

PERPUSTAKAAN UMP



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**SENSITIVITY ANALYSIS OF REINFORCED CONCRETE BEAM  
WITH THREE SMALL CIRCULAR WEB OPENING  
ON BEAM BEHAVIOUR - DEFLECTION  
USING ANSYS**

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## ABSTRACT

In modern building nowadays requires many duct and pipe to provide a comfortable accommodation. The dead space created between the beams and ceiling for installing the ducts and pipe, this cause the overall floor height. Web opening in concrete beam is the only solution to provide a clear place to install with no decrease the floor clear height. There are a number of studies have conduct related to reinforced concrete beam with web opening. This study aims to determine the deflection of reinforced concrete beam with 3 small opening by using finite element software-ANSYS. The beam model is simply supported beam with two concentrated and symmetrical loads. There are six elements of the beam been manipulated to form different modal. There are modulus of elasticity, reinforcing steel bar size at the bottom and surrounding the opening and concrete cover, apply loads and shear link spacing. The effect of the apply loads is very significant and follow by concrete cover. However, others element is insignificant of affecting the beam deflection. Based on this study, the effect of reinforcing steel bar size, shear link spacing and concrete strength is very insignificant and might be ignored, if the reinforced concrete beam with opening are well designed.

## ABSTRAK

Dalam bangunan moden hari ini memerlukan banyak saluran dan paip untuk menyediakan penginapan yang selesa. Ruang mati dicipta antara rasuk dan siling untuk memasang saluran dan paip, ini menyebabkan ketinggian lantai keseluruhan. Pembukaan Web dalam rasuk konkrit adalah satu-satunya penyelesaian untuk menyediakan tempat yang jelas untuk memasang dengan tiada penurunan ketinggian lantai yang jelas. Terdapat nombor kajian berkelakuan berkaitan dengan rasuk konkrit bertetulang dengan pembukaan web. Kajian ini bertujuan untuk menentukan pesongan rasuk konkrit bertetulang dengan tiga pembukaan kecil dengan menggunakan perisian unsur terhingga - ANSYS . The mod rasuk tersokong mudah rasuk dengan dua beban tertumpu dan simetri. Terdapat enam elemen rasuk telah memanipulasi untuk membentuk mod yang berbeza. Terdapat modulus keanjalan, mengukuhkan saiz bar keluli di bahagian bawah dan sekitar pembukaan dan penutup konkrit , memohon beban dan pautan ricih jarak. Kesan daripada memohon beban sangat penting dan diikuti dengan penutup konkrit . Walau bagaimanapun, unsur yang lain adalah tidak ketara mempengaruhi pesongan rasuk. Berdasarkan kajian ini , kesan mengukuhkan saiz bar keluli, pautan ricih jarak dan kekuatan konkrit adalah sangat penting dan mungkin mengabaikan, jika rasuk konkrit bertetulang dengan pembukaan yang direka dengan baik.

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**LIST OF SYMBOLS**

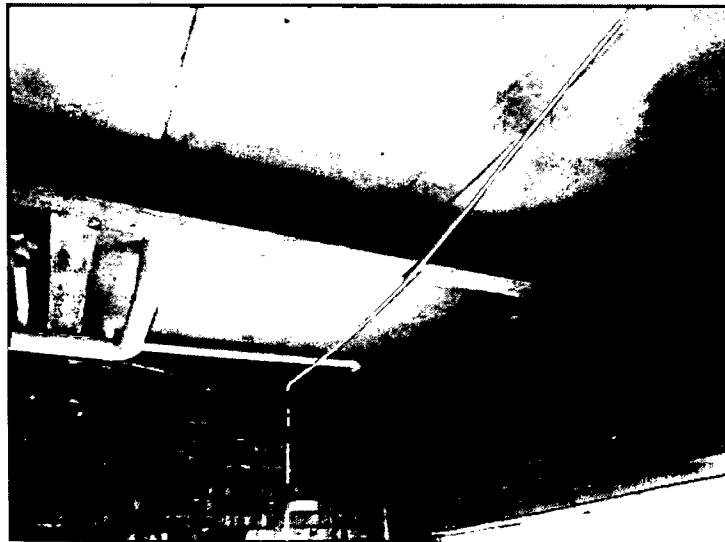
$A_s$	Area of the tension reinforcement
$f_y$	Yield strength of the tension reinforcement
$f'_c$	Cylinder compressive strength of concrete
$b$	Width of the compression zone

