ECONOMIC ASPECTS OF WEIGHT SAVING IN THE DESIGN OF BRACED STEEL FRAMES USING BS5950 AND EC3

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A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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JUNE 2015

Dedicated to all part of my immediate family, specially my father, my mother, my fiancee and my sisters; moreover, my faithful friends

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincerest gratitude and appreciation to my supervisor, Prof. Ir. Dr. Mahmood Md. Tahir for his worthwhile guidance throughout this project. His wide knowledge and his expert advice during the period I have been carrying out this research, has been of great value for me. His invaluable comments, kind consideration, encouragement and support have provided a good basis present this thesis.

In addition, I would like to appreciate who support me morally to finish my report. Their precious opinions were useful for me to have an idea in completing this report.

ABSTRACT

Eurocode 3 and BS 5950 code are usually been used to design braced steel frame. The design concept usually based on connections, where simple method associated with pinned-jointed, semi-continuous method associated with semi-rigid joints or partial strength, and continuous construction associated with rigid-joint. Partial strength joints are considered using moment resistance of connections in plastic hinge analysis of the frame. Semi-continuous design method is used instead of simple design method. This makes it achieve many benefits, for example, shallow and lighter beams, and the connections are geometrically simple, thereby producing more robust frames. The method is expected to save frame weight. This study introduces the design of multi-storey steel frame of a series of two-storey, four-storey, six-storey and eight-storey with three-bays for each case. A comparison is made between simple design and semi-continuous design using (BS 5950:2000 Part1) and (BS EN 1993-1-1:2005). This is intended to show the economic benefits of multi-storey braced steel frame design, based on weight saving in the choice of beams and columns. It is assumed that they have slight influence on the total weight of frame. Their weight is identical for all frames. I and H Rolled cross-sections are adopted for beam and column respectively. Flexible end-plate connections are used as pinned connections for simple constructions, while flush end plate and extended end plate with different geometric sizes are used as partial connection. All connections are governed by standardised tables presented by Steel Construction Institute. The results of the percentage weight savings analysed and evaluated based on the effect of changing connection types, and the steel grade from S275 to S355. The results show that semi-continuous design is more beneficial than simple design method for multi-storey braced steel frames with a steel weight saving is in the range of 6.35-18.85% by BS 5950 and 9.37-15.36% by Eurocode 3 according to design variables.

ABSTRAK

Kod Eurocode 3 dan BS 5950 biasanya digunakan untuk mereka bentuk kerangka keluli dirembat. Konsep reka bentuk biasanya berdasarkan sambungan, di mana kaedah yang mudah yang dikaitkan dengan sambungan pin, kaedah separa berterusan yang berkaitan dengan sendi separa tegar atau kekuatan separa, dan pembinaan tegar berkaitan dengan sambungan tegar. Sendi kekuatan separa dianggap menggunakan momen rintangan sambungan dalam analisis plastik engsel bingkai. Kaedah reka bentuk separa berterusan akan digunakan dan bukannya kaedah reka bentuk sambungan mudah. Kaedah ini menjadikan ia dapat mencapai banyak manfaat, sebagai contoh, rasuk cetek dan lebih ringan, dan sambungan adalah geometri mudah, dengan itu menghasilkan bingkai yang lebih mantap. Kaedah ini dijangka dapat menjimatkan bingkai berat badan. Kajian ini memperkenalkan reka bentuk bertingkat bingkai keluli daripada siri dua tingkat, empat tingkat, enam tingkat dan lapan tingkat dengan tiga ruang untuk setiap kes. Perbandingan dibuat antara reka bentuk yang ringkas dan reka bentuk separa berterusan menggunakan (BS 5950: 2000 Part1) dan (BS EN 1993/01/01: 2005). Kajian ini bertujuan untuk menunjukkan manfaat ekonomi reka bentuk bingkai keluli bertingkat dirembat, berdasarkan penjimatan dalam berat pilihan rasuk dan tiang kerangka. Kemasan dan anggota rembat diandaikan bahawa mereka mempunyai pengaruh sedikit pada jumlah berat kerangka. Berat badan mereka adalah sama untuk semua bingkai. Keratan rentas tuangan I dan H diterima pakai bagi rasuk dan tiang masing-masing. Sambungan plat akhir fleksibel digunakan sebagai sambungan pin untuk pembinaan mudah, manakala plat hujung sedatar dan plat akhir yang dilanjutkan digunakan sebagai sambungan separa. Semua sambungan dikawalatur oleh jadual yang seragam disampaikan oleh Steel Construction Institute. Keputusan penjimatan peratusan berat akan dianalisis dan dinilai berdasarkan kesan mengubah jenis sambungan, dan gred keluli daripada S275 kepada S355. Keputusan menunjukkan bahawa reka bentuk separa berterusan adalah lebih baik daripada kaedah reka bentuk mudah untuk bingkai keluli berbilang tingkat dirembat dengan penjimatan berat keluli adalah dalam lingkungan 6,35-18,85% dan 9,37-15,36% oleh BS 5950 dan Eurocode 3 mengikut pemboleh ubah reka bentuk.

