



STUDY ON THE IMPROVEMENT CODE OF PRACTICES IN STRUCTURAL
DESIGN AND MATERIAL SPECIFICATIONS

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ABSTRACT

In Malaysia, most of the design concrete structure is based on Code of Practice British Standard (BS 8110). In line with the change of time and technology, Malaysia has been introduced to Eurocode 2 (EC 2) as a new guideline in design concrete structures. However, EC2 still in early stage of implementation therefore, it widely introduced to the engineers and in the higher institutions. The main objective of this study is to find the differences between BS 8110 and EC 2 in the aspect of materials and design specifications. There have few differences identified and studies have been conducted to find out the causes and reasons of the changing. The main differences between BS 8110 and EC 2 in the design specifications is BS 8110 designed based on structure element such as beam, column, slab and others. While, EC 2 designed based on phenomenon such as flexure, shear, deflection and axial force. In terms of material, there is change in partial factor of safety for reinforcing steel. Partial factor of safety for reinforcing steel in EC 2 is higher compare with value use in BS 8110. However, this difference neutralized by the reinforcing steel with $f_{yk} = 500 \text{ N/mm}^2$. In addition, there are many factors need to be consider in EC 2 compare with BS 8110.

ABSTRAK

Di Malaysia, kebanyakan rekabentuk struktur konkrit adalah berdasarkan kod amalan British Standard (BS 8110). Sejar dengan perkembangan masa dan teknologi, Malaysia telah mula diperkenalkan dengan penggunaan Eurocode 2 (EC 2) sebagai pendekatan baru dalam merekabentuk struktur konkrit. Walaubagaimanapun, penggunaan EC 2 masih lagi diperingkat awal dan berkeseesuaian dengan perubahan ini, para jurutera dan semua institusi pengajian tinggi di Malaysia telah mula diperkenalkan dengan penggunaan EC 2. Objektif utama kajian ini adalah untuk mencari perbezaan di antara BS 8110 dan EC 2 di dalam aspek bahan dan spesifikasi rekabentuk struktur. Terdapat beberapa perbezaan yang telah dikenalpasti dan kajian telah dilakukan untuk mengetahui sebab dan kesan perubahan tersebut. Perbezaan utama di antara BS 8110 dan EC 2 di dalam aspek spesifikasi rekabentuk. Rekabentuk menggunakan BS 8110 adalah berdasarkan elemen struktur seperti rasuk, papak, tiang dan sebagainya. Manakala rekabentuk menggunakan EC 2 pula mengambil kira fenomena keadaan struktur seperti pesongan, ricih, lenturan dan paksi daya. Bagi perbandingan dalam aspek bahan, terdapat beberapa perubahan dalam faktor keselamatan separuh bahan untuk keluli. Faktor keselamatan separuh bahan untuk keluli yang digunakan di dalam EC 2 adalah lebih tinggi nilainya berbanding BS 8110. Walaubagaimanapun, perbezaan tersebut telah dineutralkan dengan mengambil kira $f_{yk} = 500 \text{ N/mm}^2$. Selain daripada itu, terdapat banyak faktor-faktor yang di ambil kira ketika melakukan proses pengiraan untuk EC 2 berbanding BS 8110.

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LIST OF SYMBOLS

G_k	Characteristic dead load
Q_k	Characteristic imposed load
f_{cu}	Characteristic strength of concrete (cube)
f_y	Characteristic strength of reinforcement
γ_f	Partial safety factor for load
f_{ck}	Characteristic strength of reinforcement (cylinder)
f_{yk}	Characteristic strength of reinforcement
γ_G	Partial safety factor for permanent action
γ_Q	Partial safety factor for variable action
γ_m	Partial safety factor for concrete material
γ_c	Partial safety factor for concrete
γ_s	Partial safety factor for steel

LIST OF ABBREVIATIONS

BS	British Standard
EC	Eurocode
Cl.	Clause

CHAPTER 1

INTRODUCTION AND GENERAL INFORMATION

1.1 Introduction

In 1954, CP 114 was introduced to guide structural engineers in Britain to design reinforced concrete structures and it was used as the standard code of practice in Malaysia. CP 114 based on the permissible stress method. This standard was then replaced by BS 110 when the principle of limit states was introduced. BS 110 encountered many comments from the contractors as well designers for its limitation, therefore BS 8110 was introduced. BS 8110 was reviewed twice since its inception. Recently the Eurocode were introduced and has been used in Europe as well as in UK. This project is proposed to identify the differences between the various codes of practice in term of the improvement and design limitation.