## CHAPTER 1

### INTRODUCTION

#### 1.1 INTRODUCTION

The purpose of the building is to provide a comfortable shelter. In a building, there are a lot of utility ducts and pipes were installed. These ducts are necessary to provide basic services such as electricity, telephone, computer network and water supply. Due to aesthetic reasons, the designer will place these ducts underneath the soffit of the beam and covered by suspended ceiling. This also creates a dead space between the ceiling levels to the bottom of the beam. The dead space depends on the number and the size of the ducts. In addition, the dead space height increased the overall floor height. In this dead space, there is a lot of empty space, and this will cause the insufficient to manage the dead space.



**Figure 1.1:** The ducts had been installed pass through the bottom of the beam.

## 1.2 BACKGROUND OF STUDY

In a conventional design and construction process, the common material for construction is reinforced concrete with the rectangular beam section to carry the load from the slab and wall. To avoid the creation of the dead space between the ceiling level and the bottom of the beam, the reinforced concrete beam with the web opening is the only solution. With the web opening, the ducts can pass through it and reduce the height of the dead space and also the overall floor height. However, there are few types of services in the building such as electricity, telephone, computer network and water supply. Hence, it must be separate to make sure it is more systematic and it is much easier for the future maintenance.

The location and the size of the opening might have effect the strength of the reinforced concrete beam. Reinforced concrete beam is one of the important parts of the building structure. Its function is to support and carry the load from the slab and wall. Improper design of the beam members might cause problems to the whole structure, and the most serious is the whole structure will collapse.

## 1.3 PROBLEM STATEMENT

The dead space cause by the duct installation that make the overall floor height increase and the designer also need to design the ceiling height to ensure the future maintenance of the service can be done much easier. The creation of the circular opening at the beam web might be affecting the original strength of the beam. The position and the size of the circular opening have to consider. Besides, the ultimate limit state and the service limit state have to consider.

The researchers of the beam with web opening have been started from 1960 and most of the research is about the reinforced concrete beam with large rectangular web opening (Mansur, 1998). The behaviour of the small circular web opening if different compare to the large and rectangular web opening. Besides, most of the experiment is carried out for the shear and flexural behaviour of the T-beam with the large rectangular web opening (Javad Vaseghi Amiri, 2006). Besides, current national Codes of Practice

such as Australian Standards, American Concrete Institute and British Standard do not include the specifications for the web openings in reinforced concrete beam (Tae, 2011). The needs of the safe have been increased due to the limit sources and experiment data.

In Malaysia, the application of the web opening at the reinforced concrete beam is a structure is very less. It might due to the lack of the experimental result and design exposure of the reinforced concrete with the web opening. In this study, a series of test will be carried out to determine the behaviour and other parameters of the reinforced concrete with circular web opening. The result and the finding in this study might can help the designer to design the building with a more economical method or design.

#### **1.4 OBJECTIVES**

The objectives of this study are:

1. Identify the beam behaviour - deflection for the various of parameters on rectangular reinforced concrete beam with 3 small web opening.
2. Determine the sensitivity of the parameters on the beam behaviour - deflection of rectangular reinforced concrete beam with 3 small web opening.

#### **1.5 SCOPE OF STUDY**

A creation of modal will carry out by using software – ANSYS. The loads will be applied of the beam. The analysis of the beam will be done by ANSYS. The numbers of opening and opening locations will be fixing. The concrete strength been use in the reinforced concrete beam will be difference. In addition, there are two type of shear reinforcement design will be apply in the beam.

