FINITE ELEMENT MODELLING ANALYSIS ON BUILT-UP COLUMN

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ABSTRACT

Build-up column is a steel structure composed of two I-beam steel joined with steel plate or angles as the lacings of the column. The build-up column is one of the main load carrying members among all the other structural components of a building. Since the build-up column is assembled manually at the construction site, there might have some error in the section and orientation of the lacings assembled which will affect the performance of the build-up column. The main objectives of this study the effect of the different section and orientation of steel elements on build-up column in terms of buckling and stress distribution. Finite Element Analysis of Ansys 12.0 software is used to design the ten model of the build-up column. In order to study the effect of section of lacings, steel plate and L-angles are used. Besides that, to study the effect of orientation of the lacings, inclination angles of 40° , 45°, 50° , 55 ° and 60° are used. Based on the results, orientation of the steel lacings influenced the stress distribution of the due to the load. The greater the inclination angle the smaller the stress builds up on the lacings. Thus, the build-up column is more stable.

Keywords: Built-up column, Chord, Lacings, Stress Distribution, Buckling, Ansys, Finite Element Modeling, Orientation, Section

ABSTRAK

Tiang "built-up" adalah satu struktur keluli terdiri daripada dua I-rasuk keluli bergabung dengan plat keluli atau sudut sebagai penyusun ikatan tiang. Tiang "built-up" adalah salah satu ahli yang menanggung beban kesemua ahli-ahli lain di kalangan semua komponen struktur lain bangunan. Sejak tiang "built-up" yang dipasang secara manual di tapak pembinaan, mungkin mempunyai beberapa kesilapan dalam penggunaan keluli penyusun ikatan tiang berbeza dan orientasi penyusun ikatan dipasang yang akan memberi kesan kepada prestasi tiang "built-up". Objektif utama kajian ini kesan seksyen yang berbeza dan orientasi elemen keluli pada ruangan membina-up dari segi lengkokan dan pengagihan tekanan. Analisis Unsur Terhingga perisian ANSYS 12.0 digunakan untuk mereka bentuk model sepuluh tiang "built-up". Untuk mengkaji kesan bahagian penyusun ikatan, plat keluli dan L-sudut digunakan. Di samping itu, untuk mengkaji kesan orientasi penyusun ikatan, sudut kecondongan 40 °, 45 °, 50 °, 55 ° dan 60 ° digunakan. Berdasarkan kepada keputusan, orientasi penyusun ikatan keluli mempengaruhi taburan tekanan daripada kerana beban. Lebih besar sudut kecenderungan yang lebih kecil tekanan yang membina pada penyusun ikatan. Oleh itu, ruang membina-up adalah lebih stabil.

Kata Kunci: Tiang, I-Rasuk, Penyusun Ikatan Tiang, Beban, Tekanan, Orientasi, Ansys

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Roof, slab, beam, column and foundations are the structural components of a building. These are the common and vital structural components that play the role of transferring the load of the building from upper part of the structure to the ground. Column is one of the members which is subjected to axial compression. Columns are vertical load bearing member. The column must be designed to withstand the compression load caused by the self-weight and other structural member as well. A column either crushes (strength failures) or it buckles (a stability failure). Both modes of failure must be considered for every column.

Build-up column is one of type of steel column used in the steel building construction. Built-up columns are often used in steel buildings and bridges providing economical solutions in cases of large spans and/or heavy loads. Depending on the way that the flanges are connected to each other, they can be grouped into laced and battened built-up columns. A build-up column is made up of two or more vertical steel member (chords) which is slightly separated and connected to each other by lacings, battens or perforated plates. The load carrying function is performed by the main structural members which are the chords. The two chord members have a tendency to buckle independently. These connectors cause the chords to behave as one integral unit and thus the column is able to achieve its maximum capacity. Lacings provide a tying force to ensure that the chords do not buckle independently.

There are several components involved in the build-up column. The main member of the column is the chord. Steel column is used as the chord member. There are wide variety of steel column that can be used as the chord for the build-up column such as I-column, channel, angles and tee steel. In this software simulation of build-up column, I-column is used as the chord member. Lacing is one of the components in the build-up column. It is believed that the connector causes built-up members to behave as one integral unit to achieve maximum capacity. These members are frequently used as light compression members, such as truss members, bracing members and columns of light steel structures. Plates, L-angle and C-angles can be used as the lacings for the build-up column. In laced columns, the lacing should be symmetrical in any two opposing faces to avoid torsion. Lacings and battens are not combined in the same column.

