ANALYSIS OF CO RDS BUCKLING ANALYSIS USING CIVILFEM WITH ANSYS SOFTWARE

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ABSTRACT

This thesis deals with the problem most faced in the design of structures whether building or bridge which called buckling. Buckling is characterized by a sudden failure of a structural member subjected to high compressive stress, where the actual compressive stress at the point of failure is less than the ultimate compressive stresses that the material is capable of withstanding. For example, during earthquakes, reinforced concrete members may experience lateral deformation of the longitudinal reinforcing bars. This mode of failure is also described as failure due to elastic instability. Mathematical analysis of buckling makes use of an axial load eccentricity that introduces a moment, which does not form part of the primary forces to which the member is subjected. When load is constantly being applied on a member, such as column, it will ultimately become large enough to cause the member to become unstable. Further load will cause significant and somewhat unpredictable deformations, possibly leading to complete loss of load-carrying capacity. The member is said to have buckled, to have deformed. In this research, the structure that going to be analyzed is simple structure of column. The purpose of this research is to observe the effects of how a simple column reacts under loading with different displacement that will be applied. By varying the end supports of a column will experience different modes of buckling. For the purposes of this project, a buckled column will be defined as a column that displays physical failure. The column is no longer able to support the loading and is forced to deflect laterally. The thesis describes the finite element analysis techniques to illustrate the column buckling modes. Using the ANSYS + CivilFEM Software will show the buckling mode and the stress of the column. CivilFEM with ANSYS is the most comprehensive and advanced finite element based civil/structural engineering simulation code proven through use. It combines the leading engineering simulation software, ANSYS, and the high-end civil engineering specific structural analysis capabilities of CivilFEM. In this research, there are steps that need to follow one by one in CivilFEM with ANSYS Software. This step have been describes in the methodology in this thesis. In this research, there are four condition of displacement or support of the column which are pinned-pinned, fixed-fixed, pinned-fixed, and fixed-free. This research is also proven by the simple formula of column buckling which is Euler Formula. In general, columns do not always terminate with simply-supported ends. Therefore, the formula for the critical buckling load must be generalized.The generalized equation takes the form of Euler's formula, where the effective length of the column L_{eff} depends on the boundary conditions.

ABSTRAK

Tesis ini membincangkan masalah yang seringkali berlaku dalam reka bentuk struktur sama ada bangunan atau jambatan yang dipanggil lengkokan. Lengkokan dicirikan oleh kegagalan secara tiba-tiba anggota struktur yang tertakluk kepada tekanan yang tinggi mampatan, di mana tekanan sebenar mampatan pada titik kegagalan adalah kurang daripada tegasan muktamad mampatan bahawa bahan tersebut adalah mampu menahan.Sebagai contoh, semasa gempa bumi, anggota konkrit bertetulang mungkin mengalami ubah bentuk sisi bar mengukuhkan membujur.Ini mod kegagalan juga digambarkan sebagai kegagalan disebabkan oleh ketakstabilan anjal.Analisis matematik lengkokan membuat penggunaan kesipian beban paksi yang memperkenalkan satu masa, yang tidak menjadi sebahagian daripada pasukan utama yang ahli adalah tertakluk. Apabila beban sentiasa digunakan pada ahli, seperti ruangan, ia akhirnya akan menjadi cukup besar untuk menyebabkan ahli untuk menjadi tidak stabil. Beban lanjut akan menyebabkan ubah bentuk yang penting dan agak tidak menentu, mungkin membawa untuk melengkapkan kehilangan kapasiti beban pembawa. Anggota itu dikatakan mempunyai lengkokan, telah cacat. Dalam kajian ini, struktur yang akan dianalisis adalah struktur mudah lajur. Tujuan kajian ini adalah untuk melihat kesan bagaimana lajur mudah bertindak balas di bawah pembebanan dengan anjakan yang berbeza yang akan digunakan. Dengan pelbagai akhir menyokong lajur akan mengalami cara yang berbeza lengkokan. Bagi tujuan projek ini, kolum lengkokan akan ditakrifkan sebagai kolum yang memaparkan kegagalan fizikal. Kolum tidak lagi mampu untuk menyokong pembebanan dan dipaksa untuk memesongkan sisi.Tesis menerangkan teknik-teknik analisis unsur terhingga untuk menggambarkan ruang bentuk lengkokan. Menggunakan ANSYS + CivilFEM Perisian akan menunjukkan bentuk lengkokan dan tekanan turus. CivilFEM dengan ANSYS unsur terhingga yang paling komprehensif dan maju berasaskan kod simulasi kejuruteraan awam / struktur terbukti melalui penggunaan.Ia menggabungkan simulasi kejuruteraan perisian terkemuka, ANSYS, dan yang tinggi-akhir kejuruteraan awam khusus analisis keupayaan struktur CivilFEM. Dalam kajian ini, terdapat langkah-langkah yang perlu untuk mengikuti satu oleh salah di CivilFEM dengan Perisian ANSYS.Langkah ini telah menerangkan dalam metodologi di dalam tesis ini.Dalam kajian ini, terdapat empat keadaan anjakan atau sokongan ruang yang disematkan-disematkan, tetap tetap, disematkan tetap, dan tetap percuma.Kajian ini juga dibuktikan oleh formula mudah lajur lengkokan yang Euler Formula.Secara umum, tiang tidak sentiasa menamatkan dengan hujung yang hanya disokong.Oleh itu, formula untuk lengkokan beban kritikal mesti umum.Persamaan umum mengambil bentuk formula Euler, dimana panjang ruang bergantung kepada keadaan sempadan.

