COMPARATIVE STUDY OF A LOW RISE BUILDING DESIGN USING EC2 AND BS8110

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CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
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by

DUONG VANNAK

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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(CIVIL ENGINEERING)

Approved by,

____

Assoc. Prof. Dr. Nasir Shafiq

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2010

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 reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

DUONG VANNAK

ABSTRACT

This report is intended to raise awareness amongst the Structural Engineering Profession of the forthcoming Eurocode for the Design of Concrete Structures EC2 which will in a few years replace the existing British code BS8110.

The two codes are compared in the context of design of primary structural elements and information is given on the availability of design aids to assist the practitioner in becoming familiar with and using the new code.

ACKNOWLEDGEMENT

Firstly, I would like deeply thank to my supervisor **AP Dr Nashir shafiq** for his commitment on guiding, advising, sharing his own knowledge for my FYP to be a successful one. I also would like to give my thanks to **AP Ir Dr Mohd Shahir Liew** for his guide for on this project as well. I got a lot of help, sharing, caring from all the stuff from Faculty of civil engineering, lecturers and my course mate and thank them for all the things they have done. I would like to thank the authors of the books I referred and the staffs of library in **Universiti Teknologi PETRONAS** for assisting us in getting these books.

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ABBREVIATION AND NOMENCLATURE

ENV	Eurocode Version of Eurocode published by CEN as a pre-standard ENV (for subsequent conversion into EN)
NAD	National Application Document for the use of ENV Eurocodes at the National level
EN	Eurocode Version of Eurocode approved by CEN as a European standard
EC	European Commission services
As	Area of tension reinforcement.
As′	Area of compression reinforcement.
d	Effective depth of the tension reinforcement.
d½	Depth to the compression reinforcement.
x	Depth to the neutral axis.
z	Lever arm.
Ac	Area of concrete section.
Asv	Total cross-section of links at the neutral axis, at a section.
d	Effective depth.
M	Design ultimate moment at the section considered.
N	Design axial force.
sv	Spacing of links along the member.
Sb	Spacing of bent-up bars.
V	Design shear force due to ultimate loads.
Vb	Design shear resistance of bent-up bars.
v	Design shear stress at a cross-section.
v_c	Design concrete shear stress
As, prov	Area of tension reinforcement provided
As', prov	Area of compression reinforcement.
As req	Area of tension reinforcement required to resist the moment due to design ultimate loads
fs	Estimated design service stress in the tension reinforcement.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

Reinforced concrete is a strong durable building material that can be formed in to many varied shapes and sizes ranging from a simple rectangular column, to a slender curved dome or shell. Its utility and versatility are achieved by combining the best features of concrete and steel.

The complete building structure can be broken down into the following elements:

1. Beams (Horizontal members carrying lateral loads),
2. Slabs (Horizontal plate elements carrying lateral loads),
3. Columns (Vertical members carrying primarily axial load but generally subjected to axial load and moment),
4. Walls (Vertical plate elements resisting vertical, lateral or in-plane loads),
5. Base and foundations (pads or strips supported directly o the ground that spread the lads from columns or walls so that they can be supported by the ground without excessive settlement, alternatively the bases may be supported on piles)

There are two design codes currently using for the reinforced concrete building structures: BS8110 and EC2 (Eurocode 2). But BS 8110 is due to be superseded by EC2 by March 2010.

Microsoft Excel (full name **Microsoft Office Excel**) is a spreadsheet-application written and distributed by Microsoft for Microsoft Windows and Mac OS X. It features calculation, graphing tools, pivot tables and a macro programming language called VBA (Visual Basic for Applications). It has been the most widely used spreadsheet application available for these platforms since version 5 in 1993.

1.2 PROBLEM STATEMENT

Since EC2 is going to implement from this year (March 2010), therefore the concrete practitioners are required to gain knowledge and understanding of EC2.

This project is aimed to compare the two codes and bring forward the critical issues and differences between EC2 and BS8110.

1.3 OBJECTIVE

The main objective of this project is

- To compare the two codes and bring forward the critical issues and differences between EC2 and BS8110.

1.4 SCOPE OF STUDY

The scope of this study will cover the designs of the **Beams**, **Slabs** and **Columns** of the 3-storey building using EC2 and BS8110 in **Microsoft Excel Worksheet Software** for analyzing and comparing the two design schemes under the Mild Exposure and Severe Exposure.

CHAPTER 2
LITERATURE REVIEW

2.1 MICROSOFT EXCEL:

Microsoft Excel offers users the useful ability to write code using the programming language Visual Basic for Applications (VBA). Programmers write this code using an editor viewed separately from the spreadsheet. Manipulation of the spreadsheet entries is controlled using objects. With this code any function or subroutine that can be set up in a Basic- or Fortran-like language can be run using input taken from the spreadsheet proper, and the results of the code are instantaneously written to the spreadsheet or displayed on charts (graphs). The spreadsheet becomes an interface or window to the code, enabling easy interaction with the code and what it calculates. VBA also supports simple GUI forms based programming embedded in the spreadsheet so that entire forms based applications can be written in Excel.

Accuracy: Due to Excel's foundation on floating point calculations, the statistical accuracy of Excel has been criticized, as lacking certain statistical tools.

Excel MOD function error: Excel has issues with modulo operations. In the case of excessively large results, Excel will return the incorrect answer of #NUM! error.

Date Problems: Excel incorrectly treats 1900 as a leap year. The bug originated from Lotus 1-2-3, and was purposely implemented in Excel for the purpose of backward compatibility. This legacy has later been carried over into Office Open XML file format. Excel also supports the second date format based on year 1904 epoch. The Excel DATE() function causes problems with a year value prior to 1900.

Excel is frequency of percentage of using software although it only normal computer software not structure engineering software but a lot of company like to use it in design structure. This is because Excel's software is easily practiced and anyone is capable to control it because it is easy to be applied during production in the calculation data with the simple calculation.

Microsoft Excel not only facilitates most operation which involves storage record and information, and also can make calculation operation able to be carried out with faster and effective than traditional method, and it also enables to producing the chart or various forms graph easily.

2.2 EC2 & BS8110:

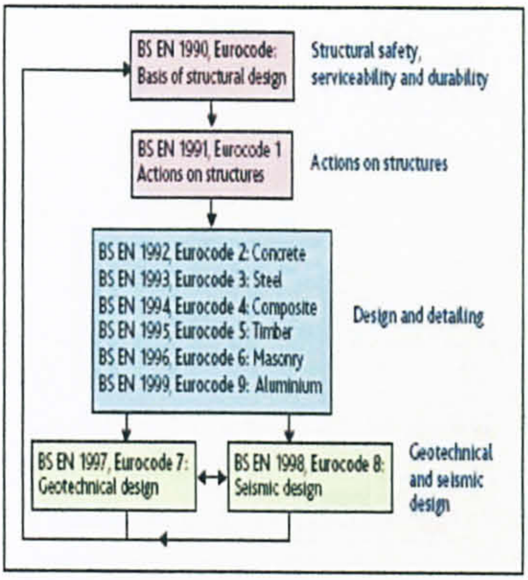
The implementation of the new Eurocodes is a significant event for the UK construction industry. BS EN 1992, Eurocode 2: Design of Concrete Structures will affect all concrete design once the current British Standards, BS 8110 for Design of Reinforced Concrete Structures, BS8007 Design of Concrete Structures for Retaining Aqueous Liquids and BS5400 Steel and Concrete Bridge Design have been withdrawn. This is due to happen by 2010, but BS 8110 may be withdrawn as early as January 2008.

Eurocode 2 (EC2) published in the UK as BS EN 1992 is one of 10 Eurocodes that will form into a uniform process of design. It applies to the design of buildings and civil engineering works in concrete. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 – Basis of structural design. Eurocode 2 is only concerned with requirements for resistance, serviceability, durability and fire resistance concrete structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

There are four parts to BS EN 1992, Eurocode 2 (Design of concrete structures)

- Part 1-1 (General – Common rules for building and civil engineering structures) was published in December 2004.
- Part 1-2 (General – Structural fire design) was published in February 2005: the relevant National Annexes were published in December 2005.
- Part 2 (Bridges) was published in December 2005.
- Part 3(Liquid retaining and containment structures) was published in July 2006 and their respective National Annexes in December 2007 and October 2007.