Build-up column is one of the structural components that have been used in the construction field. Many research, experiment and finite element modelling had been carried out to determine the stability, capacity and performance of the column under different types of conditions. It is vital to understand the characteristics of the column and behaviour of the column in order to determine suitable column for the construction process.

1.2 PROBLEM STATEMENT

Build-up column is a load carrying member. It is used to replace normal steel column in order to support the heavy loads. At the site, the build-up column is fixed manually by the workers. During the construction process, there might be some errors that contribute to the variation of orientation in the lacing system. Thus, it is important to analyze the effect of different orientation on the lacing system to the performance of the column.

There are many types of steel that can be used for the lacing system. At the construction site, there might be some changes in the design of the column due to availability of the steel at site and also due to the cost of the steel. Therefore, it is important to analyze the effect of different section of the lacing system to the performance of the column.

Thus to understand the effects of these variables to the performance of the column, variation in terms of the section and orientation of the lacings, the built-up column will be simulated and tested using finite element modelling software Ansys 12.0.

1.3 OBJECTIVES OF STUDY

The main objectives of the study are :

i. Effect of different section of steel in lacing system to build-up column behavior in term of buckling and stress distribution.
ii. Effect of different orientation in lacing system to build-up column behavior in term of buckling and stress distribution.

1.4 SCOPE OF STUDY

In this analytical investigation, ANSYS 12.0 simulation software is used in order in order to check the performance of the build-up column. The single lacing system build-up column will be analyzed using the simulation software. In this build-up column software simulation V- laced column (without transverse member) will be used throughout the simulation of the entire build-up column. The build-up column consists of two chord and lacings. Figure 1.1 illustrates the detailing involved in the simulation of the build-up column. Steel UC 203 x 203 x 127kg/m will be used for the model creation of the build-up column. The height of the column will be 7.0 m. The effective width between the chords is 1.0 m.

The column will be modelled applying an assumption that its cross section is subjected under axial force only. Load will be applied on top of the column axially. For all the tests of the columns, analysis will be performed considering two situations. The columns will be tested with different angles of inclination in the lacing system and different types of steel in the lacing system. Five models for each condition will be tested with the load applied axially.

There will be ten different types of model will be consider as shown in Table 1.1. Model sample VLC-1 to VLC-5 will be analyzed with different values of angles. The angles of inclination that will be used for the analysis are 40°, 45°, 50°, 50° and 60°. These first five models will be using lacing system with steel plates. The steel plate has a cross section area of 500mm^2 with the dimension of 100mm x 5mm.

Furthermore, VLC-6 to VLC-10 will be analyzed for the different types of steel in the lacing systems. The types of steel that will be used are L-angle, steel plate and C-angle. Combination of Steel plate with L-angle and steel plate with C-angle will also be analyzed in the simulation. L-angle with dimension of 60mm x 60mm x 8mm, C-angle with 100mm x 50mm x 10mm and steel plate of 100mm x 5mm dimension will be used for the lacing system. The angle of inclination of the lacing system is fixed at 45° for this five columns.

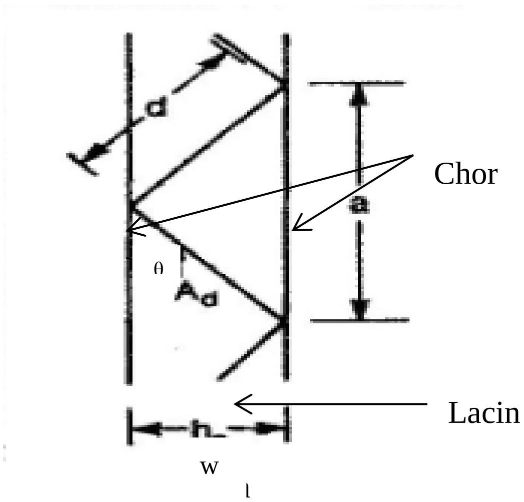

Figure 1.0 : Components of the built-up column

Table 1.1 : Property table for the built-up column models

Sample	Type of lacing	Angle, $^{\theta}$	Panel length, a	Length of lacing, d	Cross section area, Ad
VLC – 1	Steel plate	40	2.384	1.56	500
VLC – 2	Steel plate	45	2.0	1.41	500
VLC – 3	Steel plate	50	1562	1.27	500
VLC – 4	Steel plate	55	1.4	1.22	500
VLC – 5	Steel plate	60	1.154	1.15	500
VLC – 6	L - angle	40	2.384	1.56	500
VLC – 7	L - angle	45	2.0	1.41	500
VLC – 8	L - angle	50	1562	1.27	500
VLC – 9	L - angle	55	1.4	1.22	500
VLC – 10	L - angle	60	1.154	1.15	500

