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Advantage Using Eurocode 3 for Design of Factory Frame

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ABSTRACT

Eurocode 3 is actually a performance code which has more advantages over British Standard 5950. The utilization of the Eurocode 3 will be beneficial in the long term. It is a state-of-the art code and contains many improvements which one cannot find in the British Standard 5950. These details include the basis and the concept of design, specifications to be followed, design methods, serviceability, durability of structures, safety factors, loading values and etc. Under The Steel Construction Institute (SCI) claimed that a steel structural design is expected which there will be material cost savings of up 5% compare using BS 5950: Part 1: 2000. This paper presents advantage using Eurocode 3 for design of factory frame of with spans of 6m and 9m and with steel grade S275 (Fe 460) and S355 (Fe 510) which designing using BS 5950: Part 1: 2000 and Eurocode 3 (EC3). The design considers part of the structural beam and column only. Besides that, the EC3 can be reduced beam shear capacity by up to around 4.00% and moment capacity by up to 6.0%. For the requirements, structural column designed by EC3 has the compression capacity of between around up for values 5.0 % and 9.00% above which less than compare BS 5950: Part 1:2000 design. Another advantage Eurocode 3 also reduced espeacially for the part of deflection value due to unfactored life loads of up around to 3.00 % above in comparison with BS 5950: Part 1: 2000. Before this, the EC3 produced braced and truss steel frames which consume 1.60% to 17.00% more steel weight compared with using design of BS 5950: Part 1: 2000. Besides that, the percentage of difference strength connection can be reduced to the range around up to 0.10% until 10.00%.
KEYWORDS: Eurocode 3, Factory Frame, Structural Beam and Column, Braced and Truss Steel Frames, Beam Shear and Moment Capacity.

INTRODUCTION

Structural design is a process of selecting the material type and conducting in-depth calculation of a structure to fulfill its construction requirements. The main purpose of structural design is to produce a safe, economic and functional building. Structural design should also be an integration of art and science. It is a process of converting an architectural perspective into a practical and reasonable entity at a construction site.

In the structural design of steel structures, reference to standard code is essential. A standard code serves as a reference document with important guidance. The contents of the standard code generally cover comprehensive details of a design. These details include the basis and the concept of design, specifications to be followed, design methods, safety factors, loading values and etc.

In present days, many countries have published their own standard codes. These codes were a product of constant research and development, and past experiences of experts in respective fields. Meanwhile, countries or nations that do not publish their own standard codes will adopt a set of readily available code as the national reference. Several factors govern the type of code to be adopted namely suitability of application of the code set in a country with respect to its culture, climate and national preferences as well as the trading volume and diplomatic ties between these countries.

Like most of the other structural Eurocodes, Eurocode 3 has developed in stages. The earliest documents seeking to harmonize design rules between European countries were the various recommendations which published by the European Convention for Constructional Steelwork (ECCS). From these, the initial draft Eurocode 3 that published by the European Commission was developed. This was followed by the various parts of a pre-standard code, ENV1993 (ENV stands for EuroNorm Vornorm) which issued by Comité Européen de Normalisation (CEN)- the European standardization committee. These preliminary standards of ENV will be revised, amended in the light of any comments arising out of its use before being reissued as the EuroNorm standards (EN). As with other

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Europeans standards, Eurocodes will be used in public procurement specifications and to assess products for 'CE' (Conformité Européen) mark.

The establishment of Eurocode 3 will provide a common understanding regarding the structural steel design between owners, operators and users, designers, contractors and manufacturers of construction products among the European member countries. It is believed that Eurocode 3 is more comprehensive and better developed compared to national codes. Standardization of design code for structural steel in Malaysia is primarily based on the practice in Britain. Therefore, the move to withdraw BS 5950 and replace with Eurocode 3 will be taking place in the country as soon as all the preparation has completed.

Codes of practice provide detailed guidance and recommendations on the design of structural elements. Buckling resistance and shear resistance are two major elements of structural steel design. Therefore, provision for these topics is covered in certain sections of the codes. The study on Eurocode 3 in this project will focus on the subject.

BACKGROUND OF RESEARCH

The arrival of Eurocode 3 calls for reconsideration of the approach to design. Design can be complex for those who pursue an economy of material, but it can be simplified for those pursuing speed and clarity. Many designers feel depressed when new codes are introduced [1]. There are new formulae and new complications to master, even though there seems to be no benefit to the designer for the majority of his regular workload.

The increasing complexity of codes arises due to several reasons namely earlier design over-estimated strength in a few particular circumstances, causing safety issues, earlier design practice under-estimated strength in various circumstances affecting the economy and new forms of structure evolve and codes are expanded to include them.