#### **1.6 SIGNIFICANCE OF STUDY**

This research will provide a result in term of step and results of analysing reinforced concrete beam with web opening. The result of the research can be used in comparing the result of experiment that has been done in previous research. Besides, it might can be use in develop the design method of the reinforced concrete beam with web opening. In addition, the study also can provide accurate information about

reinforced concrete beam with web opening and it help for others researcher in the future study. It will save time and money if the analysis of the reinforced concrete beam with web opening has been done in the ANSYS before in proceeds to experimental analysis. This study will enhance the reputation of country- Malaysia and it very helpful in the field of Civil Engineering.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 INTRODUCTION

#### 2.2 WEB OPENING CLASSIFICATION

Web opening in beams may be of different shapes and sizes. According to (Mansur & Tan, 1999), circular opening is for pipes' line service, such as plumbing and electricity. However, the rectangular opening is for air ventilation service or air-conditioning ducts. There are some rectangular opening with the round edge, which it can reduce the stress concentration at the sharp edge. In general, there is much researcher use the term small opening and large opening without any definition or justification.

##### 2.2.1 Beam with Large Opening

Based on the research done by (Ahmed et al., 2012), the web opening with different shape such as rectangular, square or circular with its opening diameter exceeds 0.25 times of the overall depth of the beam web. (Mansur, 2006) stated the large opening beam web might be influence the beam-type behaviour. In the other words, the usual beam theory cannot be applied during beam analysis or design.

##### 2.2.2 Beam with Small Opening

The opening with the diameter less than 40% of the overall depth of the beam can be considered as the small opening (Javad Vaseghi Amiri, 2006) stated that the research on the beam with the web opening have been started since 1960 and most of



the research is about reinforced concrete with the large rectangular opening. From a survey of available literature, it has been noted (Mansur & Tan, 1999) that when the web opening is small and the beam can maintain the beam-type behaviour. Besides, (Mansur & Tan, 1999) also proved that, the presence of the small opening in the beam web would not influence the ultimate strength of the beam and it will not reduce the concrete area for the development of the compressive stress block at ultimate.

### 2.2.2.1 Pure Bending

In terms of pure bending, the presence of the small opening at the tension zone do not change the amount of load carry by the beam because the concrete beam would crack anyway when the flexure reach maximum. (Mansur & Tan, 1999) proved that the presence of the smaleffectct in the beam would not affect the ultimate moment capacity of the beam with the condition minimum dehish of the compression cord,  $h_c$  is greater than or equal to the depth of the ultimate compressive stress block.

$$h_c \leq \frac{A_s f_y}{0.85 f'_c b}$$

However, the cracks will occur at an earlier stage of loading due to the reduction of the moment inertia of the beam.

## 2.3 REINFORCED CONCRETE BEAM

From the previous researches that have been done, there are many different types of beam with opening that have been used. Such as, deep beam, normal rectangular beam and flange. For example, (Mansur, 2006) use T-beam for experiment. There are four beams have been used with 2.9 m long, 400 mm deep, 200 mm width of the web and 100 mm thick with 700 mm wide flange. The type of the reinforced concrete used will influence the beam-behaviour. Due to the web opening classification, the overall depth of the beam will directly affect the web opening categories.

The study done by (Nilesh H. Saksena, 2013) stated there are large numbers of research have been done with the effect of opening in the T-beam, pre-casted beam, pre-

stresses beam and deep beam. However, the report of the result of the effect of opening in rectangular beam is very limited due to problem of limited depth of the beam web for the opening. In this study, the rectangular beam will be used for identifying the effect of the opening of the beam web.

### **2.3.1 Rectangular beam**

Based on the research done by (Nilesh H. Saksena, 2013), the length of the rectangular beam used in that study is 2 m. Cross section of the beam: width of the web is 150 mm, depth of beam is 200 mm, the effective depth is 174 mm and the distance between compression reinforcement and compression fibre is 24 mm. The diameter for tension and compression reinforcement is 12 mm and 8 mm, respectively with Fe 415 grade of steel. The concrete grade used is M20.

However, in this study there are some modification of the dimension of the rectangular beam and numbers of bars.

## **2.4 CONCRETE STRENGTH**

Previous research shows that the concrete strength of the beam for testing is fixed variable. In the other words, the concrete strength of the beam is fixed and the researches manipulate others parameters such as type of beam being used, numbers of opening and the strip reinforcement arrangement. But the study done by (Javad Vaseghi Amiri, 2006), the concrete strength has been manipulated a surrounds reinforcement design surround the opening is fixed. Besides, the position of the opening is just limited at the shear zone (near to support). In the study, they use reinforced concrete beam using normal and high strength concrete.