Besides that, there are several constant variables that need to take into consideration. For VLC 1 up to VLC 5 same angle of inclination which is 45° is used for the entire model created. Cross section area of all the three types of steel used in the lacing system need to be the same. Besides that, the V-laced column lacing system is used for model VLC6 up to VLC 10. These two constant variables ensure the expected outcome varies only if there is a change in the types of steel used in lacing system. The welded connections between flanges and the lacings will be represented with rigid links which is considered to be realistic as it accounts for the finite dimensions and rigidity of the connections. The connection at the bottom and top is considered to be pinned connection.

1.5 SIGNIFICANCE OF STUDY

Built-up column is made up of steel column attached with steel lacings. There are many researches and studies regarding the capacity of the column. Most of the studies focused on the chord of the column. There had been less studies conducted on the lacings part of the column. Thus, based on my study on the lacings orientation and section on the performance of the column will be helpful in order to further specify the factors contributing to the capacity of the column.

Furthermore, the study is conducted using the finite element software Ansys 12.0. The common laboratory research methodology conducted, will consume time and cost. Nowadays, the most powerful method for structural analysis is the finite element method (FEM). The simplifications and idealizations of real structural conditions have influence on the final results. The usage of Ansys 12.0 software is efficient to provide informative data to analyze the structural components of built-up column.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Built-up columns are used in steel construction when the column buckling lengths are large and the compression forces are relatively low. In general, built-up columns are used in industrial buildings, either as posts for cladding when their buckling length is very long, or as columns supporting a crane girder (" Detailed Design of Built-up Column ", 2008).

A built-up column is a kind of compression member consisting of two or more longitudinal elements (chords), which are slightly separated and connected to each other at only a few locations along their lengths by means of connector-like lacings, battens or perforated plates. These members are frequently used as light compression members, such as truss members, bracing members and columns of light steel structures. It is believed that the connectors causes built-up members to behave as one integral unit to achieve maximum capacity (" Analytical Investigation of Cyclic Behaviour of Laced Built-up Columns ",2012)

Differentiating built-up column from other structural members is the interaction between global and local buckling modes. The former is associated with buckling of the built-up member as a whole, while the latter with local buckling of chord components between the points at which the chord and the shear system are connected. The effect of the interaction between global and local buckling in built-up members was investigated by Koiter and Kuiken (1971). It was concluded numerically that a laced built-up column can fail either due to elastic failure of the whole column or due to local inelastic failure of a part between joints of connectors under compression, and that in the first case EC3 may give unsafe results.

According to Charis J.Gantes et.al (2014), built-up column are often used in steel building and bridges providing economical solutions in cases of large spans and /or heavy loads. Depending on the way that the flanges are connected to each other, they can be grouped into laced and battened built-up columns. Laced columns are investigated in the present work, in which the flanges are connected with diagonal bars, thus establishing truss like action.

2.2 MATERIAL

According to Konstantinos et.al (2014), the types of chords used plays a major role in the capacity of the column. In the experiment test, two types of chords, IPE80 and UNP60 were used. IPE80 had a bigger cross section area compared to UNP60. From the experiment the collapse load obtained for IPE80 was 309kN whereas for UNP60 the collapse loads was197.8kN. Thus, this proved that cross sectional area influence the most in the capacity of the column. From his study on the built-up column the chord member properties were determined for the study of finite element modelling.

The selection of either channels or I-sections for chord members provides different advantages. I-sections are more structurally efficient and therefore are potentially shallower than channels. For built-up columns with a large compressive axial force, I or H sections will be more appropriate channels. Chords may be adequate in order to provide two flat sides.

