COMPERATIVE STUDY OF REINFORCED CONCRETE DESIGN OF COLUMN BETWEEN AMERICAN CODE (ACI 318-05) AND BRITISH STANDARD (BS 8110-97)

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ABSTRACT

The application of American Codes (ACI 318-05) popular in the West Country, this is due to the design by using ACI Codes are more technically advanced and more safety. Currently beside Euro code, American Code also is one of design codes that widely use around the world, and it slowly become an important tool of communication in Construction field. Therefore in order to communicate well between the countries it is necessary to implement the American Code. However, the usages of ACI codes in structural building design are not as popular as expected in Malaysia. This is because perception and misunderstanding are still exists among the structural designer. Designer always think that there is not much difference while using the British Standard (BS 8110-97) as compare with ACI Codes (318-05). Therefore, a study was conducted to review design steps and also to explain technically design of column with ACI Codes. For a better understanding on ACI Codes design process, a work example of ACI Codes on column and comparison of area of reinforcement on several types of column has been done. In this research, the scope of the compare are only focus on the area of reinforcement required with varies of dimension and loading. The result has indicated that although the design process of ACI Codes is more technical but it is easy to understand because the design procedure is more details with the less of assumptions as compare to BS 8110. The result of the research was then show that the area of the required reinforcement of column while design using ACI Codes is almost similar with the column design in BS 8110.

ABSTRAK

Pengaplikasian "American Codes" (ACI318-05) popular di negara barat. Ini disebabkan reka bentuk menggunakan "ACI Codes" adalah lebih teknikal dan selamat. Sejak kebelakangan ini, di samping "Eurocodes", "American Codes" juga merupakan salah satu kod reka bentuk yang banyak digunakan di seluruh dunia dan scara perlahannya, ia telah menjadi satu alat yang penting untuk komunikasi dalam bidang pembinaan. Oleh itu, untuk berkomunikasi dengan lebih baik dengan Negara lain, "ACI Codes" ini harus dilaksanakan. Akan tetapi, pengunaan "ACI Codes" dalam reka bentuk struktur di Malaysia masih tidak begitu popular seperti yang dijankakan. Ini kerana persepsi dan salah faham terhadap ACI Codes masih wujud di antara pereka-pereka struktur. Mereka sentiasa berpendapat bahawa tiada banyak perbezaan mereka bentuk dengan menggunakan "British Standard" (BS) berbanding dengan "ACI Codes". Tambahan pula, mereka mendakwa bahawa pengunaan "ACI Codes" dalam reka bentuk adalah sukar dan susah difahami. Oleh itu, suatu kajian telah dijalankan untuk mengkaji langkah-langkah mereka bentuk untuk menerangkan reka bentuk "ACI Codes" pada reka bentuk tiang dari segi teknik. Untuk memberi permahaman yang lebih jelas terhadap proses mereka bentuk dengan menggunakan "ACI Codes", satu contoh kerja pada tiang dan perbandingan luas tetulang yang dihendaki atas beberapa jenis tiang telah dilakukan. Dalam kajian ini, skop perbandingan hanya fokus kepada luas tetulang yang diperlukan dengan dimension dan daya yang berbeza. Keputusan kajian menunjukkan proses mereka bentuk tiang dengan menggunakan "ACI Codes" adalah teknikal tetapi senang difahami kerana prosedur reka bentuk adalah lebih jelas dengan andaian yang kurang jika berbanding dengan "British Standard". keputusan kajian ini juga menunjukan bahawa luas tetulang yang diperlukan apabila penggunaan "ACI Codes" adalah lebih kurang jika berbanding dengan BS 8110.

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LISTS OF ABBREVIATIONS

UAC	Unified Arabic Code
CSA-A23.3-94	Canadian Code
EC	Eurocode
BS 8110	British Standard
ACI	American Concrete Institute
ACI 318-05	American Codes
NSB	National Standard Body
ASCE/SEI 7-05	Minimum Design Loads for Buildings and Other Structures
A_g	Gross section area of column section.
A_n	Net concrete area
A_{st}	Total steel compressive areas
A_c	Net cross-sectional area of concrete in a column
A_{sc}	Area of vertical reinforcement
A_{ch}	Area of core of reinforced compression member Measured to outside edges of transverse reinforcement
A_{sp}	Area of spiral reinforcement
b	Column width
b_w	Web width or diameter of circular section
b_{min}	Minimum dimension of the column
c_m	Factor relating the actual moment diagram of a slender column to an equivalent uniform moment diagram
D	Specified Dead Load
D	Gross diameter of column