Other than that, code of practice is a document which is written to help engineers in design works. Even though there are several codes of practice being used in Malaysia such as Malaysian Standard (MS), British Standard (BS 8110) and Eurocode 2, British Standard is still the main source for structural design until today.

More than thirty years ago, many researches have been done by expertise in improving all the standard code of practices. Standard that have been improved now used as reference to meet the design requirement in term of safety and economic. Therefore, the code of practice also changed based on the design and development.

In year 1954, CP 114 was issued. In this code of practices design load factor concept has been introduced and used in design beams, slabs and column. By improving CP 114, new code of practice CP110 has been developed in 1972. Sequences to CP114 and CP110, BS 8110 have been introduced. BS 8110 covers all the principles of design in the previous code CP110 but some modifications have been made.

Design of concrete structures in Malaysia is based on BS8110 on 1997. Eurocode have been used in other country especially in Europe. Nowadays, the engineers in Malaysia take initiative to introduce the design of concrete structures using Eurocode 2. Many universities have been teaching their student in designing using Eurocode 2.

This research is to distinguish between BS 8110 and Eurocode 2 due to aspect of structural design and aspect of material specification. The improvement each code of practices and the advantages and disadvantages can identify.

1.2 Problem Statement

The standard code of practice is renewed from time to time according to the development and changes due to time and needs. The renewed matters normally in design procedure and term such as changes of symbol, terminology, review and revision of shear deflection. The major change is the design concept. BS8110 use design rules and EC2 is according to the behavior of the structure. In EC2, there are many parameters that need to be consider but in BS8110 is more simplified method.

The improvement in aspect of structural design and material specification is the main objectives that to find out and the changing of each code of practice have their own reason.

1.3 The Objective of The Research

There are the objectives of this study as shown below:

1. The aim of this research to find out the improvement in aspect of structural design based on the code of practices that have been used. The standard codes of practices use are BS8110 and Eurocode 2. The critical comments are only specific to the beam design only.
2. The objective of this research also to compare the code of practices in aspect material specification. Each of them updated time by time. Then, to find the difference concept, applications and processes involved in the design code of practice.

1.4 Scope Of Study

The scopes of work for this study are as follows:

1. Code of Practices: BS8110:1997: Part 1 Code of Practice for Design and Construction and Eurocode 2: 1992 Design of Concrete Structures (reinforced concrete beam).
2. Literature study on reinforced concrete beam.
3. Critical comments on these BS8110 and EC2.

1.5 Significant Of Studies

There are a lot of codes and rules provided by this involve the construction of reinforced concrete to facilitate the construction process until the publication of appropriate codes of practice. Significance of the study is to identify the advantages and disadvantages of using the code of practices. Each code of practice has its own

criteria, that why engineers are given the options to use the appropriate codes of practice. In addition, the studies of codes of practice are important for future reference. We will identify the best code of practice and can put forward for future engineer as their reference. In addition, a code of practice is also useful when we do the research about this. All additions and reductions in each of the code of practice BS8110 and Eurocode 2 can be identified and the reasons for the modification.

1.6 Expected Outcome

In the end of this research, the expected outcomes are:

1. The difference in structural reinforced concrete beam design.
2. The difference in aspect of material specification in beam design.

CHAPTER 2

LITERATURE REVIEW

2.1 Code of Practice British Standard (BS8110)

BS8110: Part1:1997 has been published on the orders of Civil Engineering and Building Structures Committee Standards. Code of practice is provided with BS8110:Part2:1985 to replace the CP110: Part 1:1972. Other than BS8110, there is other BS that has been published in connection with the construction industry.