Compression members composed of two angles, channels, or tees back-to-back in contact or separated by a small distance shall be connected together by tack riveting, tack bolting or tack welding so that the individual sections do not buckle between the tacks before the whole member buckles. These are special types of columns called laced and battens columns. When compression members are required for large structures like bridges, it will be necessary to use built-up sections. They are particularly useful when loads are heavy and members are long. Built-up sections are popular in India when heavy loads are encountered. the cross section consists of two channel sections connected on their open sides with some type of lacing or latticing to hold the parts together as one unit. The ends of these members are connected with battens plates which tie the ends together. ("Design of Steel Structures", 2008)

2.3 LACING TYPES

Lacing is one of the part of built-up column. It provides connections between the two chords and helps the built-up column to behave as an one integral unit. Many aspects of the build-up column had been experimented and concluded by Konstantinos et.al (2014). According to Konstantinos et.al (2014) the panels' length influences the capacity of the column. This shows that the lacing system is one of the factors influencing the capacity of the column. It was concluded that the heavily built panels influence the capacity of the column. No local buckling was also observed with the specimen tested for the shorter panel length.

There are many types of lacings for the built-up column. V-shape, N-shape and X- shape lacings are the common lacings types that are used in the built-up column. The V-shape arrangement of lacings increases the length of the compression chords and diagonals and provides a reduction of buckling resistance. This arrangement is used in frames with a low compressive force (" Detailed Design of Built-up Column ", 2008).

The N-shape arrangement of lacings, can be considered as the most efficient truss configuration, for typical frames in industrial buildings. The web of the N-shape arrangement comprises diagonals and posts that meet at the same point on the chord axes. This arrangement reduces the length of the compression chords and diagonals. It is usually used in frames with a significant uniform compressive force. the V-shape arrangement of lacings increases the length of the compression chords and diagonals and provides a reduction of buckling resistance of the members. This arrangement is used in frame with a low compressive force. The X-shape configurations are not generally used in buildings because of the cost and the complexity of fabrication.

2.4 LOAD AND CONNECTION

In the study conducted by Behrokh Hosseini et.al (2013), the behaviour of build-up column under constant axial load and cyclic lateral load were investigated. Eight columns made up of two IPE100 as the chords and plates as the lacings were used in the experiment. To evaluate effects of the axial load, different loads were applied on the specimens. Two different distances were also used to show variation on effects towards the column. The test results showed that the axial load significantly affected the ductility, the strength and the stiffness of the columns. Different in the distances between main chords had little effects on strength but had significant change in the ductility. Thus, it can be concluded that the distance between main chords need to be fixed since it affects the strength capacity of the build-up column.

There are many types of connection and load that involves and acts on the built-up column. Loads such as axial load, cyclic load and wind load can be applied on the built-up column. Many studies had been conducted in terms of different load types. Study had been conducted by A. Poursamad Bonab et.al (2012), focusing behaviour of laced column due to cyclic load. The study evaluated the effects of column's geometrical parameters and various level of axial loads on cyclic behaviour of laced columns. From this study, the load type was determined which was axial load.

2.5 EXPERIMENTAL AND FINITE ELEMENT MODELLING ANALYSIS

Ansys 12.0 had been used in the study of the built-up column model. Many experimental studies had been conducted to study and understand the behaviour of the built-up column. Ansys finite element modelling software had been widely used to simulate the built-up column model and analyse the model by simulation.

Based on the study by Vaidotas Sapalas et.al (2013), modelling the steel built-up column using FEM Ansys is restricted to the assumptions of National Lithuania Code STR and Eurocode 3. The study also states that the FEM modelling of the steel built-up column with applied end conditions being safe enough according to STR and

EC3. Models of the built-up column are check and run test to meet the requirements of EC3.

The experimental efforts related to built-up column are limited. Hashemi and Jafari (2009),compared the elastic buckling loads of battened columns with end stay plates obtained analytically with the experimental results. They concluded that Engesser's method is always on the safe side. The same authors compared experimental collapse load of simply supported battened built-up columns with the ones found analytically with the use of Ayrton-Perry method and the ultimate capacity curve method, observing the mean value of the two procedures can be both safe and economical.

Bonab and Hashemi (2012) investigated numerically and experimentally the cyclic behaviour of the laced built-up columns under a lateral concentrated load and different level of axial loading. One of their conclusions was that high level of axial load lead to poor ductility and that laced built-up columns are acceptable for use in moderately earthquake-prone areas. Additionally, they investigated the elastic critical buckling and compressive capacity of centrally loaded laced columns.