Each part deals with design alone, so the basis of design, loads, materials and workmanship. Materials and workmanship are covered by European Standards or complementary British Standards as indicated below:



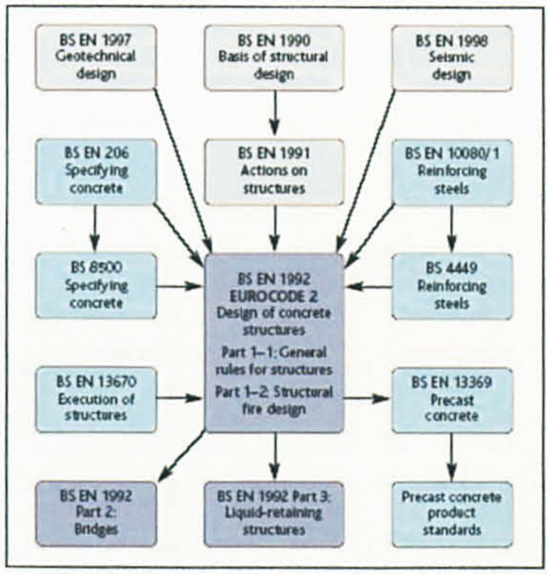


Figure1: Diagram of Eurocode

Figure 2: Diagram of European Standards or complementary British Standards

Ultimately Eurocode 2 will become the one design code for all concrete structures in the UK and Europe and bring reinforced concrete design up-to-date. National Annexes (NAs) give specific rules for the use of Eurocode 2 in a specific country. The UK annexes for Parts 1-1 and 1-2 should be available for use from January 2006. Once these are published it will then be possible to use Eurocode 2.

The design process will not change as a result of using Eurocode 2. Eurocode 2 is laid out to deal with phenomena rather than elements. There are also specific rules dealing with beams, slabs, flat slabs, columns, walls, deep beams, foundations, tying systems and precast concrete. In the long term, it is anticipated that Eurocode 2 will result in more economic structures (expected material cost savings of between 0 and 5% compared to using BS 8110 in building structures)so conceptual design done to, say, BS8100 may confidently be taken through to detail design using Eurocode 2. . In common with all EU countries, Public Authorities will have to accept Eurocode 2 as a valid method of design on major works. In some countries adoption of Eurocodes is embodied in their legal system. Although there continues to be a transition period, eventually Eurocode 2 will replace all national codes dealing with the design of structural concrete (such as BS 8110, BS 8007, BS 5400 in the UK). All the parts of Eurocodes relevant to the design of concrete have been published. The final relevant UK National Annex (for wind loads) was due to be published in late May 2008.

The UK construction industry faces a major challenge with the replacement of British Standards by Eurocodes. The Concrete Centre is making available a range of resources that will assist with the interpretation and use of Eurocode 2 and associated Eurocodes. With these resources, design offices can start introducing Eurocodes through concrete design.

The following are the benefits of the new Eurocodes 2.

- Eurocode 2 should result in more economic concrete structures
- Eurocode 2 is less restrictive than British Standards
- Eurocode 2 is extensive and comprehensive
- The new Eurocodes are claimed to be the most technically advanced codes in the world
- In Europe, all public works must allow the Eurocodes to be used for structural design.
- Use of the Eurocodes will provide more opportunity for designers to work throughout Europe and for Europeans to work in the UK
- The Eurocodes are logical and organised to avoid repetition.

Part 1-1 of Eurocode 2 gives a general basis for the design of structures in plain, reinforced and prestressed concrete made with normal and light weight aggregates together with specific rules for buildings.

The following subjects are dealt with in Part 1-1.

Section 1: General

Section 2: Basis of design

Section 3: Materials (Concrete, Reinforcement steel and Prestressing steel)

Section 4: Durability and cover to reinforcement

Section 5: Structural analysis

Section 6: Ultimate limit states

Section 7: Serviceability limit states

Section 8: Detailing of reinforcement and prestressing tendons - General

Section 9: Detailing of members and particular rules

Section10: Additional rules for precast concrete elements and structures

Section 11: Lightweight aggregate concrete structures

Section 12: Plain and lightly reinforced concrete structures

This Part 1-1 does not cover:

- The use of plain reinforcement
- Resistance to fire;
- Particular aspects of special types of building (such as tall buildings);
- Particular aspects of special types of civil engineering works (such as viaducts, bridges, dams, pressure vessels, offshore platforms or liquid-retaining structures);
- No-fines concrete and aerated concrete components, and those made with heavy aggregate or containing structural steel sections (see Eurocode 4 for composite steel-concrete structures).

Part 1-2 of Eurocode 2 deals with the design of concrete structures for the accidental situation of fire exposure and is intended to be used in conjunction with EN 1992-1-1 (Eurocode 2: Design of concrete structures – Part 1-1: General – Common rules for building and civil engineering structures) and EN 1991-1-2 (Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire). This part 1-2 only identifies differences from, or supplements to, normal temperature design.
The following subjects are dealt with in Part 1-2.

- Deals only with passive methods of fire protection. Active methods are not covered.
- Applies to concrete structures that are required to fulfil certain functions when exposed to fire.

    - Avoiding premature collapse of the structure (load bearing function)
    - Limiting fire spread (flame, hot gases, excessive heat) beyond designated areas (separating function)
- Gives principles and application rules (see EN 1991-1-2) for designing structures for specified requirements in respect of the aforementioned functions and the levels of performance.
- Applies to structures, or parts of structures, that are within the scope of EN 1992-1-1 and are designed accordingly. However, it does not cover:
    - Structures with prestressing by external tendon, shell structures,
- Applicable to normal weight concrete up strength class C90/105 and for lightweight concrete up to strength class LC55/60 and alternative rules for strength classes above C50/60.

For more information about the EC2 and BS8110, Please refer to the Appendix 1.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 RESEARCH METHODOLOGY

The general sequence of methodology showed as in Figure 1 below:

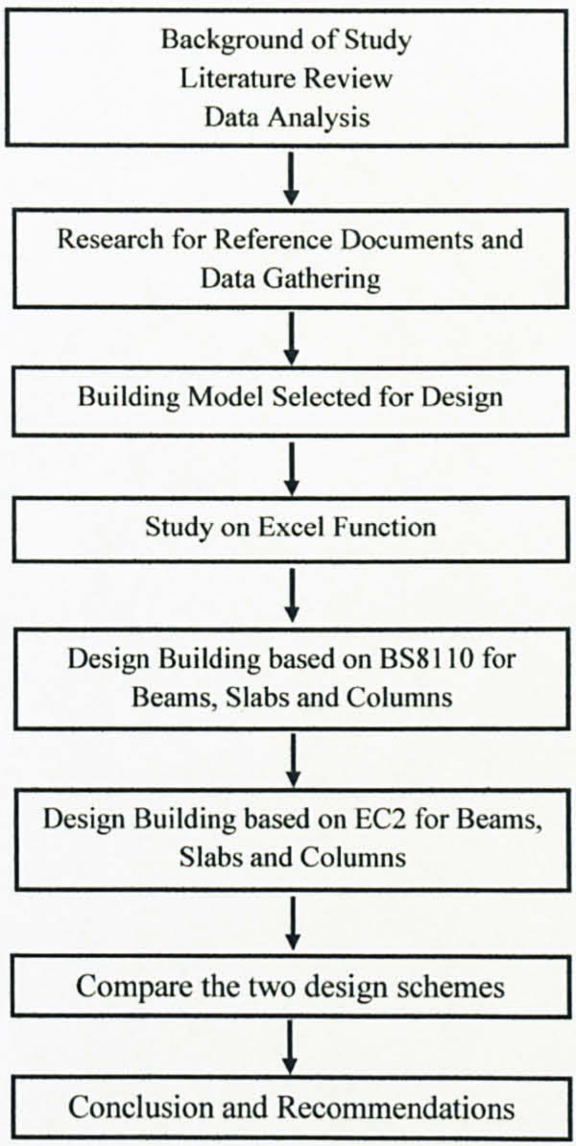


Figure 3: Flow Chart of Activities

3.2 BUILDING SELECTION FOR DESIGN IN THE PROJECT

Following figure shows the typical plan and section of a 3-storey building. 1st, 2nd and 3rd floors are carrying similar loading as shown in the plan and section. Except roof beams, all beams support 175 mm thick masonry wall, the unit weight of masonry wall is $18kN/m^3$.