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BS	-	British Standard
EC3	-	Eurocode 3
FEP	-	Flush End-Plate connection
EEP	-	Extended End-Plate

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Designing of structure is the process of choosing an optimum material in a scientific and mathematical way, to end up with a structural building that provides for efficient use, life safety, predictable behaviour and response and economical building systems.

In steel structure, standard code of practice; which consists of reference document with guide lines is usually referred. Basically, the code contains all design concepts, rules, loads and safety factors …etc. The main purpose of standard codes is to look after public health, integrity and people welfare that related to buildings construction [1].

Recently, there are many standards codes have been published to deal with the structural design such as American Standard, Euro code and British code. For the design of steel structure code such as American Institute of Steel Construction (AISC 360-10) Specification for Structural Steel Buildings [2], Japanese Society of Steel Construction [3], and British standard [4]are referred. However the British standard of BS 5950 has replaced by EN 1993: (Eurocode 3) Design of steel structures in March, 2010.

Steel structure design under the BSI was first published in 1985 under the name '*structural use of steelwork in building. Code of practice for design of floors with profiled steel sheeting*' (BS 5950-1:1985), and then it revised. In 1990 the (BS 5950-1:1990) was published under the name '*structural use of steelwork in building. Code of practice for design in simple and continuous construction: hot rolled sections*'. The last publication related with steel structure design was released in 2001 under the name '*Structural use of steelwork in building. Code of practice for design Rolled and welded sections'* (BS 5950-1:2000). On other side, the Eurocode 3 which is related with the design of steel structures was first published in 1992 under the name *'Design of steel structures: General rules and rules for buildings'* together with United Kingdom National Application Document (DD ENV 1993-1-1:1992). Finally, the publication of (BS EN 1993-1-1:2005) in 2005 under the name '*Design of steel structures: General rules and rules for buildings'* was an ambitious, because the (BS 5950-1:2000) was integrated with (BS EN 1993-1-1:2005), and the official announcement was in March 2010. [1]

A steel frame for a building consist of beams and columns, joined together by connections and designed to act together to resist load. Connections type between the members play an important part in the behaviour of the frame under load and influence economically the structural system. In design methods conventionally used in practice, joints are categorised as either "pinned" or "rigid". However, for most joints a more appropriate classification of behaviour is as "semi-rigid" or "partially restrained" [5]. The choice of connection also has a significant influence on the speed, ease, and, therefore, the cost of erection. It is evident that the potential for reducing the cost of steel construction lies in the suitable choice of the beam-to-column and beam-to-beam connections. Indeed, because of the repetitive nature of connections, even small material and labour savings in one connection can have an important effect on the overall economy of the building. This project is intended to use different types of connection to highlight the changes in Multi-storey steel frame design. [1] [6].

According to the way of providing the lateral stability, frames are generally classified into two types; braced and unbraced. This classification depends on the relative stiffness of any bracing system provided to limit horizontal deflection. A bracing system can be achieved by triangular trusses, concrete cores, lift shafts, shear walls, or by a very stiff region within the overall frame [5].

