ANALYSIS OF PRE-STR H THREE CIRCULAR OPENINGS AT SPECIFIC DISTANCE FROM BOTH END OF THE BEAM

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ABSTRACT

The purpose of this study is to analyse the flexural and ultimate bending moment of pre-stressed concrete beam with openings. There are various types of openings on concrete beam but the focus here on circular openings.

The major objectives of this study are to determine the modes of failure of pre-stressed concrete beam with circular web openings and to determine the ultimate strength and deflection of pre-stressed concrete beam. The thesis identifies that if construction of the concrete beam with web openings are not designed wisely, will lower the strength of beam and may collapsed. It further outlines the efficient method taken to overcome this problem.

The method used is by operating the ANSYS software. Comparisons are made between the software generated graphical results and results from doing manual calculation. It is proved that the values obtained are similar and that it is an effective and faster way to calculate and get results using the finite element software.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

E	exponential
D1	Density
FY1	Force applied
FY2	Force applied

LIST OF ABBREVIATIONS

UMP	University Malaysia Pahang
OPC	Ordinary Portland Cement
RC	Reinforced Concrete
FEA	Finite Element Analysis
FEM	Finite Element Method
PDS	Probabilistic Design System
CDF	Cumulative Distribution Function

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Circular openings in concrete beams appear frequently in construction to ensure easy passage of detailed services for example, sewerage pipes. Therefore, use of materials for example in high rise buildings, can be lessen which will lead to the building being lower and more stable and load reduction in concrete beams would enhance the market requirement of selecting supporting frame which saves a lot of cost (Saksena et al., 2013). Circular openings through structural members are generally needed for mechanical and electrical ducts or even for walkways, for example, openings for doors, windows and also hallways in buildings. These openings often hinder load transfer by concrete struts in these beams and cause large shrinkage in strength and accessibility. Openings are differentiated as small or big openings and the best location for the opening is based on its size (Heba A. Mohamed, 2013). These openings may be of various patterns and diameter, but are mostly placed near supports where shear is imminent (Saksena et al., 2013). (Prentzas, 1968) states that circular and rectangular openings are typically used, although there are other shapes that can be achievable. According to Mansur's (1998) findings, as the opening serves as a source of weakness, the failure plane will definitely pass through the opening, except when the opening is located near the support so as to neglect the potential inclined failure plane. Beams having two different circular opening diameters or placed at different location on the beam were subjected to numerous solutions for torsion and bending. In the meantime, many ways to analyse reinforced concrete members are possible. Finite element technique which is using the ANSYS and Civil FEM software is one of the most practical methods (Sciarmmarella, 1963; Singh, et. al., 1980 and Tan, et.al., 2003). This technique is to establish finite element models aided with computer programme to bring about a suitable analysis and prediction of the nature of the reinforced concrete beams. The concrete was shown using 2–D plane stress elements (Enem, J.I: *et al, 2012)*. Although many studies have been reported, only minority research studies have been done on reinforced concrete rectangular beams with circular opening by simulation. In order to justify the finite element model, the simulation results are researching on many different types of models and comparing between the models to get the best result (Saksena et al., 2013).

1.2 PROBLEM STATEMENT

The beam with circular openings is very generally used because of its featherweight and has immense strength to support high loadings. These types of beams with circular openings are used as abutment for the weight from the roof.

Besides that, the circular openings on the beam is for the service ducts and pipes to pass through. The circular openings on the beam grant the passing of service ducts and pipes to circulate for example, electricity ducts and water pipes around the house. This design is useful when support is needed for roof loadings and service ducts to be concealed from sight to avoid the whole house looking messy.

However, if not constructed accordingly, then these circular openings can lower the strength of concrete beam which means shorter life span of the beam. Therefore, ANSYS and Civil FEM software is used to test out the models to check for stress-strain relationship and deflection of the concrete beam.

1.3 OBJECTIVES

1. To obtain deflection, stress and strain of pre-stressed concrete beam with circular web openings.

2. To determine different input parameters which will have the most effect on the pre-stressed concrete beam with circular web openings.