Design:

a. Under Mild and Severe Exposure
b. f_{cu} = 40MPa , fy= 460Mpa for BS8110
c. f_{cu} = 32/40MPa , fy= 500Mpa for EC2

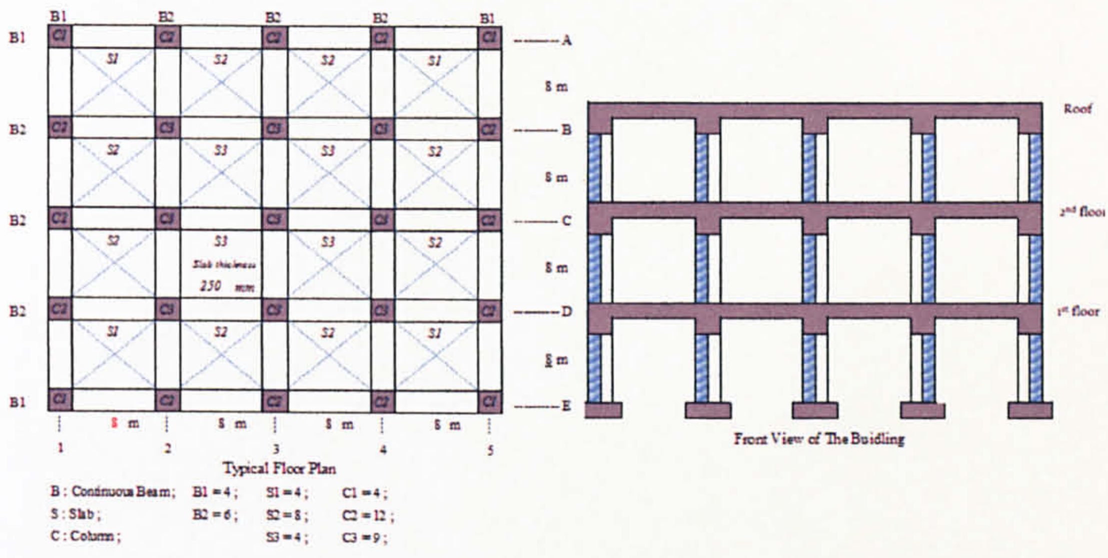


Figure 4: Building Plan

3.3 BUILDING DESIGN PROCEDURE OF EC2 AND BS8110

Use BS8110 code for Step 1 until Step 6

1. Calculate the loads on Slabs transfer to Beams

2. Transfer Load from Beams to Column

3. Calculate rebar required for beam design at each floor
   Note: Since the Building is symmetric with equal spans.
   There are two types of Beams selected for designing respectively for roof and floor:
    1. Exterior Continuous Beam and
    2. Interior Continuous Beam

4. Calculate rebar required for slab design at each floor
   Note: There are three types of Slabs selected for designing respectively for roof and floor:
    1. Two adjacent edges discontinuous (Corner Slab)
    2. One edge discontinuous and
    3. Interior panels

5. Calculate rebar required for column design at each floor
   Note: There are three type of Column selected for designing:
    1. Corner Column
    2. Edge Column and
    3. Interior Column.

6. Calculate the total rebar required for whole building, and Total Volume required

7. Repeat 1, 2, 3, 4, 5 and 6 for EC2 Code

8. Compare the two design schemes on:
    1. Total Steel Weight and Concrete Volumes used for Beams, Slabs Columns designs in BS8110 and EC2, respectively.
    2. The ratio of the steel and concrete volumes for Beams, Slabs, and Columns designs in BS8110 and EC2, respectively.

3.4 BEAM DESIGN (EC2)

1. Permanent and variable actions

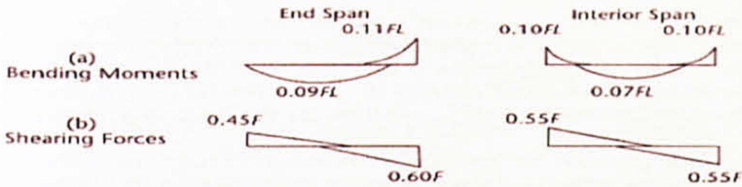
$$1.35G_k + 1.5Q_k$$

Table A.8 Minimum areas of reinforcement

Tension reinforcement in beams and slabs	*Concrete class (f_{yk} = 500 N/mm²)*			
	C25/30	*C30/35*	*C40/50*	*C50/60*
$\frac{A_{s,min}}{b_t d} > 0.26\frac{f_{ctm}}{f_{yk}}$ ($>$ 0.0013)	0.0013	0.0015	0.0018	0.0021
Secondary reinforcement $>$ 20% main reinforcement				
Longitudinal reinforcement in columns $A_{s,min} > 0.10N_{sd}/0.87f_{yk} > 0.002A_c$ where N_{sd} is the axial compression force				
Vertical reinforcement in walls $A_{s,min} > 0.002A_c$				

Note: b_t is the mean width of the tension zone.

Continuous beams with approximately equal spans and uniform loading



F = Total ultimate load on span = $(1.35G_k + 1.50Q_k)$ kN
L = Effective span

Table A.9 Limiting constant values

	Concrete class $\leq$ *C50/60*
Limiting x_{bal}/d	0.45
Maximum z_{bal}	0.82d
K_{bal} = limiting K	0.167
Limiting d'/d	0.171
Maximum percentage steel area $100A_{bal}/bd$	$23.4f_{ck}/f_{yk}$

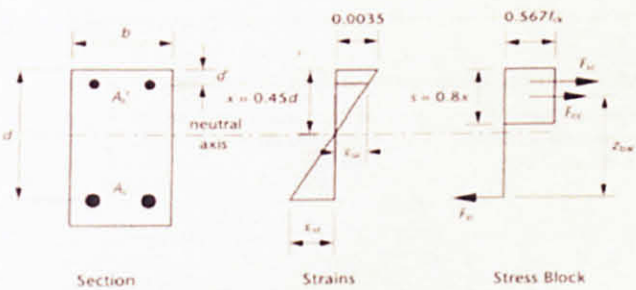


Figure 4.8
Section with compression reinforcement

$$K = \frac{M}{bd^2 f_{ck}} > 0.167$$

$$A_s' = \frac{M - 0.167 f_{ck} bd^2}{0.87 f_{yk}(d - d')}$$

$$A_s = \frac{0.167 f_{ck} bd^2}{0.87 f_{yk} z_{bal}} + A_s' \times \frac{f_{sc}}{0.87 f_{yk}}$$

with $z_{bal} = 0.82d$.

$\frac{d'}{x} < 0.38$ with $x = 0.45d$ $\quad \frac{d'}{d} < 0.171 \Rightarrow f_{sc} = 0.87f_{yk}$

$\varepsilon_{sc} = \varepsilon_y = 0.00217.$ $\quad \frac{d'}{d} > 0.171 \Rightarrow f_{sc} = E_s \times \varepsilon_{sc} = 200000\varepsilon_{sc}$

3.5 DESIGN FOR BEAM SHEAR (EC2)

$$V_{Rd,max(22)} = 0.124 b_w d (1 - f_{ck}/250) f_{ck}$$

$$V_{Rd,max(45)} = 0.18 b_w d (1 - f_{ck}/250) f_{ck}$$

$$\theta = 0.5 \sin^{-1}\left\{\frac{V_{Ed}}{0.18 b_w d f_{ck}(1 - f_{ck}/250)}\right\} \le 45$$

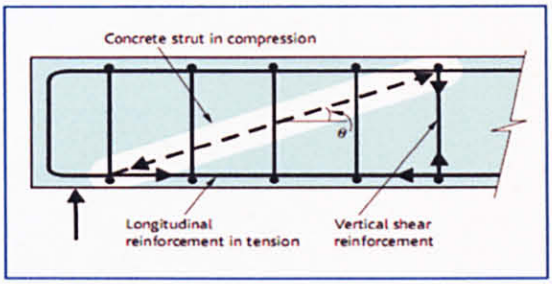
$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 d f_{yk} \cot\theta}$$

$$\frac{A_{sw,min}}{s} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}}$$

$$V_{min} = \frac{A_{sw}}{s} \times 0.78 d f_{yk} \cot\theta$$

$$\Delta F_{td} = 0.5 V_{Ed} \cot\theta$$

Strut inclination method



3.6 DESIGN FOR PUNCHING SHEAR IN SLAB (EC2)

$$V_{Rd,max} = 0.5 u d \left[0.6\left(1 - \frac{f_{ck}}{250}\right)\right] \frac{f_{ck}}{1.5}$$

The maximum permissible shear force = The maximum shear resistance

$$V_{Rd,max} = 0.5 v_1 f_{cd} u d = 0.5 v_1 (f_{ck}/1.5) u d$$

u_1 = length of the punching shear perimeter.