(Tae, 2011) studied that the strength of the concrete used in the concrete beam with web opening will affect the shear ultimate strength of the beam. Hence, in this study the concrete strength will be various; it will cover normal concrete and high strength concrete to study the effect of the concrete strength to the ultimate strength of the reinforced concrete beam with web opening.

## **2.5 REINFORCED CONCRETE BEAM ANALYSIS**

There are many studies about the reinforced concrete beam either with web opening or without web opening, but most of the studies are on experiment part. In this study, the analytical analysis will be covered by using finite element software ANSYS.

### **2.5.1 Experiment**

(Nilesh H. Saksena, 2013) and (Javad Vaseghi Amiri, 2006) study the reinforced concrete beam experimental opening based of the experiment result. In their study, the reinforced concrete beam for both studies need 28 days for curing and both perform two point flexure test. The beam was tested using proving ring loading frame jack system.

For both studies, the researches need to consume a lot of time and money to do the testing. However, in the process of the constructing the beam there might be some human errors like the position of reinforcement has been placed wrong or the concrete strength might not achieve the strength like the design. Besides, the needs of the skill technician to complete the testing with some more the testing equipment might be have error.

### **2.5.2 Finite Element Analysis – ANSYS**

The finite element software – ANSYS system is a very useful and effective tool for engineers. The ANSYS system is used in many fields to help engineers in designing, analysing, and optimizing the crucial stages of structural elements. It can be used to predict the stresses and deformation of a structure at different stages of construction and also the consequences and maximum stress that can be withstands, exerted by the wind. (Lener & Lener, 2009) had discussed about the role of ANSYS system in a floating stage construction used in the Bond movie. They have chosen this software to analyse the Tosca stage because of the effectiveness of the software which can analyse every possible standing point on the stage. Besides, they have recommended this software system as it provides a very wide range of tools including analysis of instruments like linear and non – linear analysis; analysis of material to be used like steel and rubber; and also the superior function of this software where the bidirectional communication of

this software to other software such as the CAD system. ANSYS has shown its functions in analysing structural details and evaluating the ultimate limits of a particular structure. Besides that, the effectiveness and well-function system also provides accurate analysis results along with convenience and time saving condition to the engineers that enhance the confidence of the construction team.

ANSYS is a general-purpose finite element software that contains more than 100,000 lines of code. This shows the wide range of ANSYS system that can be used throughout an engineering field and also the efficiency and multi-function of this software. The engineers are able to access through material selection and design stage efficiently by using the ANSYS system, since the system provides the accessibility to the variable's range of influence in a virtual environment (Ingeciber, n.d.). The benefit of using the ANSYS system can help the engineers determine strength, safety, comfort, and environmental considerations without testing and without conducting experiments. Therefore, this system is considered timely and cost-effective.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 INTRODUCTION**

In this study, finite element analysis will be used for reinforced concrete beam with web opening modelling and analysis. This is because the finite element analysis method is cheap, precise and easier to use compare to the experiment. Besides, current code of practice does not have a proper design methods and analysis. Most of the design is based on the experiment analysis. Hence, in this study, the software of finite element analysis – ANSYS will be used to modelling and analyse the reinforced concrete beam with web opening. It is to study the behaviour of the reinforced concrete beam with web opening under external load.

#### **3.2 FINITE ELEMENT ANALYSIS METHOD – ANSYS**

The finite element method is a powerful numerical method in solving problem of engineering and mathematical physics (Logan, 2012). The analytical modeling of reinforced concrete beam with web opening geometry has been done by using ANSYS+CIVILFEM. In modeling, the model follows the actual size 3000mm (L) X 150mm (B) x 300mm (H). The locations of three opening are located at L/4, L/2, and L-L/4. There are three major or common steps for analytical analysis in ANSYS (Saeed, 2003), which is pre-processing, solution and post – processing.

#### **3.3 GETTING DATA OF THE MODEL**

The details of the model and the material of the reinforced concrete beam with web opening are very important. It might be effect the final result of the analysis.

