian ini, justeru membantu meningkatkan ketepatan rekabentuk. Kiraan yang dibuat oleh perisian ini telah dibandingkan dengan pengiraan manual bagi memastikan ketepatannya. Keputusan dan kesimpulan pada akhir kajian dalam membangunkan perisian ini memenuhi objektif kajian, iaitu untuk membangunkan perisian rekabentuk bagi membantu para jurutera dalam merekabentuk menggunakan *BS 8110* dan *Eurocode 2*.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Design is the process which made by engineer to determine the type, size and material used through a meticulous calculation until detail drawing produced. Design is involve at all element of building such as slab, beam, column, foundation, roof and many more. Slab design will consider all aspect like bending moment, shear force, cracking and area of reinforcement.

Reinforced slab is a flat element that used in floors, roofs and walls of buildings and as the decks of bridges. The floor system of a structure can take many forms such as *in situ* solid slabs, ribbed slabs or precast units. Slabs may span in one direction or in two directions and they may be supported on monolithic concrete beams, steel beams, walls or directly by the structure's columns.

Usually in Malaysia, the design of structures will be guided by using British Standard, (BS 8110). BS 8110 is a British Standard for the design and construction of reinforced and prestressed concrete structures. It is based on limit state design principles. Although used for most civil engineering and building structures, bridges and water-retaining structures are covered by separate standards (BS 5400 and BS 8007).

The Eurocodes are a new set of European structural design codes for building and civil engineering works. Nowadays, Eurocode are being introduced and applied for design concrete structures still not yet widely use in Malaysia. The Eurocodes are intended to be mandatory for European public works and likely to become the de-facto standard for the private sector – both in Europe and world-wide.

1.2 Problem Statement

There are several problem have contributed to the needs of this research and the development of this software. The problems are:

i. Manual and countless calculations could lead to numerous mistakes and delay in design.
ii. Little knowledge and attention of the construction community about the newly developed Eurocodes.
iii. Learning to use the new Eurocode 2 will require time and effort. Therefore using programming methods on the new design elements will help designers on the transition to the adaptation of the new code.

1.3 Research Objective

The objectives of this research are:

i. To develop a program to analyze and design reinforced concrete slab by using Microsoft Excel.

ii. To compare the efficiency of designing reinforced concrete slab between British Standard, (Structural use of concrete) with Eurocode 2 (Design of concrete structures).

1.4 Scope of Research

The scope of this study will be limited to:

i) Analysis and design based on standard codes of practices, British Standard, Structural use of concrete (BS8110) and Eurocode 2 - Design of concrete structures.

ii) To develop the program only for design of reinforced concrete slab structure.

iii) To develop a program using Microsoft Excel.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses on the history and development of British Standard (BS 8110: Part 1:1997) and Eurocode 2- Design of concrete structures. The introduction and application of this code is a significant event in civil engineering, so this chapter will look closely on British Standard and Eurocode 2 and also its applications. The scope of this research is designing principles for slab design, so further details on design procedures of slabs will be discussed in this section.

The procedures and process of design based on Eurocode 2 does not change in adaptation. This section will point out the main outline in design procedures. Learning to use new codes will require time and effort, so the development of this research is hoped to ease the transition to using Eurocode 2 as the new design standards. Other than that, the principles and aims will also be discussed in this section.

2.2 British Standard

British Standards are the standards produced by BSI Group which is incorporated under a Royal Charter (and which is formally designated as the National Standards Body (NSB) for the UK). The BSI Group produces British Standards under the authority of the Charter, which lays down as one of the BSI's objectives to set up standards of quality for goods and services, and prepare and promote the general adoption of British Standards and schedules in connection therewith and from time to time to revise, alter and amend such standards and schedules as experience and circumstances require.

BSI Group began in 1901 as the Engineering Standards Committee, to standardise the number and type of steel sections, in order to make British manufacturers more efficient and competitive. BSI Group currently has over 27,000 active standards. Products are commonly specified as meeting a particular British Standard, and in general this can be done without any certification or independent testing. The standard simply provides a shorthand way of claiming that certain specifications are met, while encouraging manufacturers to adhere to a common method for such a specification.