$v_1 = 0.6(1 - f_{ck}/250)$, the strength reduction factor

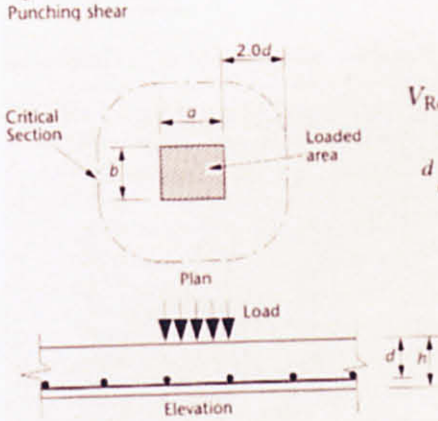
$$u_1 = 2(a + b) + 4\pi d$$

$$A_{sw,min} = \frac{0.053\sqrt{f_{ck}}(s_r \cdot s_t)}{f_{yk}}$$

$$A_{sw} \ge \frac{v_{Rd,cs} - 0.75 v_{Rd,c}}{1.5 \dfrac{f_{ywd,ef}}{s_r \times u_1}}$$

$$\text{where } v_{Rd,cs} = \frac{V_{Ed}}{u_1 d}$$

Figure 8.1
Punching shear



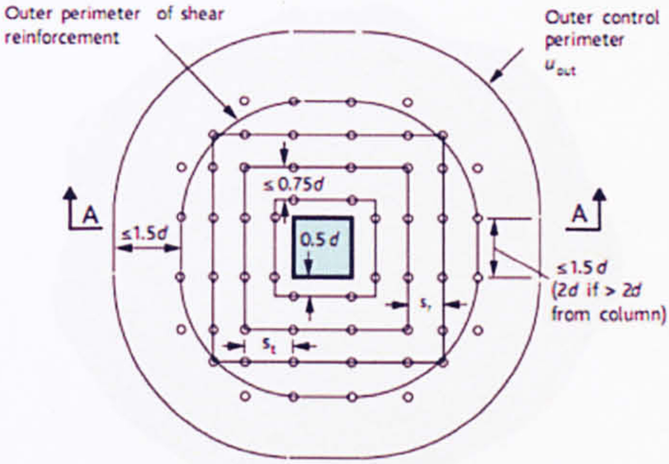
$$V_{Rd,c} = v_{Rd,c} d u$$

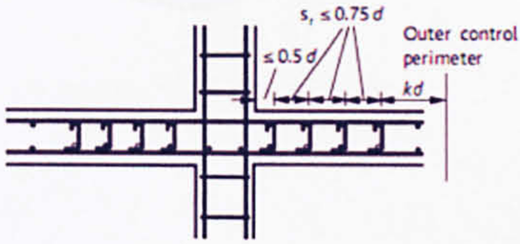
$$d_{\text{effective depth}} = \left(\frac{d_y + d_z}{2}\right)$$

EC2
At 2d
Rounded corners

BS 8110
at 1.5d
Rectangular

PUNCHING SHEAR LAYOUT (EC2)





Section A - A

3.7 COLUMN DESIGN (EC2)

Effective height l_0 of a column

the effective height:
For braced members:

$$l_0 = 0.5l\sqrt{\left(1+\frac{k_1}{0.45+k_1}\right)\left(1+\frac{k_2}{0.45+k_2}\right)}$$

For unbraced members the larger of:

$$l_0 = l\sqrt{\left(1+10\frac{k_1 \times k_2}{k_1+k_2}\right)}$$

and

$$l_0 = l\left(1+\frac{k_1}{1+k_1}\right)\left(1+\frac{k_2}{1+k_2}\right)$$

Table 9.1 Column effective lengths

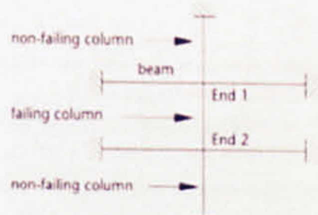
$\frac{1}{4}\frac{(I/l_{column})}{(I/l_{beam})} = k$	0 (fixed end)	0.0625	0.125	0.25	0.50	1.0	1.5	2.0
l_0 – braced (equation 9.2) $\{xl\}$	0.5	0.56	0.61	0.68	0.76	0.84	0.88	0.91
l_0 – unbraced (equation 9.3(a)	1.0	1.14	1.27	1.50	1.87	2.45	2.92	3.32
and 9.3(b)). Use greater value $\{xl\}$	1.0	1.12	1.13	1.44	1.78	2.25	2.56	2.78

k_1 and k_2 are the relative flexibilities of the rotational restraints at ends '1' and '2' of the column respectively

$$k = \frac{\text{column stiffness}}{\sum \text{beam stiffness}} = \frac{(EI/l)_{column}}{\sum 2(EI/l)_{beam}} = \frac{(I/l)_{column}}{\sum 2(I/l)_{beam}}$$

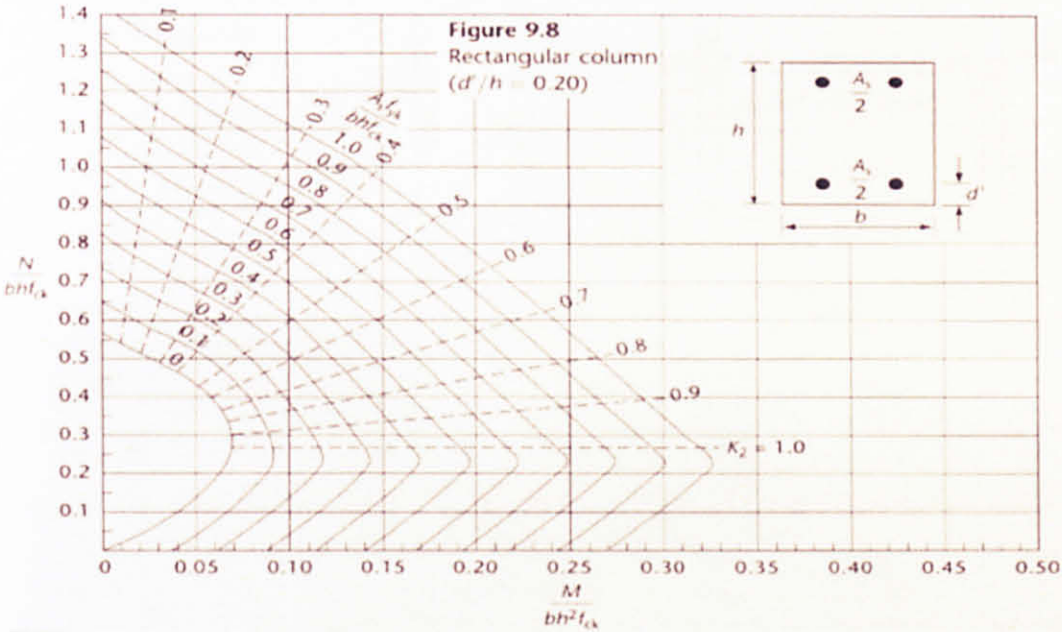
Hence, for a typical column in a symmetrical frame with spans of approximately equal length, as shown in figure 9.2, k_1 and k_2 can be calculated as:

$$k_1 = k_2 = k = \frac{\text{column stiffness}}{\sum \text{beam stiffness}} = \frac{(I/l)_{column}}{\sum 2(I/l)_{beam}} = \frac{(I/l)_{column}}{2 \times 2(I/l)_{beam}} = \frac{1}{4}\frac{(I/l)_{column}}{(I/l)_{beam}}$$



Note: the effective contribution of the non-failing column to the joint stiffness may be ignored

COLUMN DESIGN CHART (EC2)



$$\frac{N}{bhf_{ck}} = \frac{0.567s}{h} + \frac{f_{sc}}{f_{ck}}\frac{A_s}{bh} + \frac{f_s}{f_{ck}}\frac{A_s}{bh}$$

$$\frac{M}{bh^2 f_{ck}} = \frac{0.567s}{h}\left(0.5 - \frac{s}{2h}\right) + \frac{f_{sc}}{f_{ck}}\frac{A_s}{bh}\left(\frac{d}{h} - 0.5\right) - \frac{f_s}{f_{ck}}\frac{A_s}{bh}\left(\frac{d}{h} - 0.5\right)$$