d	Effective depth
d_b	Nominal diameter of bar, wire or prestressing strand
d_t	Distance from extreme-compression fiber to extreme
E	Earthquake load
E_c	Modulus elasticity of concrete column
E_b	Modulus elasticity of concrete beam
e	Eccentricity of axial load on a column
e_x	The component of the eccentricity parallel to the side ℓ_x and the x-axis
e_y	The component of the eccentricity parallel to the side ℓ_y and the y-axis
e_{ox}	Equivalent uniaxial eccentricity at x-axis
e_{oy}	Equivalent uniaxial eccentricity at y-axis
F	Load due to the weight and pressure of fluids with Well-defined densities
f_{cu}	Characteristic concrete cube strength
$f_{y'}$	Specified yield strength of reinforcement
f_y	Characteristic strength of reinforcement
f_c'	Specified compressive strength of concrete
G_k	Characteristic dead load
H	Load from soil pressure or soil weight lateral
h	Column height
h_{agg}	Maximum size of the aggregate
I_c	Second moment inertia of column
I_b	Second moment inertia of beam
k	Effective length factor
L	Live load
L_r	Roof live load
L_e	Effective height of a column
Le_x	Effective height in respect of the major axis
L_{ey}	Effective height in respect of the minor axis

L_o	Clear height between end restraints
ℓ_x	Length of side of column parallel with x-axis
ℓ_y	Length of side of column parallel with y-axis
ℓ_c	Length of column
ℓ_b	Length of beam
ℓ_u	Unsupported length of compression member
M	Moment
M_u	Moment due to factored loads
M_n	Nominal moment strength
M_o	Equivalent uniaxial moment
M_1	Smaller factored end moment on a column
M_2	Larger factored end moment on a column
M_i	Initial design ultimate moment in a column before allowance for additional design moment arising out of slenderness
M_{add}	Additional design ultimate moment induced by deflection of column
M'_x	Effective uniaxial design ultimate moment about x- axis
M'_y	Effective uniaxial design ultimate moment about y- axis
M_{min}	Moment minimum
M_c	Factored moment to be used for design of slender compression member
M_{ux}	Factored moment about x-axis
M_{uy}	Factored moment about y-axis
N	Design ultimate axial load on column
N_u	Factored axial load
P	Compressive Force
P_o	Nominal axial load strength at zero eccentricity
P_n	Nominal axial load strength at given eccentricity

P_u	Axial forces due to factored loads
P_c	Critical Load
Q_k	Characteristic imposed load
R	Roof rain load
R_n	Nominal resistance for the concrete design
r	Radius of gyration
S	Roof snow load
s	Vertical spacing of ties
s_{clear}	Clear spacing between spirals
T	Load effect produced by the combined actions
U	Sum of the Combination of Factored Loads
V_c	Nominal shear force carried by concrete
V_u	Factored shearing forces
W	Wind load
#	Bars size
φ	Strength reduction factor
ρ_g	Ratio of total reinforcement area to cross-sectional area of column
$\rho_{s,min}$	Minimum spiral steel ratio
β	Coefficient which is depends on the end condition of the column
β_{dns}	Ratio used to account for reduction of stiffness of a column due to sustained lateral loads
γ	Ratio of the distance between outer layers of reinforcement in column to the overall depth of column layer of tension steel
α	Angle defining orientation of reinforcement
Ψ	Relative stiffnesses
δ_{ns}	Moment magnification factor for frames braced against sidesway, to reflect effects of member curvature between ends of compression member

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CHAPTER 1

INTRODUCTION

1.1 General

Code design is one of the basic and important tools for a structural designer especially for the high rise building. Because different code using will affect different design and then finally affect the specification and the cost of the building. There are many existing codes for design are currently using all around the world, for example, Unified Arabic Code (UAC), Canadian Code (CSA-A23.3-94), Eurocode 2 (EC), Standard BS 8110 and also American Code (most recently ACI318-05, and older version ACI318-99). Among the existing codes, Standard BS8110 is the most common code that has been used for structure design in our country currently.