BS 8110 is a British Standard for the design and construction of reinforced and prestressed concrete structures. It is based on limit state design principles. Although used for most civil engineering and building structures, bridges and water-retaining structures are covered by separate standards (BS 5400 and BS 8007). In 2010, BS 8110 was superseded by EN 1992 (Eurocode 2) although parts of the standard have been retained in the National Annex of the Eurocode.

2.2.1 Codes of Practices

Practical codes of practice are a document on best practices has been experienced before by experienced engineer and researcher. In this study the design referring to BS 8110:Part 1:1997.

2.2.2 Types of slab

Slab consists of two types which are one way slab and two way slabs. One way slab have two types namely simply supported slab and one way continuous slab. While two way slabs also consists two types namely simply supported two way slab and constrained slab. Slab types can be decided through side ratio calculation through BS8110 reference such as:

Ly / Lx < 2.0 (two way)
Ly / Lx > 2.0 (one-way)

with Ly was longer side and Lx was shorter side.

2.2.3 One way slab

Slab is called one-way if the main reinforcement designs within one direction only. This situation happens if slab is supported only on two sides only. If slab were supported at all four sides, slab will become one way if long span ratio (Ly) to short span (Lx) is exceeding 2. Because of slab string one-way then reinforcement in span direction is main reinforcement, while reinforcement in direction perpendicular by span known as second reinforcement which functions as binding main reinforcement and help stress distribution because of temperature changes and concrete shrinkage.

2.2.3.1 One way simply supported slab

In a one-way spanning slab, the main reinforcement is designed to span in one direction only. This can only happen when the slab is supported only on its two sides as shown in Figure 2.1 below;

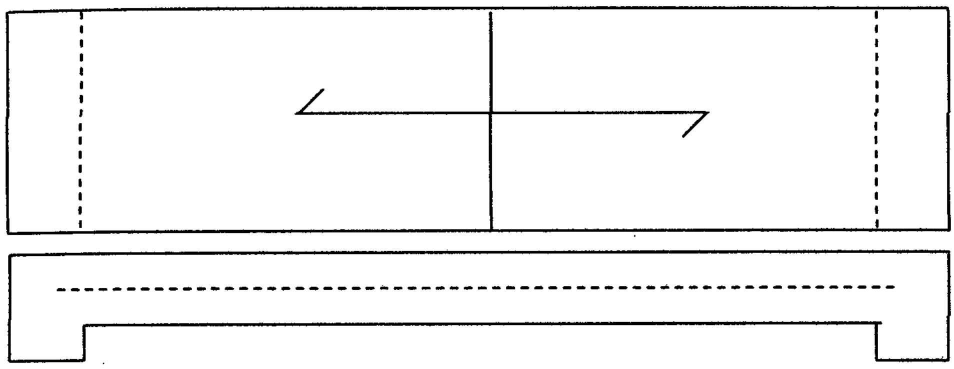

Figure 2.1: Elevation of a one-way spanning slab (supported on 2 slabs)

For slabs supported on four sides as shown in Figure 2.2 below, it is considered as a one-way spanning slab if the ratio L_y / L_x is greater than 2. L_y is the longer side and L_x the shorter side.