3.8 GANTT CHART

For Semester 1 (July 2009)

	W1	W2	HD	W3	W4	W5	W6	W7	W8	W9	MSB	W10	W11	W12	W13	W14
	20-Jul	27-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	7-Sep	14-Sep	21-Sep	28-Sep	5-Oct	12-Oct	19-Oct	26-Oct	2-Nov
Final Year Project I (Overall Activities)																
Briefing Session	20/7															
Selection of Topic																
Project Proposal Due		24/7														
Submission of Progress Report 1& 2							03/9									
Submission of Interim Report															30/1 0	
Oral Presentation																
Seminar																
IEM Talk				12/8												
IRC Workshop					17/8											
Technical Writing 1					17/8											
Technical Writing 2						24/8										
Laboratory Workshop						24/8										
Referencing									14/9							
HSE Talk														09/9		
FYP 1 Activities																
Project understanding																
Concept and Theory																
Literature review																
Research for reference documents																
Study Ms. Excel Function																
Design																
Template Layout Progress For																
- Beam (BS8110)																

For Semester 2 (January 2010)

	W1	W2	W3	W4	W5	W6	W7	MSB	W8	W9	W10	W11	W12	W13	W14	W15
	25-Jan	1-Feb	8-Feb	15-Feb	22-Feb	1-Mar	8-Mar	15-Mar	22-Mar	29-Mar	5-Apr	12-Apr	19-Apr	26-Apr	3-May	10-May
Final Year Project II (Overall Activities)																
Talk on Statistical Analysis					24/2											
Submission Progress Report I &II							12/3									
Poster Exhibition												14/4				
Submission of Dissertation (Soft bound)**													26/4			
Submission of Dissertation (Hard Bound)															30/4	
Oral Presentations**																7/6-10/6
FYP II Activities																
- Slab (BS8110)																
- Column (BS8110)																
- Beam (EC2)																
- Slab (EC2)																
- Column (EC2)																
EC2 and BS8110 Compared																

3.9 TOOLS REQUIRED

1. Microsoft Excel Worksheet Software

   With the help of following software to improve and double check on any errors that could be occurred by any mean.

   - Microsoft Work
   - Notepad,
   - MathType
   - Graph 2D,
   - Beamax,
   - RC Slab Design Application etc

CHAPTER 4

EXPECTED FINDING/RESULTS

For the expected finding/result will be calculated and showed in the Microsoft Excel Worksheet. The result based on the following criteria.

1. Total Steel Weight and Concrete Volumes used for Beams, Slabs, and Columns designs in BS8110 and EC2, respectively.
2. The ratio of the steel and concrete volumes for Beams, Slabs, and Columns designs in BS8110 and EC2, respectively.

TABLE 1: THE BASIC DIFFERENT BETWEEN BS8110 AND EC2

	BS8110	EC2
Concrete partial factor	1.5	1.15
Steel partial factor	1.05	1.15
Yield Strength	f_y = 460 N/mm^2	f_{yk}=500N/mm^2
Design Strength, Steel	0.95f_{cu} (=0.95*460=437N/mm^2)	0.87f_{ck} (=0.87*500=435N/mm^2)
Concrete Strength	f_{cu} = 40 N/mm^2	f_{ck} = 32 N/mm^2
Design Strength, Concrete	0.45fcu (=18N/mm^2)	0.567fck (=18.144N/mm^2)
S	0.9x	0.8x
Level arm, Z	0.775d	0.82d
Mu, concrete	0.156bd$^2f_{cu}$ (=6.24bd^2)	0.167bd$^2f_{ck}$ (=5.344bd^2)
Mu, Steel (For SR)	0.95f_y.As.z (= 0.95*460*As*0.95d = 415.15As.d)	0.87f_{yk}.As.z (= 0.87*500*As*0.95d = 413.25As.d)
Mu, Steel (For DR)	0.95f_y.As.z (= 0.95*460*As*0.775d = 338.675As.d)	0.87f_{yk}.As.z (= 0.87*500*As*0.82d = 356.7As.d)
Coefficient: On Load Span	Dead Load : 1.4 Live Load : 1.6	Dead Load : 1.35 Live Load : 1.5
Coefficient: On Unload Span	Dead Load : 1.0	Dead Load : 1.35

The following is the result of steel and concrete volumes using under mild and severe exposure, respectively.

- Ws : Steel Weight in t, Tones
- Vc : Concrete Volume in m^3
- Ws/Vc : Ratio of steel and concrete in t/m^3

TABLE 2:

STEEL WEIGHT AND CONCRETE VOLUMES USING UNDER MILD EXPOSURE

	BS8110			EC2		
Beam Size, (mm)	500x700			500x700		
Slab Thickness, (mm)	250			250		
Column Size, (mm)	400x400			400x400		
	Beams	Slabs	Columns	Beams	Slabs	Columns
Ws, (t)	7.835	40.072	7.718	7.443	40.237	6.709
Vc, (m^3)	336	576	39.6	336	576	39.6
Ws/Vs, (t/m^3)	0.0233	0.0696	0.195	0.0222	0.0699	0.1694
Total Ws	55.625			54.389		
Total Vc	951.6			951.6		
Total Ws/Vc	0.05845			0.05715		
% different, Ws (EC2-BS8110)/BS8110	(54.389-55.625)/ 55.625* 100 = -2.22%					
				More Cost Saving		

TABLE 3:

STEEL WEIGHT AND CONCRETE VOLUMES USING UNDER SEVERE EXPOSURE

	BS8110			EC2		
Beam Size, (mm)	500x700			500x700		
Slab Thickness, (mm)	250			250		
Column Size, (mm)	400x400			400x400		
	Beams	Slabs	Columns	Beams	Slabs	Columns
Ws, (t)	8.068	46.013	10.073	7.463	40.783	7.235
Vc, (m^3)	336	576	39.6	336	576	39.6
Ws/Vs, (t/m^3)	0.0240	0.0799	0.254	0.0224	0.0708	0.1827
Total Ws	64.154			55.481		
Total Vc	951.6			951.6		
Total Ws/Vc	0.06742			0.05830		
% different, Ws (EC2-BS8110)/BS8110	(55.481-64.154)/ 64.154* 100 = -13.52%					
				More Cost Saving		

CHAPTER 5

CONCLUSION AND RECOMMENDATION

IN CONCLUSION:

- Microsoft worksheet is a very good program with long-term advantage and time saving but there are risks that need to be well managed and organization.
- EC2 is not wildly different from BS8110 in term of Design Approach but it provided with the more economical than BS8110.
- EC2 provided more flexible strength comparing with BS8110

RECOMMENDATION:

It is good to look at the few different points below in order to make ourselves ready for the EC2.

- For the beam and slab design in both codes are similar and the main different are the partial safety factor and level arm z, especially on checking o the deflection.
- For punching shear reinforcement design have different formula for define the required and have different distance of failure zone.
  - BS8110similar to the stirrup design for the beam
  - EC2 new approach formula to be used.
- For EC2 column design is different from BS8110 on effective length *le*, and condition for biaxial bending of short columns design.
  if $(e_z/h)/(e_y/b)>0.2$ or $(e_y/b)/(e_z/h) > 0.2$ then the column must be designed for the biaxial bending, which not stated in the BS8100.

CHAPTER 6
ECONOMIC BENEFITS

6.1 ELECTRICITY

Since the project is the software simulation based, so it's electricity consumption and the electricity supply is provided in the Laboratory and consumption cost is covered by the department during the project periods.

6.2 DOCUMENTS

Below are the description and cost of the materials which are not provided in the lab and they aided in the completion of the project.
The following are the standard codes' price that needed to spend for the project.

No	Description	Purpose	Quantity	Price (RM)
1	BS EN 1992-1-1:2004	Design of concrete structures - part 1-1 General requirements - All concrete structures	1	RM 595 (£124)
2	UK National Annex to BS EN 1992-1-1:2004	All concrete structures	1	RM 287.70 (£60)
3	BS 8110-1:1997	Structural use of concrete. Code of practice for design and construction	1	RM 841.60 (£ 175.50)
4	BS 8110-2:1985	Structural use of concrete. Code of practice for special circumstances	1	RM 618.60 (£ 129.00)
5	BS 8110-3:1985	Structural use of concrete. Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns	1	RM 669.00 (£ 139.50)
Total Amount				RM 3011.90 (£ 628)

Note: 1£ = RM 4.7955

6.3 ECONOMIC BENEFITS

According to the EC, Eurocode 2 is introduced in early 2003 have been assured by most engineers that it can be used as a practical concrete design tool, as well as producing economic results more structures. It is expected that in building structures there will be material cost savings of between 0 and 5% compared to using BS8110.