However, simple design is possible if a scope of application is defined to avoid the circumstances and the forms of construction in which strength is over estimated by simple procedures. Besides, this can be achieved if the designer is not too greedy in the pursuit of the least steel weight from the strength calculations. Finally, simple design is possible if the code requirements are presented in an easy-to-use format such as the tables of buckling stresses in existing British standard (BS) codes.

In [2] has claimed to be that most technically advanced steel structural design using Eurocode 3 can achieve is 6-8% more cost saving than using BS 5950. Lacking analytical and calculative proof, this project is intended to testify the claim.

Objectives of Research

The objectives of this project are:

1) Advantage using the Eurocode 3 as a guide for designers.
2) To study on the effect economy when using Eurocode 3 for the owner.

Scope of Project

The project focuses the advantage when using Eurocode 3 as a guide for designer. This structure is intended to serve as an office building. All the beam column connections are to be assumed simply. The standard code used here will be Eurocode 3, hereafter referred to as EC3. A study on the basis and design concept of EC3 will be carried out. Comparison to other steel structural design code is made. The comparison will be made between the EC3 with BS 5950: Part 1: 2000, hereafter referred to as BS 5950.

The multi-storey steel frame will be first analyzed using Microsoft Excel worksheets to obtain the shear and moment values. Next, design spreadsheets will be created to calculate and design the structural members.

LITERATURE REVIEW

Background of EC3

European Code, or better known as Eurocode was initiated by the Commission of European Communities as a standard structural design guide. It was intended to smooth the trading activities among the European countries. Eurocode is separated by the use of different construction materials. Eurocode 1 covers loading situations, Eurocode 2 covers concrete construction, Eurocode 3 covers steel construction while Eurocode 4 covers for composite construction.

Scope of EC3

In [4] covers the general rules for designing all types of structural steel. It also covers specific rules for building structures. The EC3 stresses the need for durability, serviceability and resistance of a structure. It also covers other construction aspects only if they are necessary for design. Principles and application rules are also clearly stated. Principles should be typed in Roman wordings. Application rules must be written in italic style. The use of local application rules is allowed only if they have similar principles as EC3 and their resistance, durability and serviceability design does not differ too much. EC3 stresses the need for durability, serviceability and resistance of the structure [3]. It also covers other construction aspects only if they are necessary for design.

Design Concept of EC3

All designs are based on limit state design. The EC3 covers two limit states, which are ultimate limit state and serviceability limit state. Partial safety factor is applied to loadings and design for durability. Safety factor values are recommended in EC3. Each European country that using EC3 has different loading and material standard to accommodate safety limit that is set by the respective countries.

Design Concept of BS 5950

There are several methods of design namely simple design, continuous design, semi continuous design and experimental verification. The fundamental of the methods are different joints for different methods. In the design for limiting states, the BS 5950 covers two types of states-ultimate limit states and serviceability limit states

Application Rules of EC3

A structure should be designed and constructed in such a way that with acceptable probability. It will remain fit for the use for which it is required, that having due regard to its intended life and its cost with appropriate degrees of reliability. It also will sustain all actions and other influences likely to occur during execution and use and have adequate durability in relation to maintenance costs. It should be designed in such a way that it will not be damaged by events like explosions, impact or consequences of human errors to an extent disproportionate to the original cause.

Potential damage should be limited or avoided by appropriate choice of one or more of the following criteria. Avoiding from eliminating or reducing the hazards which the structure is to sustain, selecting a structural form which has low sensitivity to the hazards considered, selecting a structured form and design that can survive adequately the accidental removal of an individual element and tying the structure together.

METHODOLOGY

As EC3 will eventually replace BS 5950 as the new code of practice, it is necessary to study and understand the concept of design methods in EC3 and compare the results with the results of BS 5950 design. The first step is to study and understand the cross-section classification for steel members as given in EC, analyzing the tables provided and the purpose of each clause stated in the code. At the same time, an understanding on the cross-section classification of BS 5950 is also carried out.

Analysis, design and comparison works will follow subsequently. Beams and columns are designed for the maximum moment and shear force obtained from the computer software analysis. Checking on several elements, such as shear capacity, moment capacity, bearing capacity, buckling capacity and deflection is carried out. Next, analysis on the difference between the results using two codes is done. Eventually, comparison of the results will lead to recognizing the difference in design approach for each code.