1.4 SCOPE OF STUDY

The scope of study is limited to beam with the same wall thickness and with the same diameter of the web openings. The simulation of the analysis of the beam with circular openings is via the ANSYS and Civil FEM software to get the deflection of the beam at the web openings and compare the data with that obtained from the manual calculation following the finite element equations. The beam has a height of 600mm and width of 205mm. The length of the beam is 5000mm and the web opening has a diameter of 200mm. The reinforcement used will be pre-stressed steel bar strands with diameter of 12mm. The output parameters that will be determined is deflection, stress and strain.

1.5 SIGNIFICANCE OF STUDY

The fast growing construction industry is driving the structure industry to relatively upgrade their goods and services to be more competitive. In order to achieve this, finite element analysis using software is suggested as the better and faster way rather than doing laboratory test or by manual calculation. This method shows that it reduces time and cost at the same time, maintaining the strength of the reinforced concrete beam with circular openings. It will also be compared with the manual calculation done and that it has similar values obtained which prove its reliability.

Deflection, stress and strain can be determined by using finite element software, ANSYS. The different input parameters will have effects on the pre-stressed concrete beam with circular openings. There will be sensitivities plots that will show which input parameters will affect the most and which one will affect the least. Besides that, it will also show which of the input parameters has very little effect on the pre-stressed concrete beam and is negligible.

CHAPTER 2

LITERATURE REVIEW

2.1 Cement

Cement is important in construction industry as it acts as a medium which binds materials together. Cement has high mechanical strength which increases the geo-mechanical stability of the wellbore and having low absorption gives protection to metals like steel bars against erosion in saltwater and often gases like carbon dioxide (H.O Mustafa & R. Mileva, 2013). The most general used cement is Ordinary Portland Cement (OPC).

2.2 Concrete

Concrete is made up of cement, water, fine and coarse aggregates. Reinforcement is required according to the needs of building construction. Hardened concrete consists of compressive strength and tensile strength. Other characteristics of concrete are its flexible properties, contraction, creep, cracking resistance, electrical and heat resistance. Fresh concretes, like other elements in construction field, act as yield stress fluids. There exists therefore a minimum value of the stress applied to the material for irreversible deformation and flow to occur. The behaviour of fresh concrete in steady state is thus often approximated by a yield stress model of the following general form:

$$\gamma^{\cdot} = 0 \rightarrow \tau \ b \ \tau 00 \qquad (1a)$$

$\gamma^{\cdot} \neq 0 \rightarrow \tau = \tau 00 + f(\gamma)$ (1b),

where $\tau 00$ (Pa) is the yield stress, $\gamma^{\cdot}$ (s−1) the shear rate and f is an increasing function of the shear rate with f(0)=0 that rises positively (K. Konstantin & R. Nicolas, 2011).

2.3 Web openings on concrete beams

Transverse openings in reinforced concrete beams are often used for utility ducts and pipes to pass through in the new age of construction. These ducts are needed to let essential services such as water supply, electricity, telephone, and computer network to be installed in the building. Dead space present below the underside of the beam and for serviceability purposes is covered by a hanging ceiling, the pipes and ducts are installed. In each floor, the height of this dead space adds to the overall height of the building depending on the number and depth of ducts. Therefore the web openings enable the designer to reduce the height of the structure, especially with regard to tall building construction, thus leading to a highly economical design.

The presence of transverse openings will transform simple beam behaviour into a more complex behaviour, as they induce a sudden change in the dimension of the beam's cross section. However, as the opening represents a source of weakness, the failure plane always passes through the opening. The ultimate strength, shear strength, crack width and stiffness may also be seriously affected. Furthermore, the provision of openings produces discontinuities or disturbances in the normal flow of stresses, thus leading to stress concentration and early cracking around the opening region. Similar to any discontinuity, special reinforcement or enclosing of the opening close to its periphery, should therefore be provided in sufficient quantity to control crack widths and prevent possible premature failure of the beam (S. Naganathan et al, 2012).

Transverse openings through beams are often required for the passage of utility ducts and pipes. These openings may be of different shapes and sizes', and are generally located close to the supports where shear is predominant. Although numerous shapes are possible, circular and rectangular openings are the most common ones. Circular openings are required to accommodate service pipes, such as for plumbing, while rectangular openings provide the passage for air conditioning ducts that are generally rectangular in shape.