The economic advantages of EC2 for flexural design are far greater than can be assessed by looking at the partial factors for loading and materials alone.

- For similar characteristic loading, ULS loading can be 10% to 15% less.
- Rebar design stresses are almost identical, in spite of the differing γ factor.
- The difference in pattern loading may marginally increase support moments but reduce span moments.
- For the same concrete mix, EC2 gives a concrete stress 19.4% higher than BS 8110, which in turn increases the lever arm z.
- More generous span-to-depth ratios can lead to shallower members.

These economies would seem very significant. Shear and column design do not appear to have been trimmed in the same way, but this must reflect our increasing understanding of concrete design. Slabs are by far the most economically critical elements, and here there is advantage.

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    2. BS 8110-2:1985 Structural use of concrete. Code of practice for special circumstances Superseded by EN 1992
    3. BS 8110-3:1985 Structural use of concrete. Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns Superseded by EN 1992
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APPENDIX 1

The practical use of Eurocode 2

1 *Introduction*

When or before Eurocode 2 is introduced in early 2003, most engineers will need to be assured that it can be used as a practical concrete design tool, as well as producing economic results. If they are not assured of this, practices will continue to use BS 8110 in preference to adopting the new code.

Necessary guidance in the form of explanatory literature, process flowcharts, spreadsheets and other software etcetera is in preparation. This brief report will attempt to summarise the principal design procedures required by EC2, compare them with their BS 8110 counterparts, and demonstrate that the transition to EC2 need not be a difficult process.

2 *Comparisons with BS 8110*

2.1 *Loading*

	EC2	*BS 8110*
Loaded spans:	*Worst of* $\gamma_G = 1.35,\ \gamma_Q = 1.05$ *and* $\gamma_G = 1.15,\ \gamma_Q = 1.5$	$\gamma_G = 1.4,\ \gamma_Q = 1.6$
Unloaded spans:	γ_G = *as above*	$\gamma_G = 1.0$
Loading pattern:	*All + adjacent + alternate spans*	*All spans + alternate spans*

For the sake of simplicity, $\gamma_G = 1.35$ and $\gamma_Q = 1.\ 5$ may be used for loaded spans (*with* $\gamma_G = 1.35$ *on unloaded spans*), although this would be very conservative. Both γ_G and γ_Q are marginally lower than in BS 8110, but for unloaded spans γ_G is higher, reflecting a lower probability of variation in dead loads. For a typical member with $Q_k = 0.5\ G_k$, maximum ULS loading would be 13.6% lower than for BS 8110. The use of the same value for γ_G throughout also reduces the effect of pattern loading, thus marginally reducing span moments.

The loading code, EN 1991-1-1, stipulates values of imposed loads that vary only marginally from current UK practice (*e.g. 3 kN/m² for offices*). This code stipulates weights for both construction materials and stored materials, and it should be noted that the density of normal weight reinforced concrete should be taken as *25 kN/m²*.

2.2 *Cover*

Nominal covers required for durability and bond are fairly similar to BS 8110. However, nominal cover to EC2 is in two parts, $C_{nom} = C_{min} + \Delta c$, where Δc is a design tolerance varying from 0 to 10mm, depending upon quality assurance level. This can have the effect of increasing cover to slabs when larger diameter bars are used, as $C_{min} \geq bar\ \phi$ and Δc must be added.

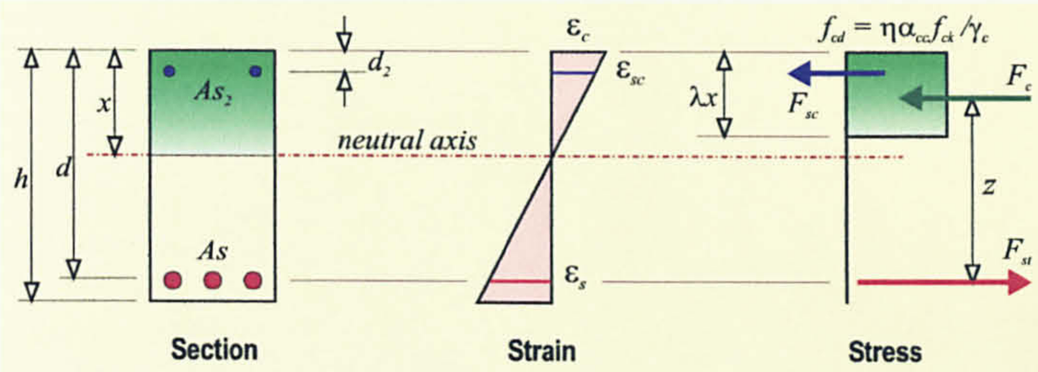
2.3 *Materials*

	EC2	*BS 8110*
Partial factor, concrete:	$\gamma_c = 1.5$	$\gamma_c = 1.5$
Partial factor, steel:	$\gamma_s = 1.15$	$\gamma_s = 1.05$

At first inspection, the higher γ_s factor in EC2 would appear disadvantageous. However, this difference is almost exactly neutralised by the introduction of reinforcing steel with f_{yk} = 500 N/mm^2.

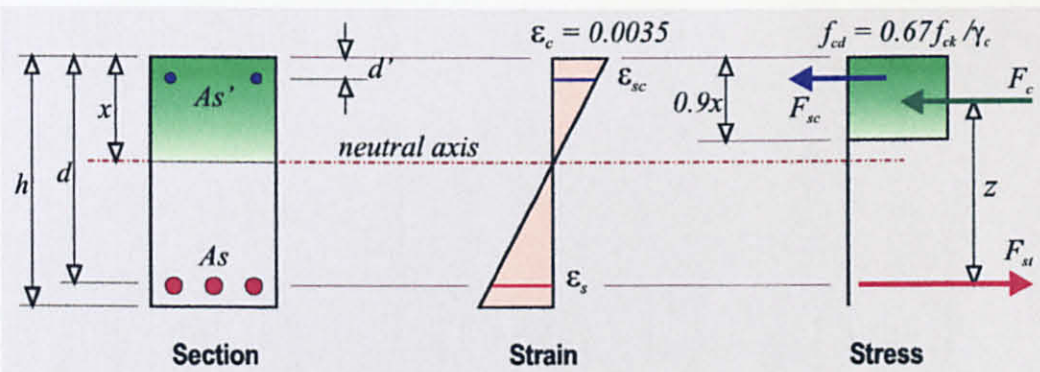
2.4 Stress block – flexure

Eurocode 2



f_{ck} = characteristic concrete cylinder strength (*equivalent to 80% cube strength*).

For $f_{ck} \leq 50$ N/mm^2, $\eta = 1$, $\varepsilon_c = 0.0035$, $\alpha_{cc} = 1.0$ and $\lambda = 0.8$. As γ_c is the same for both codes, this results in concrete design strengths being 19.4% higher than in BS 8110 below. This difference gives advantage in terms of reinforcement areas because of the resulting increase in the lever arm, z.



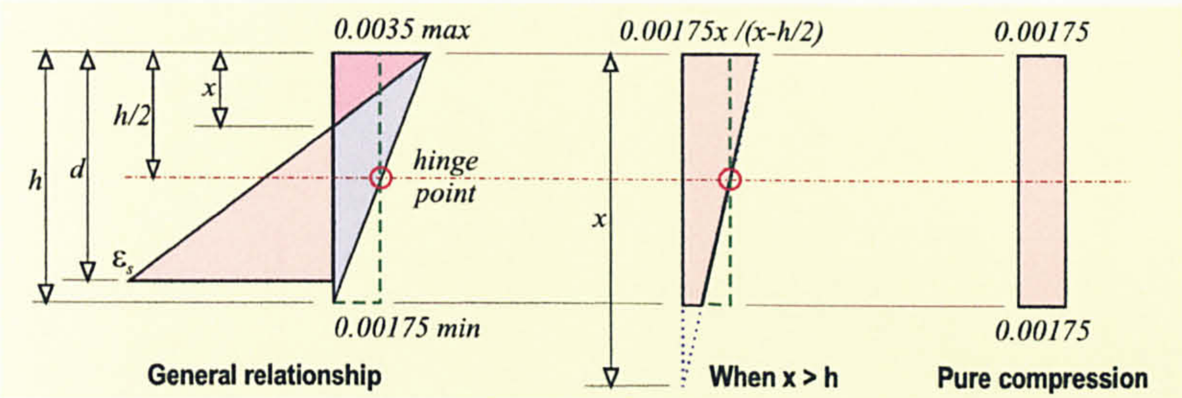
BS 8110

2.5 Stress block – columns

In BS 8110, an identical stress block is used for both pure flexure and bending with axial load. In EC2 however, ε_c the limiting concrete compressive strain, starts to reduce when the neutral axis x drops outside of the section height, h. This strain reaches a lower bound value (*0.00175 for $f_{ck} \leq 50$ N/mm^2*) when the section is in pure compression.