- i. BS 1192 Construction Drawing Practice
- ii. BS 1363 Mains Power Plugs and Sockets
- iii. BS 1852 Resistor Value Coding
- iv. BS 5750 Quality Management
- v. BS 6930 Site Investigations
- vi. BS 5950 Steel Structure
- vii. BS 6879 British Geocodes

In BS8110: Part 1, there are consists 8 parts that divided into several structural elements. Each part is as shown in Table 2.1:

Table 2.1: Parts of BS8110

Part	General matters relating to the design of reinforced concrete design scope, definitions and related symbols.
Part 1	Design objectives and recommendations on areas such as basic design, structural design, analysis, loading and material properties.
Part 2	Design objectives and general recommendation.
Part 3	Design and detailing for reinforced concrete
Part 4	Design and details for prestressed concrete
Part 5	Structural design and details of precast and composite construction
Part 6	Materials, specifications, concrete and construction
Part 7	Specifications and workmanship for the reinforcement
Part 8	Specifications and workmanship for prestressing tendons

BS 8110-1:1997 mentioned that British Standard has been provided to several sub-communities such as Association of Consulting Engineer, British Cement Association and several another communities under Civil Engineering and Building Structures Standard Committee.

There are several elements that have been contained in BS 8110:1997:

Part 1: Code of Practice for Design and Construction.

Part 2: Code of Practice for Special Circumstances.

Part 3: Design Chart for single reinforced beam, doubly reinforced beam and rectangular column. (Norfadhillah,2009)

BS 8110: Part 1: 1985 has been provided under Civil Engineering and Building Structures Standard Committee. It produced together with BS8110: Part 2:1985 to replaced CP 110:Part 1:1972. Then, BS 8110: Part 1:1997 combined all the amendment issued to BS8110:Part 1:1985 as stated before:

- a) Amendment No. 1 (AMD 5917) published on 31 May 1989.
- b) Amendment No. 2 (AMD 6276) published on 22 December 1989.
- c) Amendment No. 3 (AMD 7583) published on 15 March 1993.
- d) Amendment No. 4 (AMD 7973) published on 15 September 1993.

BS8110: Part1:1997 consist 8 parts that begin from part 1 until Part 8. Each parts in BS8110 divided regarding to structural elements. Part 1 describes the general section of reinforced concrete. While, part 2 contains the general objectives and the proposed design that explains in detail on the basis of concrete design, concrete design, evaluation and revision of the scope of the reinforced concrete structural conducted on site, the characteristics of materials used, types of loads, design analysis and design based on the tests. Section 3 includes the work of design and detailing for reinforced concrete structural elements such as beams, solid slabs, ribbed slabs, flat slabs, columns, walls and stairs.

Section 4 gives the design principles and details for prestressed concrete and section 5 covers the design and details of construction and pre-cast composite. Section 6 covers the materials, specifications and construction concrete. Section 7 consist specifications and workmanship for the reinforcement and the lastly section 8 includes specifications and workmanship for tendons prestress. (Rozita, 2008)

2.2 Eurocode 2: 1992 Design of Concrete Structures (EC2)

2.2.1 Background of ENV to Eurocode 2

Eurocode 2 will be the one design code for all concrete structures in the UK and Europe. EN 1992-1-1 was published in December 2004 and the National Annex was published in December 2005, making it possible to use in the UK. The standard was developed to bring reinforced concrete design up to date. It benefits from over 40 years of knowledge and experience since the forerunners of the UK ultimate limit

state codes (BS 8110, BS 8007) were first put together, Eurocode 2 may appear hard to comprehend and more complex, at first sight, than UK codes but it is undoubtedly more comprehensive.