Based on the experimental investigation conducted by Behrokh Hosseini (2013), when a built-up column is subjected to a lateral load in an earthquake, it may not behave in an acceptable manner. In his investigation, to evaluate the seismic behaviour, eight laced column specimens were tested. These columns were subjected to a constant axial load while a gradually increasing lateral cyclic load was applied. The experimental results showed that several seismic characteristics of the laced column were reduced as the axial load increased. however, in general, the seismic behaviour of the laced built-up columns with various geometrical properties was investigated analytically, which was a continuation of the experimental investigation of the cyclic behaviour of laced columns. Comparison of the results showed that there is a good correlation in load-displacements, failure modes and elastic behaviour between the experimental and the analytical procedure generally gives a conservative prediction for the ductility of the laced columns (" Detailed Design of Built-up Column ", 2008).

According to Mahmood Hosseini et.al (2013), compound buckling is also a factor that affects the elastic critical loads of columns. This effect was studied by Duan et.al (2002). However, in laced columns, because of the low values of slenderness of the main chords between the lacing plates compared of the with the overall slenderness of the built-up column, compound buckling cannot occur. With regard to the existing complications in calculating the exact elastic critical load of built-up columns by analytical methods, all the proposed theoretical methods contain simple assumptions, and therefore, it is necessary to evaluate the precision of the different methods experimental studies. Very few tests have been conducted on built-up columns. Hosseini Hashemi and Jafari (2009), have investigated the elastic critical load and compressive capacity of batten columns through laboratory tests and have assessed the precision level of the theoretical formulas. However, such tests have not been reported for laced columns.

The finite element method had been used to study the behaviour of single , as well as composed CFS structural members. The studied composed members, however, are of small scale and interconnected with self-tapping screws. Reasonable correspondence with experimental results has been reported, depending on the initial assumptions and complexity of the model.

General guidance for non-linear FEA of thin walled members are given by Bakker and Pekoz (2003). The authors emphasize on the importance of engineering judgement for determining the model input and for results interpretation. The effect of initial imperfections and residual stresses on the accuracy of computational model is addressed by the same author. The authors summarise a set of guidelines for the implementation of imperfections residual stress in a numerical model. These include simple rules of thumb for the amplitude of localised imperfections, as well as imperfection spectrum, based on existing experimental data. The spectrums allow for a quick assessment of the imperfection amplitude for a particular buckling wavelength.

Dubina and Ungureanu (2002) studied the erosion of the theoretical buckling strength of CFS channels in bending and compression, due to initial imperfections in single and coupled instability failure modes. The analysis is based on non-linear FE simulations, from which the higher sensitivity of the distortional-overall interactive buckling to sectional imperfections is demonstrated. Non-linear finite shell element models have been used by Shifferaw and Scafer (2007) to calibrate the Direct Strength Method design expressions for beams, to account for the existing inelastic bending reserve in local and distortional buckling. The findings of the numerical investigations are validated based on C- and Z-section beams. The authors note an important distinction between members free to warp and members, in which warping is restricted.

Seo et.al (2011) described complex light steel beams, resembling channels with rectangular hollow flanges and slender webs with circular openings. These were studied using linear finite element solid models. Linear buckling analysis was used to derive the elastic lateral-torsional buckling moments, needed for code-based predictions of the overall moment capacity. The authors proposed simplified modelling techniques, based on equivalent web thickness, to account for opening in the web. The recommendations are to be used in approximate FE models or explicit elastic buckling numerical solutions, derived by authors.

Narayanan and Mahendran (2009) investigated distortional buckling in 16 innovative cross section shapes of CFS columns. Because the overall capacity, obtained based on the Australian design code, over predicted the capacity of the columns significantly, finite elements model were used to study the failure mechanisms and obtain the axial compression capacity. The models included geometrical imperfections and residual stresses. They established that residual stresses had a very small effect on the ultimate compression capacity. The numerical analyses are validated by 15 experiments on column if intermediate length, which failed in distortional buckling with very little post-buckling strength.

Lim and Nethercot (2003) used finite element models to study the ultimate strength and stiffness of connections of light-steel frames, as well as single lap-joints between thin CFS plates. The models could only give a good prediction of the response, observed during the experiments, after the slip in bolts was eliminated from the experimentally measured graphs.