British Standard is produced by BSI British Standard, a division of BSI Group that is incorporated under a Royal Charter and is formally designated as the National Standard Body (NSB) for the UK. In 1901 under the led of James Mansergh, BSI group had become Engineering Standard Committee, to standardize the number and type of steel sections, in order to make British manufacturers more efficient and competitive. Over time the standard developed to cover many aspects of tangible engineering, and then engineering methodologies including quality systems, safety and security. Throughout the year BS become more common design tool all around the world.

Whereby, the American Code is produced by governing agency for all concrete construction in the U.S. It was established in 1904 to serve and represent user interests in the field of concrete. The ACI publishes many different standards, but the most commonly referenced standard used by architects and engineers is the ACI 318 "Building Code Requirements for Structural Concrete." It is updated every 7 years and the latest version is ACI 318-02 updated in 2002.

America Code covering all the main structural materials. In this research the main concern is on the concrete column design. Column are one of the main structural for a building where it is a primary compression member that carries and transfer the load which from beam, slab and truss to the foundation. So it plays as important role in building design.

The code of practice for column design based on British Standard is included under the BS8110=1:1997, while in American Code, it is under ACI318-05. BS8110 is reinforced concrete design code used all around world since 1985, whereby the ACI318-05 was officially published on 1910-1914. Recently, Government of Malaysia has decided to fully implement the American Code design in 2011, therefore by knowing the different between this 2 standard, it will gives advantages to current engineer to be ready during changes in Year 2011.

1.2 Problem Statement

Even though government of Malaysia had decided to fully implement the American Code in 2011, but seem like preparation of real industry or academician are still insufficient. Hence it will affect the effectiveness of the plan. In fact, in construction industry communication between different country and individual are unavoidable.

Currently beside Euro code, American Code also widely use around the world, and it slowly become an important tool of communication in Construction field. Therefore in order to communicate well between the countries it is necessary to implement the

American Code. Based on previous research, not much design method based on real cases had given whereby the examples of column design should be given to enhance the knowledge of American Code. Therefore, it is necessary and important to conduct this research.

1.3 Research Objective

Objective of research is important thing that we must be considering before we conduct research; it can avoid us from out of topic from its aim of research. So, in this research paper, there are several objectives are aim to be achieving, such as:

i. To outline the design procedure for column design by using American Code (ACI318-05).
ii. To learn about parametric study with using Microsoft Excel in designing column among both (ACI318-05) and BS 8110.
iii. To compare the column design output between British Standard BS8110 and American Code (ACI318-05).

1.4 Scope of Work

This research will mainly focus on the method of the design of British Standard and American Standard on the building column. In order to achieve the objective of this research, there are a few research scopes that are important and necessary to be revised and followed, such as:

i. Design is focused on the reinforced concrete short axial, biaxial and slender braced column which included the necessary check design process and the material selection.
ii. Difference in design procedure of reinforcement concrete column with British Standard BS8110 and American Code (ACI318-05) .
iii. Comparison the area of reinforcement required, Asreq of the design by using ACI318-05 and BS8110.

1.5 Significant of Study

The implementation of American Codes (ACI 318-05) to replace the old standard currently on going, many countries had used American Code to be the design guide especially in United State America. American Codes will slowly become the important communication tool in construction field around the world. The main reason American Codes are chosen to replace the old codes is because this codes are claimed to be most technically advanced codes in the world. Furthermore, there is less related research about the structural design with American Codes, so with this research, it can be the preparation for implement the America Codes from British Standard and to indentify whether the use of American Codes (ACI 318-05) is suitable in building sector in Malaysia and finally as a guideline for structural engineer using (ACI 318-05) in building design at future time.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to design codes

Structural design codes have developed in North America over the past few decades and will continue to evolve as engineers' changes their way of designing and as they learn more about structural behavior, material strength, and the imposed loading. (Sami W.Tabsh,1996). In future, the usage of ACI code is getting common at United States and in 2011, Malaysia is planning to replace the BS8110 with ACI 318-05. Since 1901, British Standard had developed throughout the year and currently British Standard has covers all the design parameters and design consideration. For example:

i. BS8110-1:1997 (Code of practices for design and construction)
ii. BS5950-1:2000 (Code of practices for design rolled and welded sections)
iii. BS6399-2:1995(Code of practices for wind loads)
iv. BS6399-3:1988 (Code of practices for imposed roof loads),etc

Among the existing codes, the most important code in the United States for reinforced concrete design is the American Concrete Institute's Building Code Requirements for Structural Concrete (ACI 318-05)(ACI,2005). ACI 318 have standard for all concrete design, construction, inspection, repair, and research professionals. Beside that

ACI 318-05 also contains the latest code requirement for concrete building design and construction. The ACI Building code and commentary are presented in a side-by-side column format, with code text placed in the left column and the corresponding commentary text aligned in the right column. To further distinguish the code from the commentary, the code has been printed in Helvetica, the same type face in which this paragraph is set (ACI, 2005).