The diagram below demonstrates this procedure. Effectively, the strain diagram has a "hinge point", which falls at *h/2* for normal strength concretes. This process is easily automated, but is not suited to hand calculation, so it is best accomplished by spreadsheet.

As few columns are very close to being in pure compression, this gradual reduction in strain, and hence compressive stress, has less effect than one might imagine.



EC2 strain relationship at ULS *($f_{ck} \leq 50$ N/mm^2)*

2.6 *Redistribution*

	EC2	BS 8110
Neutral axis limit:	*$x/d \leq \delta - 0.4$*	*$x/d \leq \beta_b - 0.4$*
Redistribution limit:	*30% classes B & C*	*30% generally*
	20% for class A rebar	*10% sway frames > 4 storeys*
	0% in columns	*0% in columns*
Limitations:	*Adjacent spans ratio ≤ 2*	

The EC2 *x/d* limit reduces for concrete with $f_{ck} > 50$ N/mm^2, otherwise both codes are very similar.

2.7 *Beam shear*

A strut-and-tie model is used for shear reinforcement to EC2, which can have a varying angle θ between the compressive struts and main tension chord. *Cot* θ is normally taken as the maximum value of 2.5, but may be as low as 1.0 if required for high shear forces.

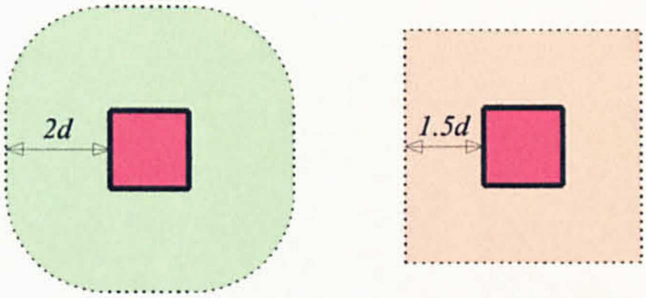
For UD loading,	***EC2***	***BS 8110***
Shear resistance:	$v = 0.7 - f_{ck}/200 \geq 0.5$	
	$k = 1 + \sqrt{(200/d)} \leq 2$	v_c = *from Table 3.8*
	$\rho_l = A_{sl}/b_w d \leq 0.02$	
At support face:	$V_{Rd,max} = 0.9 b_w d.f_{cd} /(\cot\theta + \tan\theta)$	$V_{max} = 0.8\sqrt{f_{cu}} \leq 5$
At d from support:	$V_{Rd,ct} = 0.12k(100\rho_l f_{ck})^{1/3}$	$V_c = v_c.b_v d$
	If $V_{Rd,ct} \geq V_{Ed}$ *nominal links*	*If* $Vc_{ct} \geq V$, *nominal links*

Links:	$A_{sw}/s = V_{Ed}/(0.9d.\,v.f_{cd}\cot\theta)$	$A_{sv}/s_v = 1.05\,b_v(v-v_c)/f_{yv}$
Nominal links:	$A_{sw}/s \geq 0.5\,v.f_{cd}b_w/f_{ywd}$	$A_{sv}/s_v \geq 0.42b_v/f_{yv}$

Understandably, these approaches are somewhat different although both methods are simple enough to apply. One can see from the above formulae that when more than nominal links are required, EC2 ignores any contribution from the concrete. The strut-and-tie method produces an additional tension in the main steel where the compression strut meets this steel. This effect is catered for by applying the "shift rule" when detailing (*see Section 3*).

2.8 Punching shear

The calculation of punching shear is basically similar to BS 8110, except that the control perimeter is at *2d*, rather than *1.5d* from the column face, and follows a locus from the column face, rather than being rectangular in shape.



	EC2	BS 8110
Basic control perimeter:	*At 2d*	*at 1.5d*
Control perimeter shape:	*Rounded corners*	*Rectangular*
Flat slab shear enhancement factors		
Internal:	*1.15*	*1.15*
Edges:	*1.4*	*1.4 or 1.25*
Corners:	*1.5*	*1.25*

When links are required, EC2 allows a contribution of 75% of the concrete shear resistance (*unlike beam shear*), and a radial distribution of links is assumed. An outer perimeter, at which no further links are required, is based upon the link arrangement rather than the basic control perimeter.

The much higher enhancement factor of 1.5 for corner columns may prove critical in some circumstances, when sizing flat slabs for shear. However, the method as a whole seems very logical and may result in fewer links and be simpler to detail than the BS8110 method.

2.9 Span to depth ratios

	EC2	*BS 8110*
Basic L/d ratios:	*K factors from Table 7.4 used in equations 7.14a & b*	*From Table 3.9*
Tension steel modifier:	*In equations*	*From Table 3.10*
Compression steel modifier:	*In equations*	*From Table 3.11*
Flanged sections:	$1 \geq 1 - 0.2b_w/b_f/3 \geq 0.8$	*Interpolated between Table 3.9 values*
Long span modifier:	***Only used if there are brittle partitions*** *Flat slabs:* $8.5/L \leq 1$ *Otherwise:* $7/L \leq 1$	$10/L \leq 1$
Service stress modifier:	$310/\sigma_s$ *(steel service stress)*	*Formulae included in Table 3.10*

These two methods are very similar, but in practice, Eurocode 2 effectively allows marginally shallower members than BS 8110. This is likely to be because the EC2 ratios have made no allowance for early age overloading during construction, which can increase the degree of cracking, particularly in slabs.

2.10 Maximum bar spacing

For normal internal exposure, EC2 recommends a maximum crack width of 0.4mm compared to 0.3mm in BS 8110. However, the maximum bar spacings in Table 7.3 are somewhat less than those now commonly used in the UK. This will tend towards the use of slightly smaller diameter bars in slabs. The actual calculation of crack widths to clause 7.3.4 allows more flexibility.

2.11 Beam flange widths

To both codes, effective flange widths may be calculated directly from the distances between points of contraflexure, but the default values below give an indication of comparative values.

	EC2	*BS 8110*
Effective span, spans:	*Simple supports, L* *End span, 0.85L* *Internal span, 0.7L*	*Simple supports, L* *End span, 0.85L* *Internal span, 0.7L*
Effective span, supports:	*Cantilever, L.* *Others, 0.15L either side of support.*	*Not applicable*
Effective b_f*, T-beam:*	$[b_1/5+L_{eff}/10] \leq L_{eff}/5$ plus $[b_2/5+L_{eff}/10] \leq L_{eff}/5$ $\leq b_w+b_1+b_2$	$b_w+L_{eff}/5 \leq b_w+b_1+b_2$
Effective b_f*, L-beam:*	$b_w+\{[b_1/5+L_{eff}/10] \leq L_{eff}/5\} \leq b_w+b_1$	$b_w+L_{eff}/10 \leq b_w+b_1$

b_1 and b_2 are the actual flange outstands on either side of the web

The practical use of Eurocode 2

It should be noted that EC2 requires a portion of beam support steel to be spread across the width of flange. This is why a method is also provided for assessing the widths of tension flanges.

