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*Overview Of Structural Eurocode Adoption In Bridge Design*

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## INTRODUCTION

The Malaysian construction industry has adopted many British Standards (BS) as Malaysian Standards (MS), and also eventually adopted ISO standards, ASTM, ACI, JIS, AS/NZ as MS. Generally, the common codes of practice for structural design that are being used extensively in Malaysia are Malaysian Standards and British Standards.

Malaysia, due to historical background as a British colony has traditionally adopted the British Standards in bridge design starting with the introduction of the limit state philosophy through BS 153 Part 3A, then BS 5400, and followed by the UK Departmental Standard BD 37/01, which subsequently was incorporated into the Design Manual for Roads and Bridges (DRMB) until today.

Eurocode are being developed jointly by experts throughout the European countries for about 30 years and has been accepted in meeting ISO standards. This opens greater opportunity for the code to be accepted worldwide alongside other well-known codes. They are applicable to whole structures including bridges and to individual elements of structures and cater for the use of all the major construction materials such as concrete, steel, timber, masonry and aluminium. There are essentially three (3) categories of European standardization for construction; the Eurocode are the design standards, the Execution Standards set out requirements that must be achieved during construction, and Product Standards set out the requirements for material and products.

Presently, most of the European countries have adopted Eurocode for the design and construction of building and civil engineering works which has eventually superseded the differing rules in member states. In UK, the date set for the full implementation of Eurocode had been shifted from 2006 to 2008 and finally to 2010. The British Standards Institution (BSI) withdrew UK National Standards (BS) that was in conflict with Eurocode on 31 March 2010, at which point Eurocode became the published and maintained structural design standards in the UK. The structural Eurocode became mandatory throughout Europe for public sector bodies.

In-line with the move in the UK and 27 European Union (EU) countries, Malaysia having no better options, accepted Eurocode as the best alternative for Malaysian construction practice. Continuing to use BS 5400 and BD 37/01 for bridge design means we would not achieve the best design, as they are already obsolete since 1st April 2010. British Standard Institution (BSI) has stated that there will be no further updates of design BS. This paper will only emphasize on the implementation of Eurocode in structural bridge design.

## BENEFIT OF ADOPTING DESIGN EUROCODE

Eurocode are a set of harmonized technical rules developed by the European Committee for Standardization for the structural design of construction works in the European Union. The purposes of the Eurocode are as following:

i. To prove compliance with the requirements for mechanical strength and stability and safety in case of fire established by European Union Law.

ii. A basis for construction and engineering contract specifications.

iii. A framework for creating harmonized technical specifications for building and infrastructure product.

The benefits of adopting the Eurocode which were highlighted by UK Concrete Centre (Narayanan, 2005) are summarized as below:

i. Eurocode are claimed to be the most technically advanced codes in the world

ii. Eurocode should result in more economic structure than BS

iii. Eurocode are logical and organized to avoid repetition

iv. Eurocode is less restrictive than existing codes

v. Use of Eurocode will provide more opportunity for designers to work throughout Europe

For engineers in Malaysia the additional benefits of using Eurocode can be listed below:

- Able to compete globally in providing building design services since the code has been accepted by ISO
- Enjoy the benefit of continuous improvement and advancement in concrete design as it will be updated according to the progress in the new knowledge discovered through extensive research in Europe
- Utilizing local values in Malaysian National Annex

## SIMILARITY BETWEEN EUROCODE (EN) AND BRITISH STANDARDS (BS 5400)

Each structural Eurocode is established in a number of parts, covering a range of application. There are ten (10) Structure Eurocode covering the technical aspects structural design of buildings and civil engineering works, each one consisting of several parts. The Structural Eurocode comprises of the following:

1. EN 1990 Eurocode 0 : Basis of Structural Design
2. EN 1991 Eurocode 1 : Actions on structures
3. EN 1992 Eurocode 2 : Design of concrete structures
4. EN 1993 Eurocode 3 : Design of steel structures
5. EN 1994 Eurocode 4 : Design of composite steel and concrete structures
6. EN 1995 Eurocode 5 : Design of timber structures
7. EN 1996 Eurocode 6 : Design of masonry structures
8. EN 1997 Eurocode 7 : Geotechnical design
9. EN 1998 Eurocode 8 : Design of structures for earthquake resistance