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LIST OF SYMBOLS

λ	Lambda
P_c	Compressive Strength
F	Force
L_e	Effective Length
L	Length
r	Radius of Gyration
I	Moment of Inertia
A	Area
s	Slenderness
P_{cr}	Critical Load
E	Modulus of Elasticity
k	Coefficient of Effective Length

LIST OF ABBREVIATIONS

EN	Eurocode
BS	British Standards
CHS	Cold Hot Section
RHS	Rolled Hot Section
SHS	Square Hot Section
WTC	World Trade Centre

CHAPTER 1

INTRODUCTION

1.1 General

This chapter will give some introduction and therefore a little explanation on the research on going. This research will be on the analysis of column buckling of four cases. The four cases of column buckling is the different type of column which are pinned-pinned, pinned-fixed, fixed-fixed and fixed-free column. Th research will be done with the software simulation. The results that will be simulated are elements is OK or NOT OK, the section classification, the slenderness and the compressive capacity.

The software that is used in this research is CivilFEM with ANSYS Software. This kind of software is another type of ANSYS branch software. This software is usually practise by civil engineering students. The different of CivilFEM software to its originality ANSYS Workbench software is the time taken to simulate. As this research has two months to be finished, the CivilFEM with ANSYS is suitable software to use. Furthermore, the software is more to the steel material. As this research is on the steel column analysis, this will be an advantage og this research.

For using the CivilFEM with ANSYS Software, there will no need to have detail on the laboratory data. For example, in this research, the steel grade used is S275. This means there will no need any data implementation from laboratory. In can be straight use S275 by clicking on the table in the software. As this research is on British Stndards, the software can also be set to follow this standard.

1.2 Problem Statement

One problem most faced in the design of structures whether building or bridge, etc is buckling, in which structural members collapse under compressive loads greater than the material can withstand. This research is proposed based on the World Trade Centre disaster as the building is buckling before it collapses. World Trade Centre disaster is one of the biggest failures in civil engineering field. There are many researchers out there are doing the research in this disaster. One of the previous study, they are relating this disaster to the engineering phenomenon which is also failure that always happen in any structural members called buckling. As the steel properties is high temperature, the buckling can also affected by this property. However, this research will not go to that far as it will analyse the results that leading to the structure buckle.