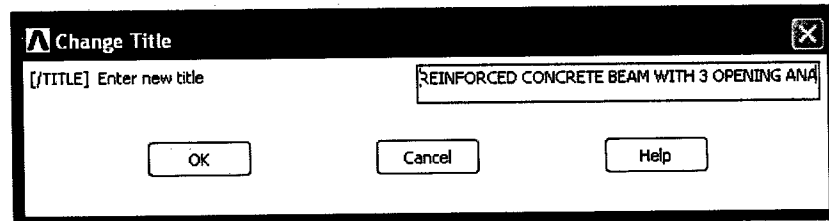
Besides, the code of practice that will be use also will influence the output of the analysis. In this study, the code of practice for concrete and the steel reinforcement will use Eurocode 2 as the reference. After all the relevant data has been collected, it can be proceeds to next step.

### 3.4 PRE-PROCESSING

A typical ANSYS+CIVILFEM analysis started with setting out the information such as, code of practice, units, materials, element types used, geometry model, and section

#### 3.4.1 Assign Project Title

Before start any step in ANSYS, the project title need to change. This title is important, because it will appear in the window of the interface and as well as in the result. By this way user can easily identify the project that in progress. The Figure below shows that the change title dialogue box.



**Figure 3.1:** Change title of the project.

#### 3.4.2 Assign Codes and Units for The Project

After the title of the project has been changed, the software needs to set the codes of practice that used for the analysis of the model. For this study, the codes used is Eurocodes 2 (EN 1992-1-1:2004/AC:2008). This code only covers reinforced concrete analysis and design. For this study, the unit system that has been used is user units. The length in meter, time unit in second, force unit in Newton, pressure or stress unit in pascal, and mass unit in kilogram. This entire unit needs to clearly state before

modelling process start. This is because; the model can be modelled according to the actual size.

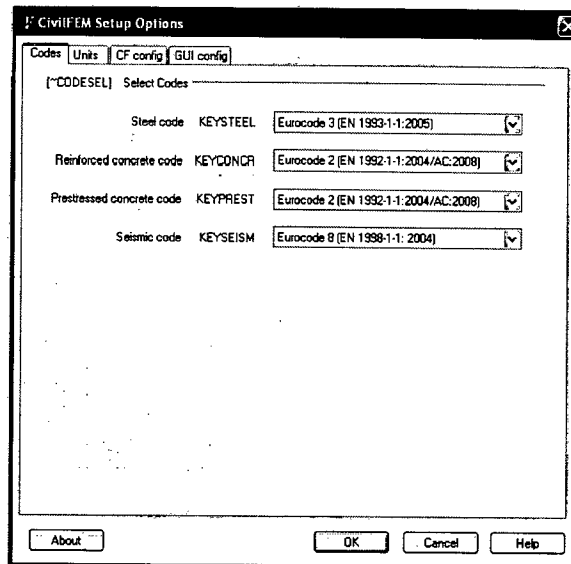


Figure 3.2: Codes setup option.