1.2 Braced frame and unbraced frames

Multi-storey steel frame is considered as braced if both axes of the frame are braced. Frames are classified as braced when the bracing system reduces the horizontal displacement by at least 80%. To meet this requirement the stiffness of the two systems (unbraced frames and braced frames) have to be compared and the following relationship has to be satisfied: $K_b \geq 5K_a$ where K_a and K_b are lateral stiffness spring constant for unbraced and braced frame respectively. In checking for ultimate limit state, it is important to make sure that the bracing system is capable of transferring the factored loads down to the foundations. On the other hand, Multi-storey steel frame is considered as unbraced frames when they are braced on major or minor axis. In addition, a steel frame which does not satisfied the criterion for a braced frame is classified as unbraced. Unbraced frames may also be "sway" frames in which second-order effects need to be accounted for. Therefore, it is important to satisfy the limitation of sway under both ultimate strength and service loading [5].

1.3 Problem statement

Conventional analysis and design of steel frames are usually carried out under the assumption that the beam to column connections are either fully rigid or ideally pinned (Hadianfard, 2001). Therefore, the actual behaviour falls between these two boundaries. Therefore, it is necessary to look into the exact behaviour of the connection, which is defined as partial strength connection. There are many researchs reported on economic aspect of multi-storey steel frame (Weynand, Jaspart, and Steenhuis, 1998). Moreover, different codes were used to achieve cost saving of the

whole frame (Kameshki, 2001). However, the study on comparing EC3 and BS 5950 codes is yet to be established using semi-continuous construction. The expected results from using semi-continuous frame, is to achieve a steel weight saving for the whole frame (Bjorhovde and Colson, 1991). Therefore, this study is to show the aspect of weight saving using partial strength connection as compared to pinned beam to column connection in designing braced frame by using two different codes. This project is intended to study the effect to weight saving for design of the frame by changing steel grades and connection types. The finding from this research should be able to enhance the use of partial strength connection in semi-continuous construction.

1.4 Objectives

The objectives of this project are:

1. To investigate the economic aspects of using partial strength connection in the design of multi-storey braced steel frame based on BS 5950: Part 1: 2000 and Eurocode 3

2. To study the effect of steel weight saving by changing the steel grade from S275 to S355.

3. To study the effect on steel weight saving by changing the connections from flush end-plate to extended end plate connection.

1.5 Scope of Project

The project focuses mainly on the design of multi-storey braced steel frame (plane frame) of a series of (2-Storey, 4-Storey, 6-Storey, and 8-Storey) with 3-spans of 6m length. Moreover, two types of steel strength are used in this project (S275

and S355). The Simple construction and semi-continuous construction methods are adopted for all frame. Connection namely a fine end plate are used for "simple" construction, when a flush end plate and extended end plate are used for the semi-continuous approach. Bolts were taken as M20 Grade 8.8. S275 steel was chosen for all end plates and the connected members. Typical plate thicknesses used for flush end plates and extended end plate were 200×12. The standard code adopted are British Standard (BS 5950-1:2000) and Eurocode 3 (BS EN 1993-1-1:2005). Design concept for both codes is explained later on in this thesis. Comparison of the design results between the two codes are described in this thesis based on simple design and semi-continuous design.

1.6 Significance of the Study

When the need to construct an optimum structure steel building, partial strength connection is used to achieve economical and strong multi-storey braced steel frames by reducing the whole frame weight and achieving a more robust and ductile steel frame compared with simple construction, and semi-continuous constructions have less complicacy connections compared to continuous construction.

1.7 Thesis layout

This thesis is divided into five main chapters. Chapter I presents an introduction to the study. Chapter II presents the literature review that discusses the design procedures and recommendations for steel frame design of the codes EC3 and BS 5950. Chapter III presents the research methodology. Results and discussions are presented in Chapter IV. Meanwhile, conclusions and recommendations are presented in Chapter V.

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