In this era of globalisation, there are many technology implement throughout the world. In civil engineering field, there were many technology were develop. For example, to make easier for structural design, software like Esteem Plus and others are implemented to the field. It is same way to the steel analysis, software like ANSYS, Abaqus and so on were introduced. However, there was some problem regarding of the uses of the software. This is refer to the failure of some building design that only refer to the software analysis. This is simply that machine can make mistakes too.

Due to the cases like these, this research will be analyse steel column using CivilFEM with ANSYS Software version 12.0 and will be compare to the steel manual calculation. Both of the analyses are referred to the British Standards, BS5950 Part 1, 2000.

1.3 Objectives of the study are :

i. To present software analysis with analytical results.
ii. To identify the adequate column size for four cases column.
iii. To illustrate the mode of buckling of four cases column using ANSYS Software.

1.4 Scope of study

These researches are mainly focused on the design of steel column structures by using British Standard. In order to achieve the objectives of the researches, there are few researches scope is necessary to be followed:

- The analysis is tested using CivilFEM Software version 12.0
- Types of column are axially loaded column and axially loaded column with bending.
- Four basic cases: pinned-pinned, fixed-fixed, pinned-fixed and fixed-free column.
- Using British Standard, BS5950 Part 1 :2000
- The axial loaded = 2500kN and moment = 30kNm (same to both x and y axis).
- The results to be checked are element OK or NOT OK, section classification, slenderness and compressive capacity(Pc)

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Load-carrying structures may fail in a variety of ways and forms, depending upon the type of structure, the condition of support, the kinds of loads, and the materials used. For instance, an axle in a vehicle may fracture without notice from repeated cycles of load, or a beam may deflect excessively, so that the structures are unable to perform its intended fuctions (Gere and Goodno, 2012). These kinds of failure are prevented by designing structures so that the maximum stresses and maximum displacements remain within acceptance limits. Thus, strength and stiffness are important factors in design of any structure.

Another type of failure is buckling. If a compression member is relatively slender, it may deflect laterally thus the structure will fail by bending. When lateral bending occurs, we say that the column has buckled(Gere and Goodno, 2012). In buckling, the case under an increasing axial load, the lateral deflections will increase too. This will lead the column will collapse completely. The phenomenon of buckling is not limited to columns only. In some aspect, Gere and Goodno said that buckling can occur in many kinds of structures and can take many forms (Gere and Goodno, 2012). When a column is subjected to a compressive axial force, the only deformation that takes place is a shortening of the column. This will lead the column to buckle. For small values of force, F, if the column were to be deflected laterally by a force perpendicular to the column, the column would return to its straight position.

In the previous study of How did the WTC collapse, the column failure theory was rolled out days after the attack to replace the claims of structural engineers. It is on the day of the attack that the jet fuel had melted the towers' steel. Usmani. Chung and Torero defined a complete consensus on any detailed explanation of the definitive causes and mechanism of the collapse of these structures is well nigh impossible given the enormous uncertainties in key data (Usmani, Chung and Torero, 2003). Research so far on composite steel frame structures in fire has shown that the steel frame composite structures have a considerably more robust performance in fire than accounted for in design. This was refer to the properties of the steel itself. Torero has been proved that in UK the most important event was the Broad gate Phase 8 fire.

If a column is sufficiently slender, as measured by the slenderness ratio Le/r, buckling occurs at a stress that is below the proportional limit(Pytel and Kiusalaas, 2002). At the other extreme, short columns where the lateral displacements play a negligible role in the failure mechanism. Therefore, these columns fail when P/A reaches the yield stress of the material. Various design formulas have been proposed for columns of intermediate length, which bridge the gap between short and long columns. These formulas are primarily empirical in nature, being derived from the results of extensive test programs. Materials properties play a major role in the failure of intermediate columns.