10. EN 1999 Eurocode 9 : Design of aluminium structures

The relationship between structure Eurocode and its aspects is shown in the Table 1 below:

| Eurocodes | Contents/Description |
|---|---|
| BS EN 1990: Eurocode: Basis of structural design | Structural safety, serviceability and durability |
| BS EN 1991, Eurocode 1: Actions on structures | Actions (loads) on structures |
| BS EN 1992, Eurocode 2: Concrete<br>BS EN 1993, Eurocode 3: Steel<br>BS EN 1994, Eurocode 4: Composite<br>BS EN 1995, Eurocode 5: Timber<br>BS EN 1996, Eurocode 6: Masonry<br>BS EN 1999, Eurocode 9: Aluminium | Design and detailing |
| BS EN 1997, Eurocode 7: Geotechnical design | BS EN 1998, Eurocode 8: Seismic design |
| Seismic design BS EN 1998, Eurocode 8: | |

Table 1: Eurocode in Construction

Each Eurocode, except EN 1990, is divided into a number of parts that cover aspects and material as shown in Table 2:

| EN Part | Scope | Concrete | Steel | Composite |
|---|---|---|---|---|
| EN 1990 | Basis of Design | √ | √ | √ |
| EN 1990/A1 | Bridges | √ | √ | √ |
| EN 1991-1-1 | Self-weight | √ | √ | √ |
| EN 1991-1-3 | Snow loads | √ | √ | √ |
| EN 1991-1-4 | Wind actions | √ | √ | √ |
| EN 1991-1-5 | Thermal actions | √ | √ | √ |
| EN 1991-1-6 | Actions during execution | √ | √ | √ |
| EN 1991-1-7 | Accidental actions | √ | √ | √ |
| EN 1991-2 | Traffic loads | | | |
| EN 1992-1-1 | General rules | √ | | √ |
| EN 1992-2 | Bridges | √ | | √ |
| EN 1993-1-1 | General rules | | | |
| EN 1993-1-5 | Plated elements | | √ | √ |
| EN 1993-1-7 | Out-of-plane loading | | √ | √ |
| EN 1993-1-8 | Joints | | √ | √ |
| EN 1993-1-9 | Fatigue | | √ | √ |
| EN 1993-1-10 | Material toughness | | √ | √ |
| EN 1993-1-11 | Tension components | | √ | √ |
| EN 1993-1-12 | Transversely loaded plated structures | | √ | √ |
| EN 1993-2 | Bridges | | √ | √ |
| EN 1993-5 | Piling | | √ | √ |

| | | | | |
|---|---|---|---|---|
| EN 1994-1-1<br>EN 1994-2 | General rules<br>Bridges | | | √<br>√ |
| EN 1997-1<br>EN 1997-2 | General rules<br>Testing | √<br>√ | √<br>√ | √<br>√ |
| EN 1998-1<br>EN 1998-2<br>EN 1998-5 | General rules, seismic actions<br>Bridges<br>Foundations | √<br>√<br>√ | √<br>√<br>√ | √<br>√<br>√ |

Table 2 – Principal Eurocode Parts used for the Design of Concrete, Steel and Composite Bridges and Bridge Elements
*(Bridge Design to Eurocode Works Example, 2012)*

As an example, for a concrete bridge, Figure 1 below shows the inter-relating use of Eurocode documents required in the bridge design:

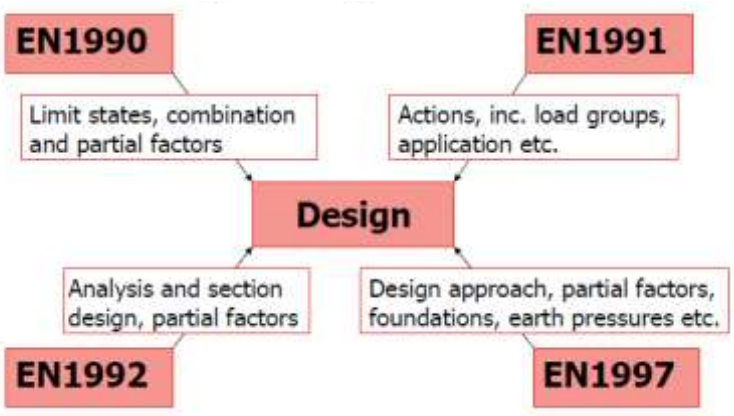


Figure 1: Eurocode required for concrete bridge design

Under the reference of British Standard BS 5400, there are 10 parts covering bridge design, materials and workmanship as listed below. It should be noted that BS 5400 is both a Code of Practice and a Specification, whereas on structural Eurocode only cover the structural design aspects.

