FINITE ELEMENT ANALYSIS ON THE DEFECTED REINFORCED CONCRETE COLUMN

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To my beloved family

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ABSTRACT

In construction industry, misinterpretation of detail drawings is likely to occur in a tight-scheduled project, leading to the non-conformance with the detail drawings. This study is conducted on a damaged column of a real construction project, where the as-built dimension of its stump does not comply with the detail drawings. The stump is protruded from the wall and is hacked for aesthetic reason, thus the strength of the column is reduced. The aim for this study is to conduct a finite element analysis on the reinforced concrete column whose stump is damaged, to study the behaviour of the column. The strength level and maximum hacking allowed are determined. Non-linear analyses are performed on the column model using LUSAS. The accuracy of the finite element model is verified against experimental data published. The theoretical results are also used to verify the finite element model. From the analysis results, the load capacity, deflection and stress contour of the column with the respected degrees of damage at stump due to hacking are known. Subsequently, the failure mode of the column and the maximum hacking allowed are determined. Besides that, an equation for the particular column is established to determine the column capacity based on the damage done to the stump due to hacking. At the end of the study, it is found that the column having its stump hacked is still able to sustain its design load and maintain its stability.

ABSTRAK

Dalam industri pembinaan, kesilapan membaca lukisan perincian sering berlaku disebabkan oleh kesuntukan masa pihak bertanggung-jawab. Hal menyebabkan kesilapan dalam pembinaan di mana pembinaan tidak sama dengan lukisan perincian. Kajian ini dilakukan ke atas tiang dengan merujuk kepada projek pembinaan sebenar, yakni ukuran 'as-built' untuk tunggul tiang tidak sama dengan lukisan perincian. Oleh yang demikian, sebahagian daripada tunggul tiang tersebut telah dipecahkan, dan menyebabkan kekuatan tiang tersebut telah berkurangan. Tujuan utama kajian ini adalah untuk menjalankan analisis unsur terhingga ke atas tiang konkrit bertetulang, bagi mengkaji kelakuan tiang tersebut dan seterusnya mencari tahap kekuatan serta menentukan tahap pecahan maksimum yang dibenarkan. Justeru, analisis tidak lelurus dijalankan ke atas model tiang dengan menggunakan LUSAS. Demi menentukan kejituan analisis unsur terhingga, data eksperimen makmal dari pihak lain telah dirujuk. Daripada keputusan analisis yang dijalankan ke atas tiang tersebut, kapasiti beban, pesongan and kontur tegasan telah diperolehi. Hasil analisis mod kegagalan dan tahap pecahan yang dibenarkan telah dikenalpasti. Selain itu, satu rumus yang dapat menentukan kapasiti tiang telah diperolehi. Akhirnya, tiang tersebut didapati masih berupaya untuk menahan beban rekabentuk.

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A_e	-	Transformed sectional area
A_s	-	Area of reinforcement
A_s'	-	Area of compression reinforcement
b	-	Width of column
d	-	Effective depth
d'	-	Depth to the compression reinforcement
E	-	Elasticity
E_c	-	Secant or static modulus of concrete
E_s	-	Young's modulus of steel
e	-	Eccentricity of load
F_{cc}	-	Concrete compression force
F_{sc}	-	Reinforcement compression force
F_s	-	Reinforcement tension force
f_b	-	Bond stress
f_{bu}	-	Ultimate bond stress
f_{cu}	-	Characteristic strength of concrete
f_y	-	Characteristic strength of reinforcement
h	-	Depth of column in the plane under consideration
I_e	-	Transformed section second moment of inertia
l_{anc}	-	Anchorage length
l_e	-	Effective column height
M_c	-	Moment before column buckle
M_{cap}	-	Moment capacity
M_o	-	Moment due to eccentric load
N	-	Column design load
N_{cap}	-	Column capacity
$N_{crushing}$	-	Crushing load of column

P	-	Vertical load to the column
P_c	-	Buckling load
r	-	Radius of gyration
x	-	Depth to the neutral axis
α	-	Modulus ratio
β	-	Coefficient dependant on the bar type
γ_m	-	Partial safety factor
δ	-	Second order lateral deflection
δ_o	-	Maximum deviation from the straightness at mid-height
δ_y	-	Vertical displacement of column
ε_{sc}	-	Reinforcement compression strain
ε_s	-	Reinforcement tension strain
σ	-	Stress
φ_e	-	Effective bar size

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CHAPTER 1

INTRODUCTION

1.1. Background

In construction industry, structural and architectural elements of a building are detailed in separate sets of drawings. When the time allocated for a project is short and the schedule is tight, misinterpretation of the drawings is likely to occur. As a result, non-conformance with either one of the drawings may happen during construction stage, leading to a conflict between aesthetic quality and structural stability.

This study is conducted in reference to a real construction project[1] where non-conformance of architectural and structural drawing has occurred. The site problem was initiated when a stump was cast higher than finished floor level, due to the misinterpretation of the drawings during levelling survey work. This resulted in the protrusion of the stump from acoustic wall surface. Hence, the stump was hacked to provide a flat surface for the installation of the acoustic wall (see Figure 1.1).

[1] The project name is not disclosed due to the request by the project owner.

Figure 1.1 : The damage to the column

The strength of the defected column is assumed to have reduced due to hacking. Because the column is an important structural member of the building, a study to determine its capacity is proposed.

1.2 Problem Statement

The type of structural defect due to hacking to the column as presented in this study is not common. Therefore, there is no comprehensive reference available with regards to the acquisition of the maximum capacity for the column. Also, the current code of practice (i.e. BS 8110) does not provide any provision on the design of structural members with openings, hence useful data and references are not available.

For the reasons stated above, analysis is required to understand the structural behaviour of the defected column and consequently know its load bearing capacity. The finite element method (FEM) is chosen as the analysis tool in this study, because it has the advantages in the ability of predicting localised and global behaviours of a structural member.

1.3 Objectives of the study

The objectives of the study are listed as below:

1. To conduct a study on a reinforced concrete (RC) column using finite element analysis, before and after the damage due to the over-hacking.
2. To comprehend the behaviour and to determine the strength level of the damaged RC column.
3. To determine the maximum hacking allowed to the RC column before failure.

1.4 Scopes of the Study

The scopes of the study are listed as below:

1. The finite element analysis is done by using LUSAS.
2. The linear and the non-linear analysis is done in 2-dimension.
3. Material and geometrical non-linearity are included in the analysis.
4. The study is based on the short-term behaviour of the concrete.
5. Analysis is conducted on a column according to the as-built details in the project