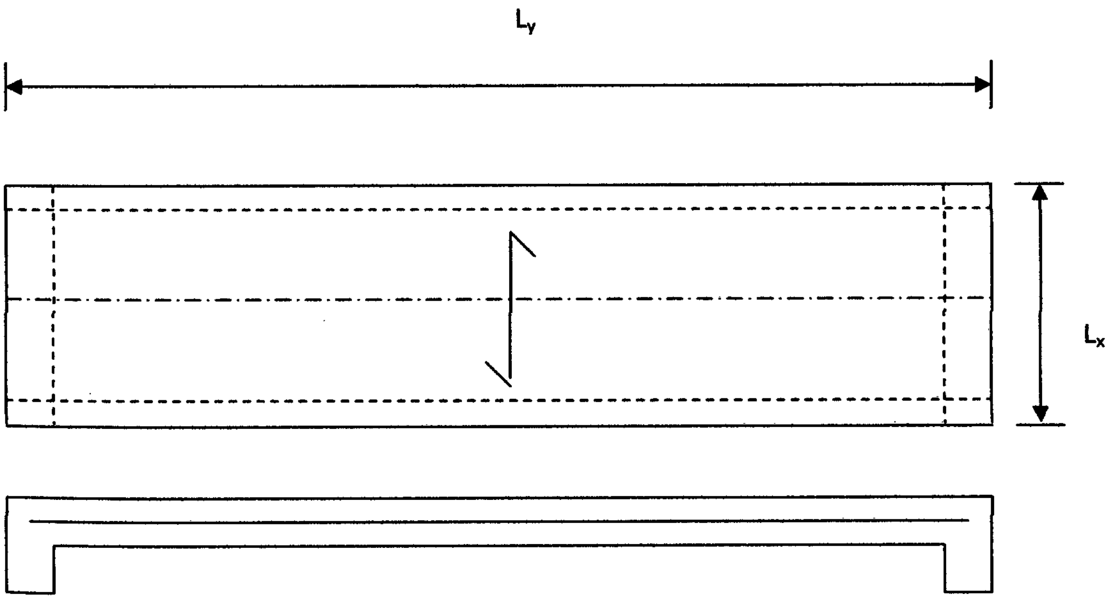

Figure 2.2: One-way spanning slab (supported on 4 sides)

For these types of slabs, the main reinforcement is in the direction of span because the slab is spanning in one direction. Reinforcement, which is perpendicular to the direction of span, is also known as distribution bars. They act as ties to the main reinforcement and help to distribute any stress caused by any change in temperature and shrinkage of concrete. The analysis and design of simply supported one-way spanning slab is similar to the analysis and design of simply supported beams.

2.2.3.2 One way continuous slab

For one way continuous slab, moment and shear force can be determine from Table 3.13: BS 8110, if following terms filled.

i. Area of each bay exceeding 30 m^2

ii. Imposed load is less than 1.25 times dead load

iii. Imposed load not exceeding 5.0 kN/m^2

2.2.4 Two way slab

Main reinforcement for two way slabs designs in both directions. This situation happen when slab were supported at all four span sides and ratio long per short span less or equivalent to two. Bending moment and shear force for two way slab depends on ratio ly / lx and extension between his slab and supporter whether easily supported or constrained.

2.2.4.1 Two way simply supported slab

Two way simply supported slab have a panel and easily supported in edge and panel can lift upward when moment acting on it, slab is supported by beam steel or extension between slab and non monolithic beam. Moment only exist in center part of span.

Short span moment, $M_{sx} = \alpha_{sx}.n.L_x^2$
Long span moment, $M_{sy} = \alpha_{sy}.n.L_y^2$

with α_{sx} is shorter span coefficient and α_{sy} is longer span coefficient may be derived from Table 3.13 BS 8110:Part 1:1997. While *n* is design load in m^2 unit.

2.2.4.2 Two way Slab Constrained

Two way slab constrained have more than one panel or in section slab edge can be prevent from lifted. This situation happen when slab connected by monolithic with the supporter or slab panel connected by monolithic between one and another and moment acting at slab edge. This type of slab has four moment value at one slab panel namely two moment amid span and two moment at direction x and y.

For border continuous,

$$M_{sx} = -\beta_{sx}.n.Lx^2$$
$$M_{sy} = -\beta_{sy}.n.Ly^2$$

For central span,

$$M_{sx} = \beta_{sx}.n.Lx^2$$
$$M_{sy} = \beta_{sy}.n.Ly^2$$

with β_{sx} was shorter span coefficient and β_{sy} is span coefficient longer may be derived from Table 3.14 BS 8110:Part 1:1997. While *n* is design load in m^2 unit.

2.2.5 Design load

Design load divided into three parts:

i. Dead load (g_k) is not changed much from value which is estimated. Among dead load feature is self weight slab and finishing weight.

ii. Imposed load (q_k) was unsteady load and will changes depended on structure use.

iii. Wind loading (w_k) which depended location, form, dimension building, and wind velocity at that area.