1. Part 1: General Statement
2. Part 2: Specification for Loads
3. Part 3: Code of Practice for Design of Steel Bridges
4. Part 4: Code of Practice for Design of Concrete Bridges
5. Part 5: Code of Practice for Design of Composite Bridges
6. Part 6: Specification for Materials and Workmanship
7. Part 7: Specification for Materials and Workmanship, Concrete, Reinforcement and Prestressing Tendons
8. Part 8: Recommendations for Materials and Workmanship, Concrete, Reinforcement and Prestressing Tendons
9. Part 9: Bridge Bearings
10. Part 10: Code of Practice for Fatigue

According to Chriss (2007), the equivalent between Eurocode and BS 5400 are shown in Table 3:

| EUROCODE PART | BS 5400 PART |
|---|---|
| EN 1990 Basis of structural design | Part 1: General statement<br>Part 2: Specification for loads |
| Actions<br>EN 1991-1-1 Self Weight<br>EN 1991-1-4 Wind actions<br>EN 1991-1-5 Thermal actions<br>EN 1991-1-6 Actions during execution<br>EN 1991-1-7 Accidental actions<br>EN 1991-2 Traffic loads on bridges | Part 2: Specification for loads |
| Concrete<br>EN 1992-1-1 General rules<br>EN 1992-2 Bridges | Part 4: Code of practice for design of concrete bridges |
| Steel<br>EN 1993-1-1 General rules<br>EN 1993-1-5 Plated structural elements<br>EN 1993-1-8 Design of joints<br>EN 1993-1-9 Fatigue<br>EN 1993-1-10 Material toughness<br>EN 1993-2 Bridges | Part 3: Code of practice for design of steel bridges |
| Steel-Concrete Composite<br>EN 1994-2 Bridges | Part 5: Code of practice for design of composite bridges |

Table 3 – Equivalent between Eurocode and British Standard (BS 5400)

*(The implication of the Change to Eurocode for Bridge Design)*

## DEVELOPMENT OF EUROCODE (EN) IN MALAYSIA AS MALAYSIAN STANDARDS (MS EN)

As Malaysia has limited research and development capability in developing codes of practice and furthermore has always used the British Standards as the main source of reference for structural design, it would be prudent to follow suit the UK in practicing the Eurocode.

Through the Department of Standards Malaysia (Standards Malaysia), the adopted Malaysian Standard is identical with European Standard without alteration as to oblige with the European Committee for Standardization (CEN) regulations. The Malaysian Standard was recommended by Technical Committee on Code of Practice for Design of Concrete Structures under the authority of the Industry Standards Committee on Building, Construction and Civil Engineering to adopt the EN Standard as the MS EN. The MS EN have a National Annex – formerly referred to as National Application Documents (NAD), constructed based on the relevant National Determined Parameters (NDP) to be used for the design. This NAD allows the incorporation of local parameters or items for special considerations, such as creep and shrinkage of concrete components especially in hot and humid Malaysia climates. In 2006, the Department of Standard Malaysia (DSM) gave the approval to The Institution Engineers, Malaysia (IEM) as Standards-Writing Organization (SWO) in charge of standards writing to form a Technical Committee on Design Standards. The Technical Committee had produced sets of MS EN Standards for the local construction industry, and accompanying National Annex that went with them. Based on Malaysia

Standard Online (MOSTI), September 2016 there are 6 parts for Malaysia Standards based on Eurocode. The Malaysian Standards are listed as below:

1. MS EN 1990:2010 Eurocode : Basis of Structural Design

   1.1. MS EN 1990:2010 (National Annex) — Malaysia National Annex to Eurocode – Basis of Structural Design

2. MS EN 1991:2010 Eurocode 1: Actions on Structures – Part 1-1: General Actions – Densities, Self-Weight, Imposed Loads for Buildings

   2.1 MS EN 1991-1-1:2010 (National Annex) — Malaysia National Annex to Eurocode 1: Actions on Structures – Part 1-1: General Actions- Densities, Self-Weight, Imposed Loads for Buildings

3. MS EN 1992-1-1:2010 — Eurocode 2: Design of Concrete Structures – Part 1-1: General Rules and Rules for Buildings

   3.1 MS EN 1992-1-1:2010 (National Annex) — Malaysia National Annex to Eurocode 2: Design of Concrete Structures – Part 1-1: General Rules and Rules for Buildings

4. MS EN 1993-1-1:2010 — Eurocode 3: Design of Steel Structures – Part 1-1: General Rules for Building

   4.1 MS EN 1993-1-1:2010 (National Annex) — Malaysia National Annex to Eurocode 3 – Design of Steel Structures – Part 1-1: General Rules and Rules for Buildings