2.2 ACI Codes (ACI 318-05)

2.2.1 Strength Design

In the ACI Code, most of the reinforce concrete design is based on required strength computed from combinations of loads and design strength computed as φR_n, where φ is a resistance factor, and it also known as a strength-reduction factor while R_n is the nominal resistance for the concrete design (Wight & MacGregor, 2009). This process is called strength design. The design strength of a member refers to the nominal strength calculated in accordance with the requirements stipulated in this code multiplied by a strength reduction factor φ, which is always less than one.

Design strength is provided by a member, its connections to other members, and its cross sections, in terms of flexure, axial load, shear, and torsion, shall be taken as the nominal strength calculated in accordance with requirements and assumptions of this code, multiplied by the strength reduction factors φ (ACI, 2005).

The basic requirement for strength design may be expressed as follows:

$$\text{Design Strength} \geq \text{Required Strength}$$

$$\varphi\ (\text{Nominal Strength}) \geq \boldsymbol{U}$$

2.2.2 Strength-Reduction Factors

ACI Code allows the use of either of two sets of load combinations in design, and it also gives two sets of strength-reduction factors. One set of the load factors is present in Section 9.2.1 in ACI Code while another corresponding strength-reduction factor, φ, is given in ACI Code Section 9.3.1. As the result, the load factor which come from Code Section C.9.2.1 and the corresponding strength-reduction factor, φ in ACI Code Section C.9.3.1 may be used.

The purposes of using the strength reduction factor φ are (MacGregor, 1976), (Winter, 1979):

i. To allow for the probability of under-strength members due to variations in material strength and dimensions.
ii. To allow for inaccuracies in the design equations.
iii. To reflect the degree of ductility and required reliability of the member under the load effect being considered.
iv. To reflect the importance of the member in the structure.

In the 2002 code, the strength reduction factors were adjusted to be compatible with the SEI/ASCE 7-02 load combinations, which were the basis for the required factored load combinations in model building codes at that time (ASCE.2002). The strength reduction factor for some limit states are given below.

Flexural or Combined Flexural and Axial load

1. Tension-controlled sections φ= 0.90
2. Compression-controlled sections:
   a) Members with spiral reinforcement φ= 0.75
   b) Other compression-controlled sections φ= 0.65

Other actions

Shear and torsion	φ= 0.75
1. Bearing on concrete	φ= 0.65
2. Strut-and-Tie Model	φ= 0.75

2.2.3 Load Factors and Load Combinations

Load factors are needed when designing structures to compensate for variations in loads and the magnitude of the load factor for a certain load component depends on how variable the load is (Sami W.Tabsh,1996). While the Load combinations are used for determining the various combinations of the load cases for which the structure needs to be designed and checked. The load combination factors not only to be used vary with the selected design code, it also can applied to the forces and moments obtained from the associated load cases and are then summed to obtain the factored design forces and moments for the load combination (Wight & MacGregor. 2009).

The load factors and local combinations are presented in the ACI Code Sections 9.2.1 through 9.2.5. The load factor which from code section 9.2 are to be used with the strength-reduction factor in code sections 9.3.1 through 9.3.5 in the ACI Code (ACI.2005). These loads factor and strength reduction factor were designed and derived for use in the design of steel, timber, masonry and also concrete structure.

Subscript U will be used in the ACI Codes to designate the required strength, which is a load effect, computed from combinations of factored loads. Factored loads are the load which specified in the general of building code multiplied by the appropriate and suitable load factors.

In ACI Codes, it state that "The factor assigned to each load is influenced by the degree of accuracy to which the load effect usually can be calculated and the variation that might be expected in the load during the lifetime of the structure. Dead loads, because they are more accurately determined and less variable, are assigned a lower load factor than live