2.12 Flat slabs

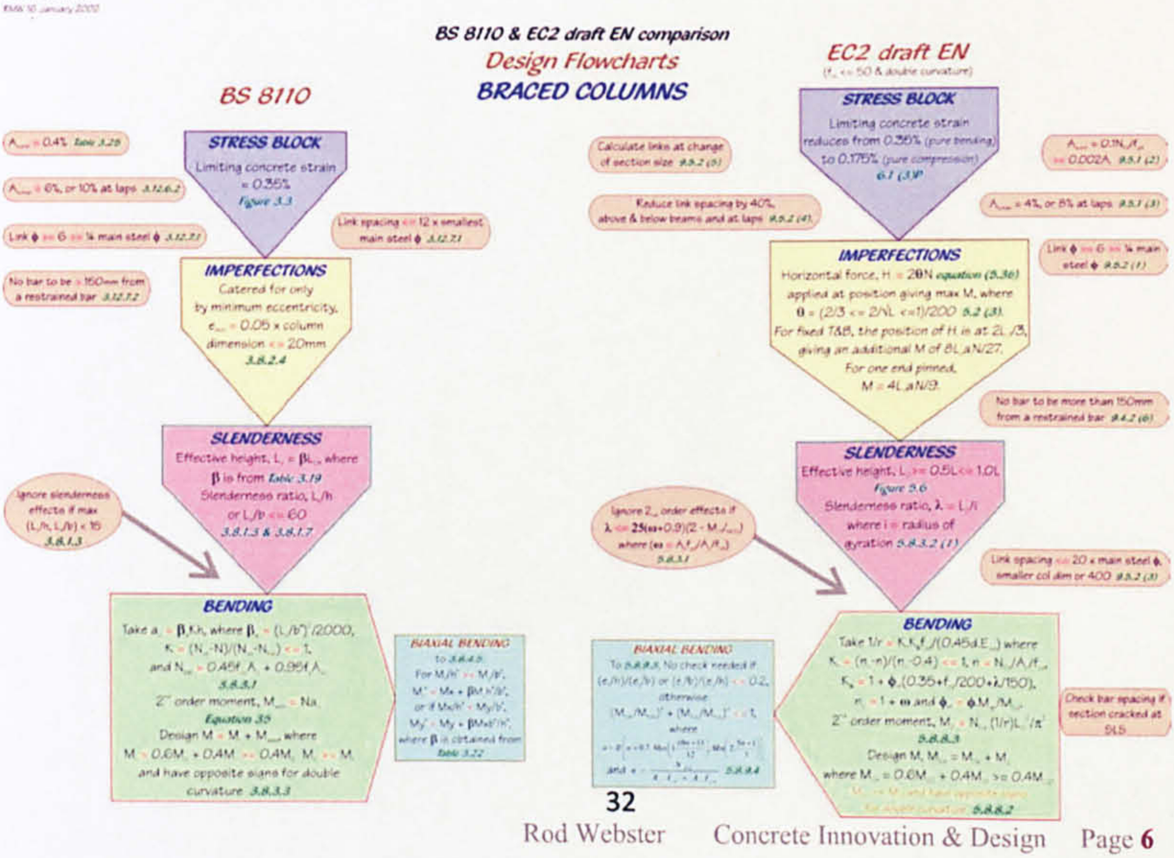
For flat slabs, the two codes are almost identical, the relevant EC2 clauses having been drafted in Britain. Slightly more latitude is suggested however, for the apportioning of moments between column strips and middle strips.

$M_{t,max}$, the limit on moment transfer into edge/corner columns, is approximately 10% lower than for BS 8110.

2.13 Columns

Some of the terminology in Eurocode 2 relating to column design may be slightly unfamiliar, with minimum eccentricities being described under "imperfections" and buckling etcetera falling within "second order effects". Alternative design methods are given, but the "curvature" method is similar in approach to current practice. As with BS 8110, the column design process is quite tedious to perform manually, but is relatively easy to automate. The simplified method given for carrying out biaxial bending checks is more logical than in BS 8110, and is simple to apply.

A comparison between the EC2 and BS column design processes is shown in the flowcharts below.



3 *Detailing*

3.1 *General*

EC2detailing rules are slightly more complex than for BS 8110. It will no longer be possible to make simple assumptions, such 35 or 40 diameters for an anchorage length, and technicians will need to learn the necessary skills, as there are differing anchorage rules for different types of member. There are also many small changes to be learned, such as the detailing of beam support steel within flanges, minimum reinforcement percentages, and new rules regarding the staggering of laps.

3.2 *The shift rule*

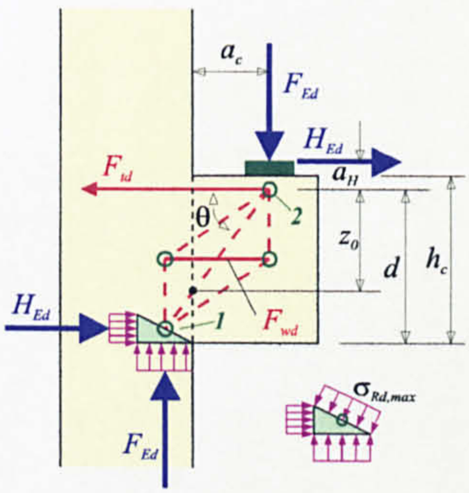
This is the recommended method for working out curtailment points for beam reinforcement, which at the same time ensures the provision of sufficient steel near to supports, to accommodate the additional tensile forces generated by the strut-and-tie shear action described in 2.7.

Basically, the bending moment envelope is "shifted" a distance between *0.45d* and *1.125d* and bars should have an anchorage length beyond their relevant "shifted" point of being no longer required.

4 *Unfamiliar processes*

4.1 *Strut-and-tie models*

The strut-and-tie method should be used for the design of D-regions, which are described as "*discontinuities in geometry or action*". Some such discontinuities are frame corners, corbels, or abrupt changes in section. It is also important to note that this method is implied within the shear design process described in 2.7 and 2.8 above.



Typical node model for a corbel

Although widely used in other European countries, this approach, while not being particularly complex, will be unfamiliar to many designers in the UK, so both engineers and technicians are likely to require guidance.

5 EC2 overview

5.1 General

The areas covered by this document are not exhaustive; only what are considered to be the more important and commonly used procedures have been discussed. Eurocode 2 is a very comprehensive code and also includes rules for precast concrete, post-tensioned members etcetera, but the focus here has been on everyday insitu reinforced concrete design.

5.2 Code philosophy

The general philosophy of EC2 is quite different from that found in BS 8110. The Eurocode is less empirical and more logical in its approach. For example, variables such as partial factors for materials are shown within formulae, rather than being "built in" as part of an obscure number. If one wishes to go into greater detail, there are appendices to the code that give derivation formulae for items such as creep coefficients and shrinkage strains, which are most helpful when attempting to automate the design process.

EC2 makes no attempt to be a design "guide"; it is a code giving general rules. There are no simplified tables of moment or shear factors for example, as one would be expected to look for these in separate design guides or standard textbooks.

In my view, EC2 has great potential of being accepted as a very good replacement for BS 8110. Inevitably there will be those who wish to resist any change, but I am sure that, after an initial learning period, the superiority and economic advantages of EC2 will universally recognised.

5.3 What is needed?

To smooth the transition to EC2, the following tools will be required; preferably to be available before the predicted formal release of the new code in early 2003.

- General design guides
- Worked examples
- A "Concise EC2"
- A full set of design spreadsheets
- Comparative and calibration studies
- An EC2 version of "Economic Frame Elements"

Hopefully, specialist software houses can also be encouraged to update their programs in due time. Of prime importance will be the availability of updated finite element software, as moments generated by programs written to the ENV version of EC2 will not be correct.

5.4 "Factors of safety"

There has been recent discussion regarding comparative "*factors of safety*" between BS 8110 and EC2 (*also CP49!*), which shows a massive misunderstanding of the basic principles of limit state design.

- A true factor of safety can only be determined by comparing design loading with that at collapse.
- Partial factors for materials and loading are not safety factors; they only reflect degrees of confidence.
- Any basic understanding of statistics proves that to simply multiply together sets of factors or probabilities is completely meaningless.

The economic advantages of EC2 for flexural design are far greater than can be assessed by looking at the partial factors for loading and materials alone.

- For similar characteristic loading, ULS loading can be 10% to 15% less.
- Rebar design stresses are almost identical, in spite of the differing γ factor.
- The difference in pattern loading may marginally increase support moments but reduce span moments.
- For the same concrete mix, EC2 gives a concrete stress 19.4% higher than BS 8110, which in turn increases the lever arm z.
- More generous span-to-depth ratios can lead to shallower members.

These economies would seem very significant. Shear and column design do not appear to have been trimmed in the same way, but this must reflect our increasing understanding of concrete design. Slabs are by far the most economically critical elements, and here there is advantage.