5. MS EN 1997-1:2012 — Eurocode 7: Geotechnical Design – Part 1: General Rules

   5.1 MS EN 1997-1:2012 (National Annex) — Malaysia National Annex to Eurocode 7: Geotechnical Designs – Part 1: General Rules

6. MS EN 1998-1:2015 — Eurocode 8: Design Of Structures For Earthquake Resistance – Part 1: General Rules, Seismic Actions and Rules for Buildings

The MS EN has yet to be completed to date and there are four (4) more documents that need to be produced as listed below:

1. EN 1994 Eurocode 4: Design of composite steel and concrete structures
2. EN 1995 Eurocode 5: Design of timber structures
3. EN 1996 Eurocode 6: Design of masonry structures
4. EN 1999 Eurocode 9: Design of aluminium structures

Apart from the published MS EN documents above, they covered only up to Part 1-1 specifically for building design. Other parts including bridge related design and Malaysia National Annex has yet to be developed. Bridge related design is covered in Part 2 in most of the Eurocode documents.

## CHALLENGES IN IMPLEMENTING EUROCODE IN MALAYSIA

At the moment, local authorities are simply not aware of the seriousness in the conversion of design standards for structural design from BS to Eurocode. Based on data from BEM, in which a total of 1398 engineers responded, the results are as tabulated below (Jeffrey, 2015):

| Composition of respondents | PEs<br>51% | Graduates<br>49% |
|---|---|---|
| Sector of employment/practice | Private<br>87% | Public<br>13% |
| | | |
| **Question posed to all registered engineers** | **Responded YES** | **Responded NO** |
| 1. Are you familiar with the application of Eurocode or MS EN standards for structural design and construction? | 36% | 64% |
| 2. Are you ready to adopt MS EN as the design standards in place of British Standards in practice? | 51% | 49% |
| 3. Are your engineers and designers (subordinates or colleagues) able to follow MS EN as design standards? | 48% | 52% |
| 4. Are you adequately equipped in facility/software to adopt MS EN for design of structures? | 30% | 70% |
| 5. Are you ready to submit designs based on MS EN standards? | 35% | 65% |
| 6. Are you aware that you can purchase MS EN standards from SIRIM (or via website www.sirim.my) | 42% | 58% |

Table 4 – Statistical Findings of the BEM Survey (2014) on Eurocode Awareness and Confidence among Professional and Graduate Engineers

*(Structural Eurocode to Replace British Standards in Malaysia, 2015)*

From that survey, most engineers gave a negative response to the questions posed on their awareness and confidence level in the use and adoption of Structural Eurocode in place of British Standards.

As discussed in the IEM Position Paper (2003) that the implications in the transition to Eurocode in Malaysia are:

i. The practicing engineers and academicians will have to re-learn new terms and different design approach or philosophy.
ii. Besides that, needs more supporting trades and skilled persons such as material suppliers, engineers, architects and quantity surveyors to adopt new mentality in terminology and standard practices.
iii. Approving authorities may have to re-organize standard practices and to re-train qualified engineers, to comprehend the acceptable level of submitted designs.
iv. Current national regulation should be made changes to reflect in adopting another code of practice
v. Need more research to develop National Annexes based on the Malaysian standard

**IMPLEMENTATION OF EUROCODE FOR BRIDGE DESIGN BY JKR MALAYSIA**

Although switching from BS5400 and BD37/01 to the EN Standards involves a number of changes to the method of implementation of a design, Bridge Design Section of Road Branch, JKR Malaysia has decided to use Eurocode for the in-house design of all new concrete bridges. The usage of Eurocode documents for bridge design has been started in the middle of 2014 in-line with the concern expressed by the JKR Top Management at the end of year 2013. Despite a lack of complete MS EN documents on bridge related design, as a transition we adapt BS EN 1991 - 'Actions On Structures-Part 2: Traffic loads on bridges' with UK National Annex in replacing BD 37/01- 'Loads for Highway Bridges', MS EN 1990:2010 – 'Basis of Structural Design' with Annex A2 to MS EN1990 and BS EN 1992- Part 2 - 'Concrete Bridges-Design And Detailing Rules' with UK National Annex in replacing BS 5400-'Steel, Concrete And Composite Bridges'. With respect to bridge foundation design, MS EN 1997-1:2012: 'Geotechnical Design – Part 1: General Rules' with Malaysia National Annex to Eurocode 7 are referred. In addition to that the specification for bridge works has been reviewed to suit the Eurocode requirements.

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