2.2.6 Slab design procedure for BS 8110: Part 1:1997

2.2.6.1 Determine area of reinforcement, As

Step to determine wide concrete slab reinforcement reinforced refer BS 8110 were as follows:

a) Calculate $K = M / bd^2fcu$

b) If K < K', compression reinforcement does not require

(K' = 0.156 to redistribution < 10%)

i. Calculate $z = d \{ 0.5 + (\sqrt{0.25 - K/0.9}) \}, z < 0.95d$

ii. Calculate $As = M/0.95fyz$

c) If K > K', compression reinforcement needed

i. Calculate $z = d \{ 0.5 + (\sqrt{0.25 - K'/0.9}) \}$

ii. Calculate depth neutral axis, $x = (d-z)/0.45$

iii. Check d'/x, with d' = depth compression reinforcement

iv. Calculate, $As' = (K-K') f_{cu}bd^2/0.95fy(d-d')$, if $d'/x < 0.43$

$As' = (K-K') f_{cu}bd^2/700 (1-d/x')$, jika $d'/x > 0.43$

$As' = (K' - f_{cu}bd^2/0.95f_yz) + As$

2.2.6.2 Checking

Check carried out to design reinforced concrete slab are percentage check reinforcement, shear check, deflection and cracking.

2.2.6.2.1 Checking reinforcement percentage

Feature strength value reinforcement (f_y) used in study this is 460 N/mm^2. Based On Schedule 3.25 BS8110:Part 1:1997 minimum percentage reinforcement (As_{min}) permitted is 0.13%bh. While maximum percentage (As_{max}) reinforcement allowed is 4%bh.

2.2.6.2.2 Shear checking

Check shear in slab were as follows :

a) Calculate ultimate shear stress,

$v = V/bd$,

which V is shear force;

$V_{sx} = \beta_{vx}.n.L_x$

b) Calculate concrete shear resistance,

$v_c = 0.79 (100 As / bd)^{1/3} (400/d)^{1/4} /\gamma_m$;

(γ_m =1.25)

c) If $v < v_c$, shear link does not required. Usually, slab does not required link.

d) If $v_c < v < (v_c + 0.4)$, minimum link are needed at area where $v > v_c$. Equation used to calculate area of reinforcement is $A_{sv} \geq 0.4b_v s_v/0.95f_{yv}$.

e) If $(v_c + 0.4) < v < 0.8\sqrt{fcu}$ (or 5 N / mm2), link or bent up is required. Equation used is $A_{sv} \geq b_v s_v(v - v_c)/0.95f_{yv}$ if only link were used.

2.2.6.2.3 Deflection checking

Deflection checking are comparing span length ratio, L with effective depth, d. Deflection is safe if,

$$(L/d)_{actual} < (L/d)_{allowable}$$

with,

$$(L/d)_{allowable} = (L/d)_{basic} \times m.f.t.r \times m.f.c.r$$

Value $(L/d)_{basic}$ obtained from Table 3.9 BS8110:Part 1:1997.

m.f.t.r = modification factor for tension reinforcement

$$= 0.55 + ((477 - f_s)/(120(0.9 + M/bd^2)) \leq 2.0$$

with $fs = (5/8)f_y As_{req} / As_{prov}$

As_{req} = area of tension reinforcement required

As_{prov} = area of tension reinforcement provided

m.f.c.r = modification factor for compression reinforcement

$$= 1 + (100\, As'_{prov} / bd)/(3+100\, As'_{prov}/bd) \leq 1.5$$

with As'_{prov} = area of compression reinforcement provided

2.2.6.2.4 Cracking checking

Cracking checking slab is adequate if fulfill one of the conditions in below like those stated in clause 3.12.11.2.7 in BS8110:Part 1:1997:

a) Clear distance between tension reinforcement should not exceed least between 3d or 750mm.

b) If condition (a) already fulfill, so further cracking control is not required if either subsequently filled:

   i. fy = 250 N / mm2, h < 250 mm

   ii. fy = 460 N / mm2, h < 200 mm

   iii. area of reinforcement and concrete ration (100As / bd) < 0.3%

c) If not even one condition in (b) filled, so clear distance of main reinforcement need to be limited as follows:

   i. If ($100A_s$/bd) > 1.0%, so clear distance between reinforcement cannot exceed the maximum value according to Table 3.28, BS8110: Part 1: 1997

   ii. If (100As / bd) < 1.0%, so clear distance between reinforcement cannot exceed the value obtain in Table 3.28, BS8110:Part 1: 1997 divided by (100As/bd).