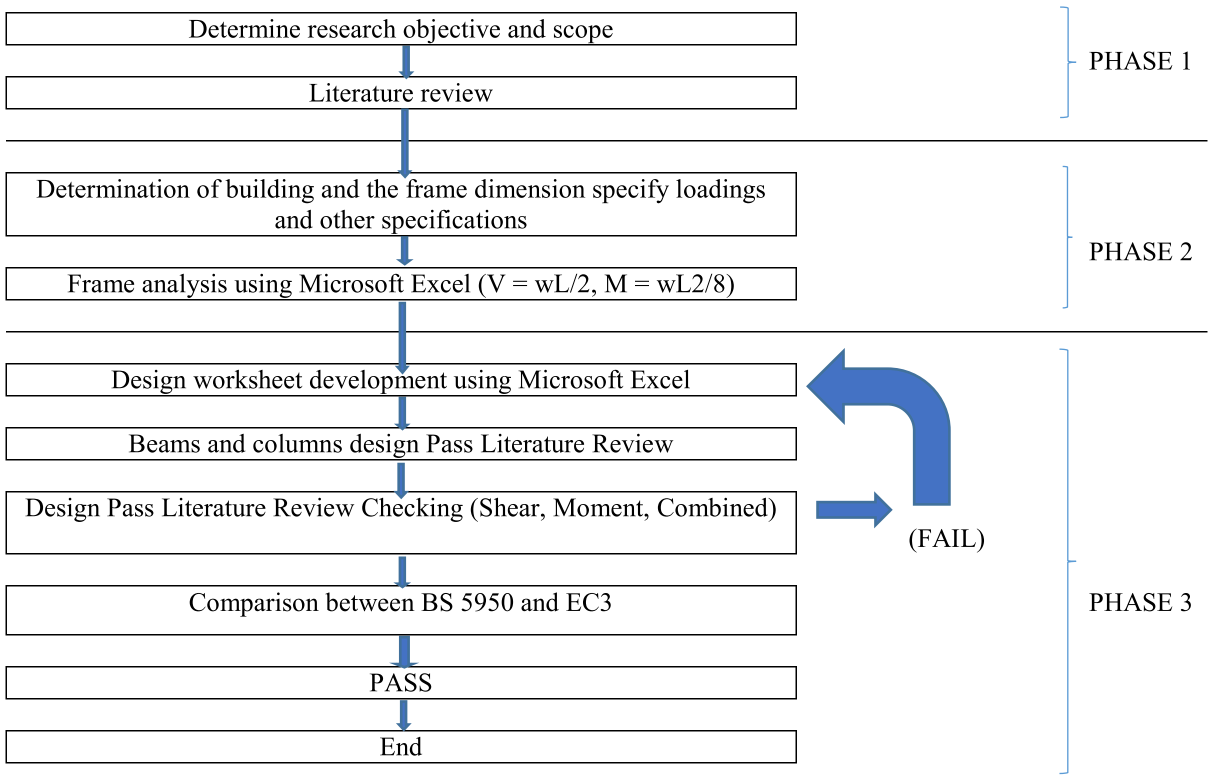

Figure 1: Flowchart of the methodology of this study

COMPARISON BETWEEN BS 5950 AND EC3

Structural Beam

Table 1 compares the criteria that need to be considered when designing a structural beam.

Table 1: Criteria to be considered in structural beam design BS 5950

	Criteria	EC3
Flange subject to compression 9ε 10ε 15ε **Web subject to bending (neutral axis at mid depth)** 80ε 100ε 120ε $\varepsilon = (275 / p_y)^{0.5}$	**Cross-sectional classification** Class 1 Plastic Class 2 Compact Class 3 Semi-compact Class 1 Plastic Class 2 Compact Class 3 Semi-compact	**Flange subject to compression** 10ε 11ε 15ε **Web subject to bending (neutral axis at mid depth)** 72ε 83ε 124ε $\varepsilon = (235 / f_y)^{0,5}$
$P_v = 0.6p_y A_v$ $A_v = Dt$	**Shear capacity**	$V_{pl.Rd} = f_y A_v / (\sqrt{3} \times \gamma_{M0})$ $\gamma_{M0} = 1,05$ A_v from section table
	Moment capacity Class 1, 2 Class 3 Class 4	$M_{c.Rd} = W_{pl} f_y / \gamma_{M0}$ $M_{c.Rd} = W_{el} f_y / \gamma_{M0}$ $M_{c.Rd} = W_{eff} f_y / \gamma_{M1}$ $\gamma_{M0} = 1,05$ $\gamma_{M1} = 1,05$

Structural Column

Table 2 indicates a comparison of the criteria that to be considered when designing a structural beam.