Back to the research on the WTC disaster, on the contrary to plain-webbed columns, shear deformations have a more pronounced impact on the buckling capacity of built-up columns(Usmani, Chung and Torero, 2003). This is support by Pytel, 2002 which said that the vital rule that shear plays in reducing the buckling capacity of built-up columns was evident following the catastrophic failure of the first Quebec Bridge in 1907 (Pytel, 2002; Usmani, 2003). An extensive literature survey has been conducted by Elmahdy on the effect of shear on the buckling capacity of built-up columns. In his report of investigations revealed that build-up columns exhibit reduced shear stiffness resulting in an increase in lateral deflection and consequently a reduction in the compressive load carrying capacity (G.M El-Mahdy, 2000). Timoshenko and Gere derived approximate formulae that account for the shear flexibility of built-up columns with battened, laced or perforated cover plates as interconnectors (Timoshenko and Gere,1963). These are some extra information to the buckling.

The previous review demonstrated by Khaled M. El-Sawy defined that the lack of information related to the influence of shear deformations on the buckling capacity of castellated columns. Castellated column is different with the composite column. In other word, the neutral axis for both columns is not the same. This may be attributed to the limited production of such structural members which means column structure in the past. Besides, the current paper presents a compressive study to quantify the effects of shear deformations on the compressive capacity of castellated column when it is buckling about the cross-section major axis. This can be related to the Euler theory of buckling. The equivalent slenderness ratio for the geometric dimensions and boundary conditions of castellated columns is assessed to help characterizing the compressive response of such columns.

Casafont,Pastor,Bonada,Roure and Pekoz have studied the buckling analysis plays an important role in the research. The buckling analysis is on the design of cold-formed steel members(Casafont,Pastor,Bonada,Roure and Pekoz, 2012). For examples, buckling loads are used as parameters in the determination of ultimate behaviour and loads in the Direct Strength Method. In other similar procedures, that have been adopted by current cold-formed steel design codes (Casafront, 2012). This have related to the properties of steel where steel buckling is high subjected to high temperature.

Cold-Formed Steel (CFS) is the common products made by rolling or pressing thin gauges of sheet steel into goods. CFS goods are created by the working of sheet steel using presses, rolling, or stamping to deform the sheet into a usable product. There are many research on the design of perforated cold-formed steel members can be found in the scientific literature members (Casafont, Pastor, Bonada, Roure and Pekoz, 2012). Most of these investigations are focused on the holes of the studs and beams that used in light weight construction of residential buildings. These holes are usually isolated, or far apart from each other, and their size is large. This can affect the mode of buckling or in other words is its bent shape.

El-Sawy, Sweedan and Martini have performed the Major-axis elastic buckling of axially loaded castellated steel columns (El-Sawy, Sweedan and Martini, 2004). In an attempt to enhance the flexural behaviour without increasing the cost of the material, perforated-web steel sections have been used as structural members since the Second World War. In this paper the author have use ANSYS Workbench software as to differentiate the buckling modes of castellated columns for various boundary conditions which are pinned-pinned, fixed-fixed, pinned-fixed and fixed-free. There are some procedure followed to determine the buckling modification factor involves the following steps; i) identification of the critical load P_{cr} using the developed finite element model, ii) equation critical buckling is applied to calculate the corresponding equivalent slenderness ratio $(kL/r)_{eq}$, and iii) the buckling modification factor is obtained based on its equation (Usmani, Chung and Torero, 2003).

Attard and Hunt have studied the Column Buckling with Shear Deformations-A hyperelastic formulation (Attard and Hunt, 2008). This paper does not support the existence of shear buckling mode for straight prismatic columns made of an isotrophic material. Attard and Hunt have done the research on hyperelastic neo-Hookean formulation. It defined that this formulation is derived to the relationship of column constitutive and buckling equation. Shear deformations during buckling are also important in the research of the compressive strength of fiber composites. This fiber of microbuckling models has been postulated. The first to modify the Euler column buckling formula to include shear deformations was Engesser (1889), Engesser (1891).