2.3 Eurocode 2

Introduction of European standards to construction is a significant event and soon it will be introduced to the Malaysian construction industries as well. The ten design standards, known as the Eurocodes, will affect all design and construction activities as current British Standards for design are due to be withdrawn in 2010. Since the developments of the Eurocodes in 1975, the codes have significantly evolved and are now known to be the most technically advanced structural codes in the world. These ten Eurocodes covers all the main structural materials (see Figure 2.3). These codes produced by the European Committee for Standardization (CEN), will replace existing national standards in 28 countries.

Eurocode 2 is one of 10 Eurocodes that will form into a uniform process of design. Eurocode 2 and EC2 are both abbreviations for BS EN 1992, Eurocode 2: Design of concrete structures. Although there is a transition period, eventually Eurocode 2 will replace all national codes dealing with the design of structural concrete (such as BS8110, BS 5400 in the UK).

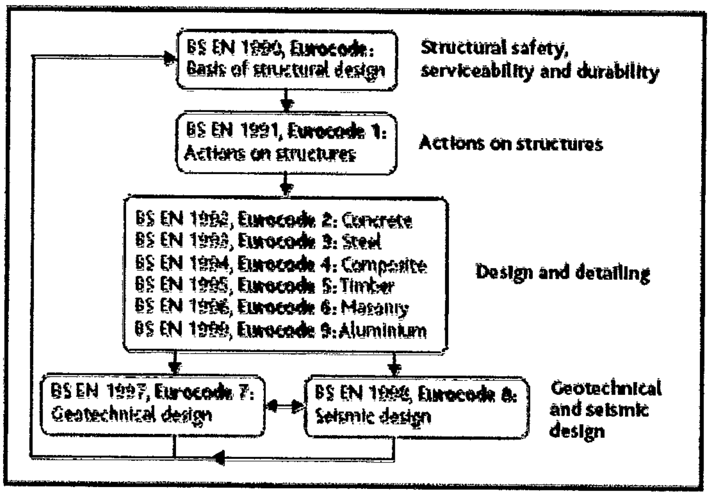

Figure 2.3: The Eurocodes

2.3.1 Principles of Eurocode 2

EN 1992 Eurocode 2: Design of concrete structures is of fundamental importance to civil engineers given the predominance of concrete in civil engineering construction. Ultimately Eurocode 2 will become the one design code for all concrete structures. It will bring reinforced concrete design up-to-date. The general basis for design of structures in reinforced and prestressed concrete made with normal and lightweight concrete together with specific rules given are mainly aimed at building structures as explained in the first section of the first part of Eurocode 2. The new code will thus be a more comprehensive document than its predecessor.

The scope of design in Eurocodes is similar to many current national codes in Europe. The main chapters of the code deal with:

- Basis of design
- Materials
- Durability
- Structural analysis
- Ultimate limit state
- Serviceability limit state
- Detailing of reinforcement
- Detailing of members
- Additional rules for precast elements and structures
- Lightweight aggregate concrete
- Plain concrete

It has been known that the design process will not change as a result of using Eurocode 2. But there is a change of emphasis as Eurocode 2 is laid out to deal with phenomena such as flexure, shear and deflection rather than beams, slabs, column and foundation which are dealt with in BS8110.

2.3.2 Aims and Purposes of Eurocode 2

Officially, the Eurocodes are intended to serve as reference documents to act as a means of compliance of building and civil engineering works. It also acts as a framework for drawing up harmonized technical specifications for construction products. The aims and benefits of the