With regard to the size of openings, many researchers use the terms "small" and "large" without drawing any clear-cut demarcation line. Mansur and Hasnat* have defined small openings as those circular, square or nearly square in shape. Whereas, according to Somes and Corley', a circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the web because introduction of such openings reduces the strength of the beam. The author however considers that the essence of classifying an opening either small or large lie in the structural response of the beam. When the opening is small enough to maintain the beam-type behaviour or, in other words, if the usual beam theory applies then the opening may be termed as small. When beam-type behaviour ceases to exist due to the provision of openings, then the opening may be classified as a large opening. According to the above criterion, the definition of an opening being small or large depends on the type of loading. For example, if the opening segment is subjected to pure bending, then the beam theory may be assumed applicable up to a length of the compression chord beyond which instability failure takes place. Similarly, for a beam subjected combined bending and shear, test data reported in the literature have shown that beam type behaviour transforms into a vierendeel action as the size of opening is increased. Since the behaviour of a beam depends on the size of opening, small and large openings need separate treatment.

The effects of transverse openings on overall response of a reinforced concrete beam in shear are considered in this study. Based on a survey of available literature, the behaviour and design of such beams are presented and discussed. For small openings, two different failure modes are identified, and a method of design using the current code provisions is proposed and illustrated by a design example. The need for further research is also highlighted.

2.4 Type of openings

This section presents the classification of Reinforced Concrete (RC) beams with web openings based on the opening's size and position. Openings are classified as small or big openings and the best position of the opening is decided based on its size. Web openings have been found to take many shapes such as circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes. However, circular and rectangular openings are the most common ones in practice. With regards to the size of openings, many researchers use the terms ''small'' and ''large'' without drawing any clear-cut demarcation line. Small openings are defined as those which are circular, square or nearly square in shape (Hasnat A, Akhtaruzzaman AA, 1987). In contrast, and according to Somes and Corley (1987), a circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the web. The author however feels that the essence of classifying an opening as either small or large lies in the structural response of the beam. When the opening is small enough to maintain the beam-type behaviour, or in other words, if the usual beam theory applies, then the opening may be termed as small. When beam-type behaviour ceases to exist due to the provision of openings, then the opening may be classified as a large opening. By assuming the prevalence of Vierndeel action and considering the fact that failure occurs after the formation of a four-hinge mechanism, Mansur (1998), recommended certain criteria with which to classify the size of an opening as either large or small. It can be assumed that hinges form in the chord members at a distance of h/2 from the vertical faces of the opening. This is shown where h is the overall depth of a chord member, and the subscripts t and b refer to the top and bottom chords, respectively.

- Small opening, $l_0 \leq$ hmax
- Large opening, $l_0 >$ hmax

where h_{max} is the larger of h_t and h_b. That is, when the length of opening I_0 is less than or equal to h_{max}, it may be defined as a small opening. In this definition, it is assumed that the members above and below the opening have adequate depth to accommodate the reinforcement scheme. In the case of circular openings, the circle should be replaced by an equivalent square for the determination of the value of h_{max}.