The curved configuration of a column, under axial load is called buckled shape. Due to this, the distribution of stress over the section will not be uniform, and the resulting eccentricity, however slight, will cause bending moment. This bending moment produces bending stresses which are referred as buckling stresses simply to prevent confusion with bending stresses produced by the eccentricity of applied loads (Punmia and Jain, 2000). Thus the bending stresses are in addition to the direct compressive stress due to applied load. In general, the buckling tendency of a column varies with the ration of the length to least lateral dimension. The ration is known as slenderness ratio (Punmia and Jain, 2000). For tall slender columns, this ratio is large and if failure occurs, it will be entirely due to buckling mode 2. When this ratio is very small, failure occurs due principally to yielding or crushing (mode1). Between these extremes are the so called intermediate columns where failure will due to combination of buckling and crushing (mode3).

A building frame made of beams and columns. A slender column may fail by buckling well before the stress reachs the yield point. The term column is applied to a member that carries a compressive axial load Columns are generally subdivided into the following three types according to how they fail (Pytel and Kiusalaas, 2011). Short columns fail by crushing (e.g yielding). Even if loaded eccentrically, a short column undergoes negligible lateral deflection, so that it can be analyzed as a member subjected to combined axial loading and bending. Long columns fail by buckling. If the axial load is increased to a critical value, the initially straight shape of a slender column becomes unstable, causing the column to deflect laterally and eventually collapse. This phenomenon, which is known as buckling, can occur at stresses that are smaller or often much smaller than the yield stress or the proportional limit of the material. Intermediate columns fail by a combination of crushing and buckling. Because this mechanism of failure is difficult to analyze, intermediate columns are designed using empirical formulas derived from experiments (Pytel and Kiusalaas, 2011).

Ellobody have done the buckling analysis of high strength stainless steel stiffened and unstiffened slender hollow section columns. This paper investigates the buckling behaviour of cold formed high strength duplex material. In this research, the section used to simulate is cold-formed section. This cold-formed section is austenitic-ferritic stainless steel and it design regarding to the EN 1.4462 and UNS S31803. These standards are used in American and New Zealand. Ellobody have used two different types of columns in his research which are stiffened and unstiffened hollow section columns. Each of the columns will be analyse with different column length but same support which is fixed end. The objective of the study is to investigate the effects of cross section on behaviour on stiffened and unstiffened column. Ellobody found that the stiffened column have high strength compare to the unstiffened column (Ellobody.E, 2012).

The behaviour of a column is also affected by any initial lack of straightness of the axis of the column, or initial imperfection of the column (Rasmussen and Hancock, 2012). The ideal pin-ended column is replaced by the column that has an initial crookedness. Long columns fail at their elastic buckling limit, namely, the Euler buckling stress. If an ideal column is very short, it will not buckle at all, but it will simplify fail by crushing of the material at the ultimate compressive stress. Columns that fail in this manner are called short columns, and they fail at their compressive-strength limit. Between short columns and long columns lies a range of columns, called intermediate columns, whose failure mode is referred to as inelastic buckling. They fail when the average stress P/A reaches the inelastic-buckling limit.

Phenomenon of inelastic buckling to determine the inelastic buckling limit of an ideal column whose compressive stress-strain diagram has the form tangent. If the column fails in the range of intermediate columns, so buckling does not occur at a stress below the proportional limit. When its average compressive stress P/A reaches the value, the column is just on the verge of inelastic buckling. There are two principal theories that predict the value of stress which a column will buckle in elastically. The simplest theory is the tangent-modulus theory, developed in 1889 by F.Engesse, a German engineer. The tangent-modulus formula is obtained by replacing Young's modulus, E, in Euler's buckling formula by the tangent modulus, which is the slope of the compressive stress-strain curve (Rasmussen and Hancock, 2012).

A slender column with pinned ends and length, acted on by a compressive load as the centroid of the cross section, and restricted to linear elastic behaviour will buckle. This is referring to the Euler buckling load in fundamental mode. Thus, the buckling load depends on the flexural rigidity and length of the structural member itself but not the strength of the material (Gere and Goodno, 2012). The critical buckling load for inelastic buckling is always less than the Euler buckling load. To investigate the buckling behaviour of slender columns with pinned ends, the column is tested by subject a vertical load that is applied through the centroid of the cross-section and aligned with the longitudinal axis of the column. From the Euler theory, if the load that applied is less than the critical load, this means that the column structure will not fail due to bending. If the load applied to the column is more that the critical load calculated from the Euler method, and referred to its effective length which related to the flexural rigidity of the column. From the Euler method, it stated that slenderness, cross section and radius of gyration have strong relationship throughout the buckling phenomenon (Rasmussen and Hancock, 2012). The strength to resist buckling is greatly affected by conditions of the structure ends support, whether free or fixed.