Eurocode 2 has four parts:

- i. BS EN 1992-1-1 Common rules for buildings and civil engineering structures
- ii. BS EN 1992-1-2 Structural fire design
- iii. BS EN 1992-2 Bridges
- iv. BS EN 1992-3 Liquid retaining structures

Each part has a National Annex (NA) which gives national values for certain partial factors (or Nationally Determined Parameters, NDP's). Besides safety, the NA might also include matters of national custom and practice. These NA's are backed by PD6687 which gives the background to UK choices. PD6687 covers BS EN 1992-1-1 and BS EN 1992-1-2. During 2008 it is anticipated that PD6687 will be extended to cover BS EN 1992-3 and PD6697-2 covering the NDP's to BS EN 1992-2. In the UK, Eurocode 2 will replace BS 8110 for buildings, BS 5400 for bridges, BS 8007 for water-retaining structures and BS 6349 for maritime structures.

Table 2.2 Parts of Eurocode

EN Number	Part	Subject that involved
EN 1990	Eurocode	Basis of structural design
EN 1991	Eurocode 1	Actions on structures
EN 1992	Eurocode 2	Design of concrete structures
EN 1993	Eurocode 3	Design of steel structures
EN 1994	Eurocode 4	Design of composite steel and concrete structures
EN 1995	Eurocode 5	Design of timber structures
EN 1996	Eurocode 6	Design of masonry structures
EN 1997	Eurocode 7	Geotechnical design
EN 1998	Eurocode 8	Design of structures for earthquake resistance
EN 1999	Eurocode 9	Design of aluminium structures

2.2.2 Scope of EC2

EC2 is a guide for the construction of buildings and civil engineering works which are occur in reinforced concrete works and prestressed concrete. The standard Code of practice also complies with the principles and requirements of safety and serviceability as the fundamentals of structural design and verification found in EN 1990: Fundamentals of Structural Design. EC2 emphasizes the need for resistance, serviceability, durability and resistance to fire for concrete structures. In EC2, there are some clauses which are divided according to the behavior of a structural member. Table 2.3 states the clauses contained in Eurocode 2. (Rafizah Jaafar, 2009)

Table 2.3: Clause of EC2

Clases	Subject that involved
Clause 1	Introduction to EC2
Clause 2	Basis of Design
Clause 3	Characteristics and behavior of materials
Clause 4	Durability and cover to reinforcement
Clause 5	Structural analysis
Clause 6	Ultimate limit state
Clause 7	Serviceability limit state
Clause 8	Detailing of reinforcement and prestressing tendons
Clause 9	Detailing of members and particular rules
Clause 10	Additional rules for precast concrete elements and structures
Clause 11	Lightweight aggregated concrete structures
Clause 12	Plain and lightly reinforced structures

2.3 Objectives of Eurocode

There are ten code of practice Eurocode being published from 2002 until 2006 to replace the old practice of code since 2007. Eurocode will be used for construction work in Europe and is designed to help make the construction industry in Europe more competitive and improve the safety of the structure. In addition, Eurocode become the main reference material, guides and guidance to the recent development and provide training to all users.

Other than that, EC2 also describes the use in general for all buildings structures, reinforced and prestressed concrete. Both concrete of normal weight concrete and light weight are included in this section. Each part explains the difference in EN 1992-1-1 basic phenomenon (eg, flexure, shear, deflection and bending) more than the types of members (eg beams, slabs, columns). (Hayder, 2009)

Table 2.4: Relationship between Eurocode and British Standard

Eurocode	Title	British Standard
BS EN 1990	Basic of structural design	BS 8110:Part 1 – section 2
BS EN 1991-1-1	Densities, selfweight and imposed loads	BS 6399:Part 1
BS EN 1991-1-4	Wind actions	BS 6399: Part 3
BS EN 1992-1-1	General rules of buildings	BS 8110:Part 1,2 and 3
BS EN 1992-1-2	Fire resistance concrete structures	BS 8110:Part 1, table 3.2 and BS 8110:Part 2, section 4

2.4 Differences between BS8110 and EC2

Significant differences between BS8110 and EC2 are as follows:

- i) Terminology and symbols
- ii) The contents and clauses
- iii) Material characteristics
- iv) Durability design
- v) Partial safety factor of materials
- vi) Stress and strain distributions of the section

2.4.1 Terminology and symbol

Terminology and symbols used in Eurocode is somewhat similar to that found with a BS in 8110. However, there are several different between the two codes in this practice. Table 2.5 and Table 2.6 show the difference:

Table 2.5: Differences Terminology between BS8110 and EC2

BS 8110	EC2
Loads	Actions
Dead load	Permanent action
Imposed load	Variable action
Bending moment	Internal moment
Axial forces	Internal forces

Table 2.6: Differences symbol between BS 8110 and EC2

BS8110	EC2
Characteristic dead load, G_k	Characteristic permanent action, G_k
Characteristic imposed load, Q_k	Characteristic variable action, Q_k
Characteristic strength of concrete (cube), f_{cu}	Characteristic strength of reinforcement, f_{ck}
Characteristic strength of reinforcement, f_y	Characteristic strength of reinforcement, f_{yk}
Partial safety factor for load, γ_f	Partial safety factor for permanent action, γ_G Partial safety factor for variable action, γ_Q

2.4.2 Contents and chronology of clause

In EC2, organization structure is based behavior such as shear flexure, shear, deflection and bending while for BS8110, the clause arrangement is by type of structural elements such as slabs, beams, columns and so on.

2.4.3 Material characteristics

In EC2, the formula is based on the design of cylindrical concrete strength 28 days, f_{ck} while BS 8110 using 28 days concrete cube strength, f_{cu} . By estimation, the strength of the cylinder is 80% of the cube strength.

2.4.4 Partial safety factor of materials

BS 8110 and EC2 have identified the durability of concrete structure is closely related to environmental conditions, reinforcement cover, concrete quality and maximum width of the crack. To select the cover in EC2, environmental condition has been considered with classified the environment into 9 sections (EC 2 – Section 4 Durability and Cover to Reinforcement) and BS 8110 does not specify the circumstances but exposed only to classify the situation as mild, moderate, severe, very severe and abrative (BS 8110, Table 3 Nominal Cover To All Reinforcement To Meet Durability Requirement).

2.4.5 Partial safety factor of materials

Same as BS 8110, EC 2 also use the factor of safety for concrete material γ_m is 1.5. Then, the factor of safety for steel in BS 8110 has been reduced from 1.15 to 1.05. For existing yield strength, BS 8110 has taken 460 N/mm² while EC2 taking 500N/mm². (Hasnita, 2008,)

2.5 Comparison Between Structural Eurocodes and British Standards

Eurocode 2 or in short EC2 is the European proposed standard for the structural design of concrete structures. The British Standards Institution (BSI) has planned to publish 9 separate documents related to concrete design under EC2. The publications, known as European Prestandards (ENV) are listed as follows:

- i. DD ENV 1992-1-1: 1992 General rules for buildings.
- ii. DD ENV 1992-1-2: 1996 Structural fire design
- iii. DD ENV 1992-1-3: 1996 Precast concrete elements and structure
- iv. DD ENV 1992-1-4: 1996 Lightweight aggregate concrete
- v. DD ENV 1992-1-5: 1996 Structures with unbonded and prestressing tendons
- vi. DD ENV 1992-1-6: 1996 Plain concrete structures
- vii. ENV 1992-2 : 1996 Concrete bridges
- viii. ENV 1992-3 : 1998 Concrete foundations
- ix. ENV 1992-4 : 1998 Liquid retaining and containment structures

Publications with DD notation have been adopted in the UK and accompanied by its corresponding National Application Document (NAD). The NAD provides operational guidance for each country. There are other documents under EC2, apart from those listed, yet to be published. Generally, EC2: Part 1 is broadly comparable to the existing British Standard, BS 8110 Part 1 and 2 [2--3]. Whilst BS 8110 is basically applicable to buildings, EC2 comprised of various parts and covers on the different types of structures. Building is generally covered by EC2: Part 1.