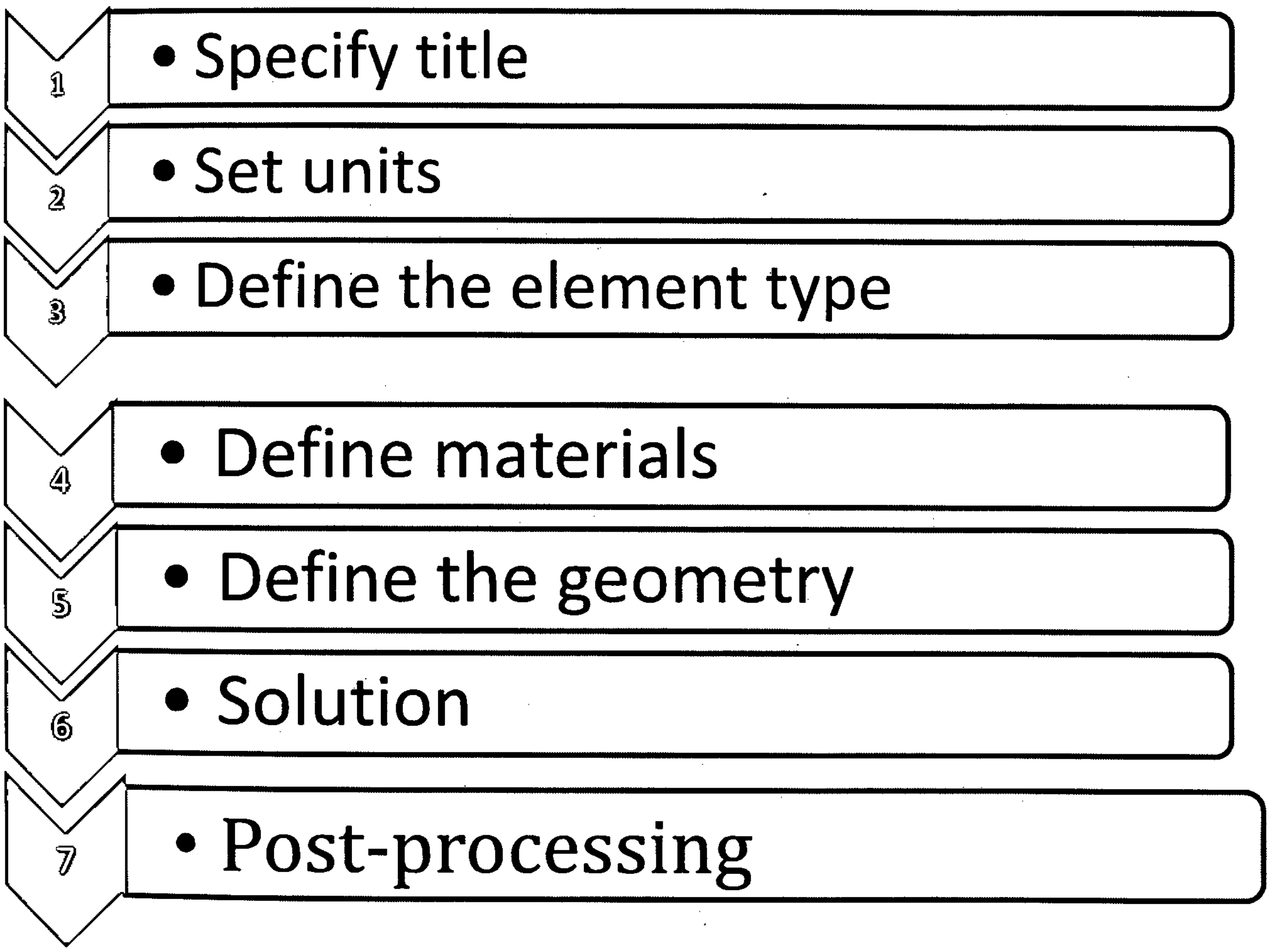
2.5 Finite element

There are several analytical tools available for analysing deep beams. Among all the available analytical methods, finite element analysis (FEA) offers a better option. This method discretizes the continuum into finer elements, making it somewhat tedious and complex to handle manually. Computer–assisted programmes make the use of finite element method quite easier. The availability of advanced analysis tools based on finite elements and matrix structural analysis concepts has enabled engineers to model, analyse and design innovative complex and unusual structures. The software is simple, modular and governed by fundamental principles and aspects of finite element methodology. Finite element method (FEM) offers a powerful and general analytical tool for studying the behaviour of reinforced concrete deep beams (Sciarmmarella, 1963; Singh, et al 1980 and Tan, et al. 2003). Finite element method as a tool can provide realistic and satisfactory solutions for linear and nonlinear behaviour of deep beam structural elements (Quanfeny and Hoogenboom, 2004; Samir and Chris, 2005). Finite element method uses many elements in analysing any continuum which makes it cumbersome for manual analysis. As the number of elements used increases, the manpower and effort required to prepare the relevant and necessary data and interpret the results increase. Therefore computer based programmes
help to reduce the effect and rigour involved by analysing a continuum using manual analysis. The limitations of some programmes may prevent the use of a large number of finite elements to idealize the continuum. The effectiveness of a programme depends essentially on the following factors: Firstly, the use of efficient finite elements; Secondly, efficient programming methods and effective use of the available computer hardware and software. Thirdly, a very important aspect in the development of a finite element programme is the use of appropriate numerical techniques (Klus, 1990).