When the axial load is small, the column remains in its straight position and undergoes only axial compression. The compressive stress, P/A, and is uniform. The column thus remains in stable equilibrium. As the axial load is increased, the structural member reaches a condition of neutral equilibrium in which the column may have bent shape. The load causing neutral equilibrium is called the critical load (P_{cr}) (Rasmussen and Hancock, 2012). At this load, the column may buckle in any direction, if its moment of inertia is the same about both the axes. Generally, a compression member does not possess equal flexural rigidly in all directions. The significant flexural rigidity of a column depends on the minimum inertia and at the critical load that applied to the column. A column buckles either to the side of one axis or to the other, in that plane about which inertia is in minimum value. The buckled shape is possible only at a critical load called buckling load, crippling load or Euler load as prior to this load, the column remains straight. The smallest load at which a buckled shape is possible is called critical load. A theoretical analysis of the critical load for long columns was made by great Swiss mathematician Leonhard Euler in 1757 column (Rasmussen and Hancock, 2012). His analysis is commonly known as Eluler's theory.

In Euler method, theoretically, it can be defined that for different types of end support of column, it can be referred to the Euler theory of pinned ended. This shows that the theory of Euler method can be used in all different of boundary condition of support. Basically, Euler method is having relationship with slenderness ratio. This means that the buckling affects takes the length and cross section of the structure itself. From previous study, Goodno have investigated that the radius of gyration takes an important role as slenderness ration. This is due to the formulae of slenderness which having radius of gyration in it. Automatically, the radius of gyration takes places in the effect of slenderness ratio to the buckling problem. In other words, the radius of gyration is depends on its area of section. The increasing of the cross section makes the decreasing of radius of gyration. Thus, the slenderness ratio will also affected the buckling. This is because the buckling will take places for the more slender the structure. The effective column length, for the fundamental case is L, but for the cases discussed it is 0.7L, 0.5L, and 2L respectively. For a general case, Le=KL, where K is the effective length factor, which depends on the end restraint. For case 0.5L, it is theoretically. In practise, the effective length is taken into 0.85L and it is followed to The British Standards, BS 5950 Part 1, 2000. In British Standards, there are also some other cases from these four cases. There are also different in the slender and non-slender column calculation.

Turvey and Zhang, 2006, finished a research of a computational and experimental analysis of the buckling, post buckling and initial failure of pultruded GRP Columns. In their study, they are using steel grade S275 of the GRP Columns. GRP here means Glass Reinforced Plastic. From theoretically, to determine the failure load of GRP column is by physically testing. However, this test will take much time and it is expensive. So, in this research, the author is using compressive test. Moreover, Turvey and Zhang, 2006 is done the test for short column first to define the initial failure of buckling and post buckling. In this research, they found that the column had faced the catastrophic collapse of columns. There is extensive test on the buckling test, which are carried out by laboratory test and therefore compare to the computational test. The software used in this research is ANSYS and it used model of SHELL 91. In other to prove that the ANSYS Software can be trusted, the authors are using Finite Element Method to prove the result by software simulation is the same as finite element calculation. The calculation is done by manually (Turvey and Zhang, 2006).

Before considering the stability of columns, the stability of a simplified model consisting of two rigid rods connected by a pin and a spring and supporting a load P need to analyze first (Enggeser, 1889). If its equilibrium is disturbed, the system will return to its original equilibrium position as long as P does not exceed a certain value Pcr, called the critical load. However, if P > Pcr, the system will move away from its original position and settle in a new position of equilibrium. In the first case, the system is said to be stable, and in the second case, it is said to be unstable.