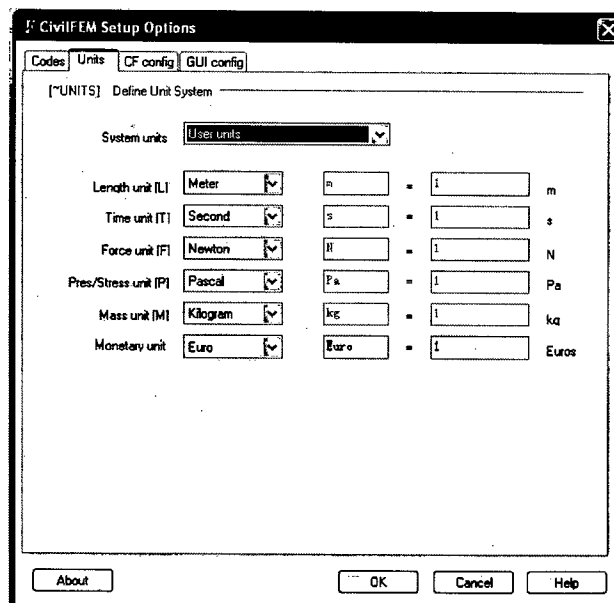
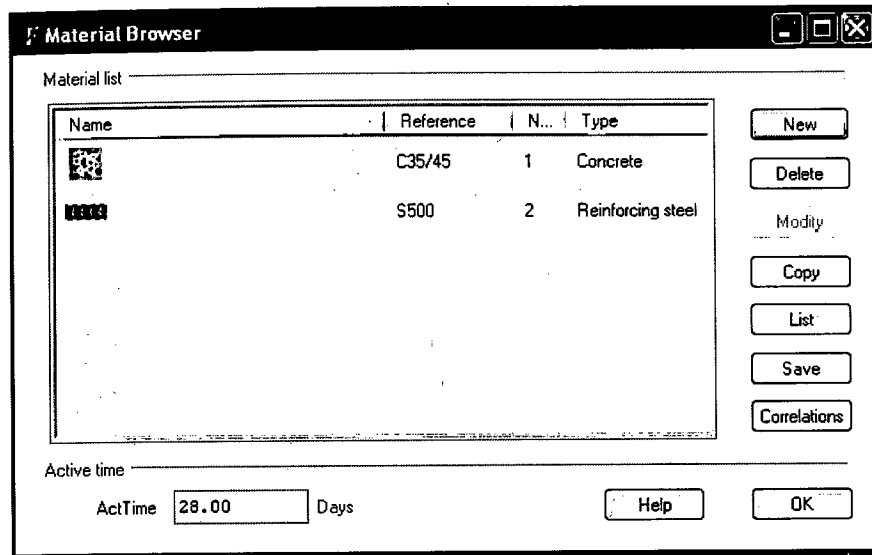


Figure 3.3: Unit setup option.

### 3.4.3 Material and Element Type Selection

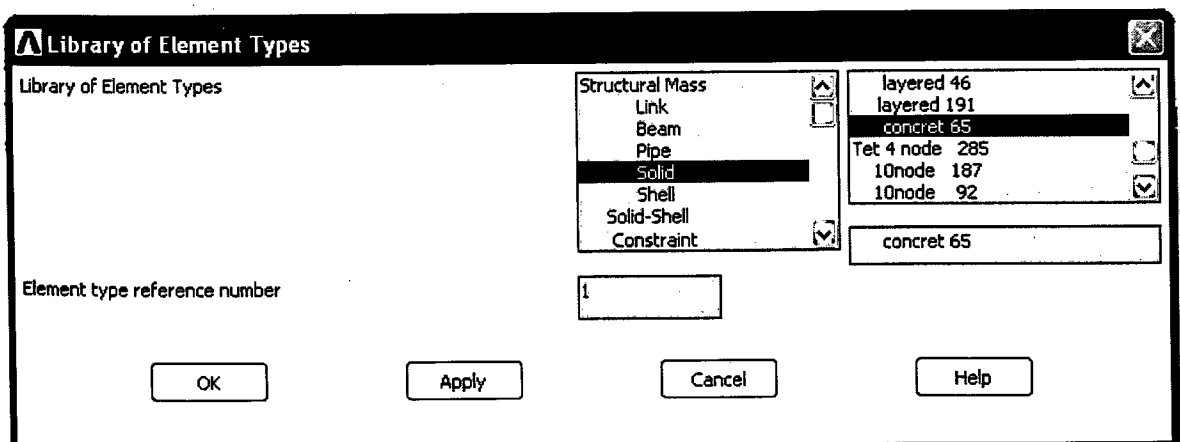
After the codes and units have been set for the model. The material will be chosen according to the actual model based on the Eurocode 2. The material that used in

this model is concrete with grade C35/45 and reinforcing steel with grade S500 (500N/mm<sup>2</sup>).



**Figure 3.4:** Selected material for modelling.

Next the element type for the model must select first before it proceeds to modelling. This model use 3D Solid 65 as the model element type. Solid 65 is used for the three-dimensional modelling of solids with or without reinforcing bars (rebars). Hence it is suitable to model reinforced concrete beam.



**Figure 3.5:** Define Element Type of the model.