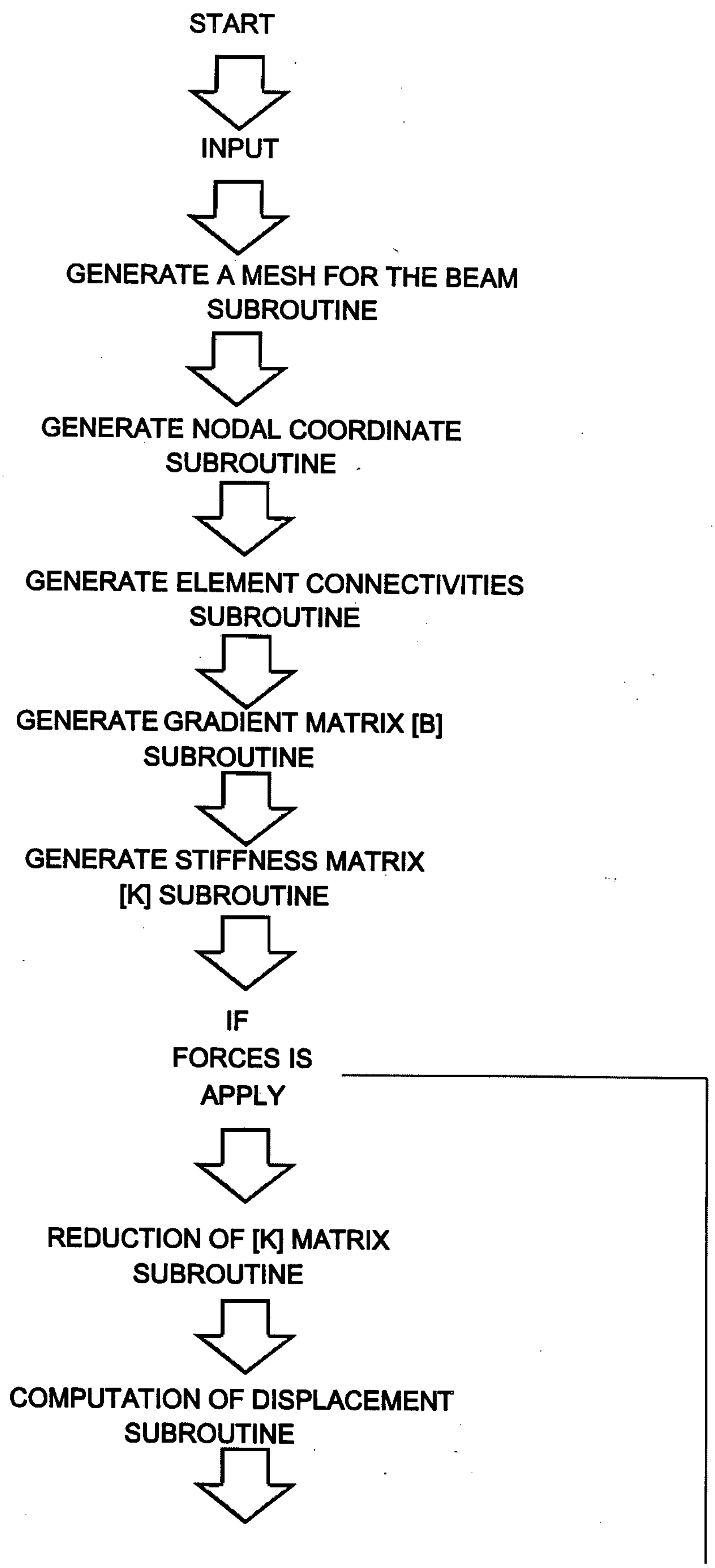
CHAPTER 3

METHODOLOGY

3.1 Finite element



3.2 ANSYS software



COMPUTATION OF STRAIN, STRESS AND NODAL FORCES SUBROUTINE

PRINT

STOP

The flow chart above shows briefly from start to stop of the generation of report in ANSYS software.

3.3 Log File

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FINISH

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/FILNAME,PrestressedBeam 3 no,0

/TITLE,ANALYSIS OF REINFORCED CONCRETE BEAM WITH 3 CIRCULAR
OPENINGS AT SPECIFIC DISTANCE FROM BOTH END OF THE BEAM

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~UNITS,SI

~CFACTIV,PRSC,Y                 !Activates the selected CivilFEM module PRSC

~CFACTIV,NLBR,Y                 !Activates the selected CivilFEM module NLBR

/uis,msgpop,3

!*****************************************************************

/PREP7

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~CFMP,1,LIB,CONCRETE,BS8110,C50

~CFMP,1,UPDATE                 !Updates in real time all the time dependent properties
in all materials.
```