Table 2: Criteria to be considered in structural column design BS 5950

	Criteria	EC3
Flange subject to compression	**Cross-sectional classifications**	**Flange subject to compression**
9ε	Class 1 Plastic	10ε
10ε	Class 2 Compact	11ε
15ε	Class 3 Semi-compact	15ε
Web (combined axial load and bending)	Class 1 Plastic	**Web (combined axial load and bending)**
$80\varepsilon / 1 + r_1$	Class 2 Compact	396ε / (13α – 1)
$100\varepsilon / 1 + 1.5r_1$		456ε / (13α – 1)

RESULTS AND DISCUSSION

Economy of Design

After all the roof beams, floor beams, external columns and internal columns have been designed for the most optimum size, the results of the design (size of structural members) are tabulated in Table 3 and Table 4 for BS 5950 and EC3 design respectively. To compare the economy of the design, the weight of steel will be used as a gauge.

Table 3: Percentage difference of steel weight (ton) between BS 5950 design and EC3 design (revised) frame

	Bay width (m)	Steel grade	Total steel weight (ton)		
			BS 5950	EC3 (Semi-cont)	%
2Bay, 4Storey	6	S275 (Fe 430)	4.744	4.749	0.11
		S355 (Fe 510)	3.750	4.211	10.95
2Bay, 4Storey	9	S275 (Fe 430)	9.122	9.645	5.42
		S355 (Fe 510)	7.889	8.503	7.22

From Table 3, it can be seen that there is an obvious reduction of steel weight required for the braced steel frame, if it is built semi-continuously. Even though EC3 design still consumed higher steel weight compare BS5950, where the percentage of steel weight EC3 can achieve from 0.11% to 10.95%. The effect of dead load on the deflection of the beam had been gradually reduced. The greater difference in steel grade S355 indicated that deflection still plays a deciding role in EC3 design. However, as the connection stiffness become higher, the gap reduces.

Table 4: Percentage difference of steel weight (ton) between BS 5950 design and EC3 design frame

	Bay width (m)	Steel grade	Total steel weight (ton)		
			BS 5950	EC3	%
2Bay, 4Storey	6	S275 (Fe 430)	4.744	4.821	1.60
		S355 (Fe 510)	3.750	4.571	17.96
2Bay, 4Storey	9	S275 (Fe 430)	9.122	9.645	5.42
		S355 (Fe 510)	9.889	9.313	15.29

As shown in Table 4, all frame types, beam spans and steel grade designed using BS 5950 offer weight savings as compared with EC3. The percentage of savings which offered by BS 5950 design ranges from 1.60% to 17.96% depending on the steel grade. The percentage savings for braced steel frame with 9m span is higher than that one with 6m span. This is where deeper, larger hot-rolled section is required to provide adequate moment capacity and also stiffness against deflection

CONCLUSION

The study on the advantages between BS 5950 and EC3 for the design of factory frame. In review of the research objectives, a summary of the results of the objectives is categorically discussed. For the shear capacity of a structural beam, calculation based on EC3 had reduced a member's shear capacity of up to 4.06% with regard to BS 5950. This is due to the variance between constant values of the shear capacity formula specified by both codes. Beside that, a reduction in the range of 5.27% to 9.24% of column compressive resistance was achieved when designing by EC3 which is compared to BS 5950. This comparison is based on a structural column of 5.0m long.

The application of different steel grade S275 to S355 did not contribute a greater percentage of difference between the shear capacities calculated by both codes. Meanwhile, for the moment capacity of structural beam, calculation based on EC3 had effectively reduced a member's shear capacity of up to 6.43%.

Economy aspect in this study focused on the minimum steel weight that is needed in the construction of the braced steel frame. The total steel weight of structural beams and columns was accumulated for comparison. In this study, it was found that EC3 design produced braced steel frames that require improvement in economy steel weight compared design using with BS 5950. For a 2-bay, 4-storey, 6m bay width steel frame, the percentage savings using BS 5950 are higher than EC3 for S355 steel grade with respect to S275 steel grade. This is due to the overall deflection was considered in EC3 design. Meanwhile unaffected by the effect of imposing load deflection, BS 5950 design allowed lighter section. This resulted in the highest percentage difference.

RECOMMENDATION FOR FUTURE STUDIES

In future studies, it is suggested that an unbraced steel frame design is conducted to study the behavior, structural design and economic aspect based on both of the design codes. However, since the results of the third objective contradicted with the background of the study (claim by SCI), it is recommended that further studies to be conducted to focus on the economy aspect of EC3 with respect to BS 5950. This study showed that steel weight did not contribute to cost saving of EC3 design.

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