EFFECT OF OPENING WITH VARIOUS SIZE AND LOCATION ON RC DEEP BEAM

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EFFECT OF OPENING WITH VARIOUS SIZE AND LOCATION ON RC DEEP BEAM

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Thesis submitted in fulfilment of the requirements
for the award of the degree of
B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources
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JUNE 2015

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Dedicated to my parents,
for their love and devotion
making me be who I am today

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ABSTRACT

This study is about analysis of the behaviour of the reinforced concrete deep beam with different sizes of opening and different location of the opening by using ANSYS. The opening on RC deep beam is made for the mechanical and electrical purposes. Before the opening is made, it is important to know the optimum size and its location in order to prevent structural failure. The main objective of this study is to determine the effect of the opening size and its location on the reinforced concrete deep beam in terms of crack pattern and deflection. The study is conducted by using ANSYS 12.0. In this study, there are 7 models. There is one solid beam (DBS), three beams with different size of opening namely DBO1, DBO2 and DBO3, and three beams with opening but different location were designated as DBL1, DBL2 and DBL3. The three point test was used for the analysis. The loading used for the analysis is axial load. The deflection and the crack pattern obtained from the ANSYS were used for discussion. Based on the result, the deflection of the RC deep beam was increase in 31.2% as the opening size increase in 60%. For the different location of opening, as the location of opening move from 350mm to centre of the RC deep beam, the deflection of the RC deep beam was increased in 31.8%. In conclusion, the most appropriate location of the opening on RC deep beam is the place where far away from the loading.

ABSTRAK

Kajian ini adalah mengenai analisis kelakuan rasuk konkrit bertetulang dalam dengan saiz pembukaan yang berbeza dan lokasi pembukaan yang berbeza dengan menggunakan ANSYS. Pembukaan di rasuk konkrit bertetulang dalam dibuat bagi tujuan mekanikal dan elektrik. Sebelum pembukaan itu dibuat, ia adalah penting untuk mengetahui saiz optimum dan lokasinya bagi mengelakkan kegagalan struktur. Objektif utama kajian ini adalah untuk menentukan kesan saiz pembukaan dan lokasinya di rasuk konkrit bertetulang dalam dari segi corak keretakan dan lenturan. Kajian ini dijalankan dengan menggunakan ANSYS 12.0. Dalam kajian ini, terdapat 7 model, satu rasuk pepejal (DBS), tiga rasuk dengan saiz yang berbeza pembukaan iaitu DBO1, DBO2 dan DBO3, dan tiga rasuk dengan pembukaan tetapi lokasi yang berbeza telah dinamakan sebagai DBL1, DBL2 dan DBL3. Ujian lenturan tiga titik telah digunakan untuk analisis. Beban yang digunakan untuk analisis adalah beban paksi. Lenturan dan corak retak diperolehi dari ANSYS digunakan untuk perbincangan. Berdasarkan keputusan, lenturan rasuk konkrit bertetulang dalam meningkat sebanyak 31.2% apabila saiz pembukaan meningkat sebayank 60%. Untuk lokasi yang berbeza, pembukaan di lokasi dari 350mm ke pusat rasuk konkrit bertetulang dalam, lenturan rasuk konkrit bertetulang dalam telah meningkat sebanyak 31.8%. Kesimpulannya, lokasi yang paling sesuai untuk pembukaan pada rasuk konkrit bertetulang dalam adalah pada lokasi yang jauh dari pembebanan.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The construction of tall building is different from the construction of a normal building. In the construction of the tall building, the beams at the lower part will carry larger loads when compare with the beams in a normal building. The deep beam was created to solve these problems.

A deep beam is a beam which has a deeper depth compared with a normal beam. In the ACI 318, it stated that a beam with the clear span equal to or less than 4 times the overall member depth, which is the depth of a deep beam, is comparable with its span length. To design a reinforced concrete deep beam, most of the engineers followed the strut and tie model (STM). The principle of the strut and tie stated that a truss is design as all stress are compacted into compression members and tension members connected by nodes. The members subjected to compression are strut; members subjected to tension are tie, while the intersection between strut and tie is node.

The deep beam has a larger depth because it is a load transferring structural component which is usually used to transferring a great amount of loads from above to supports at below. Deep beam usually used in the construction of high-rise buildings. In a high-rise building, the deep beam is used as a transfer girder. When a lower column was removed from the lower floor, the deep beam has to transfer the load from the upper column to the other lower columns. The application of deep beam can provide more space for the lower floor. The deep beam also used in concrete gravity foundation and bridge construction.

In a building, there are mechanical, electrical, and passage ways access that need to be consider during construction process. The larger size of deep beam will cause obstruction to these utilities. In some cases, these utilities have to penetrate the deep beams. The solution to solve this problem is providing opening at the beam. These openings are required for the passage utilities lines and ventilation ducts.

1.2 PROBLEM STATEMENT

The openings on a structural element were made for mechanical and electrical purposes. From the view point of a structural engineer, there are some difficulties to make decision when the openings are required to be made on the reinforced concrete deep beams. This is because there is no code of design for structural with openings. The effect of making opening on the RC deep beam is unpredictable. The opening may reduce the strength of the RC deep beam will lead to structural failure. Therefore, the analysis of the structural elements with web openings should be conducted before the web opening made for the safety of the RC deep beam.

For the mechanical and electrical purposes, there are many essential ducts will be installing in a building and sometimes there need to penetrate the concrete deep beams. The ducts to be used in mechanical and electrical purposes are various in sizes. Because of the size of ducts are various, the size of opening on the beam will be various. Besides that, the system routing for the essential ducts are very complex in the large structural. This will caused various location of the opening on beam. The optimum size and location of the opening have to be determined. So that the study on the size and location of the opening on deep beam may be useful and need to be take note.

1.3 OBJECTIVE OF STUDY

The main objectives of this study are:

(i) To study the effect of the size of opening on deep beam based on crack pattern and mid span deflection.

(ii) To study the effect of the location of the opening on deep beam based on crack pattern and mid span deflection.

1.4 SCOPE OF STUDY

In this study, the model of solid RC deep beam was adopted and modified from previous study by Preetpal & Nasir (2014). The dimension of the RC deep beam models was 2300mm length, 150mm width, and 800mm depth. There are total of 7 models were analysed in this study. A solid deep beam model was used as controlling model, which is a reinforced concrete deep beam without any opening. There are 6 models with opening were analysed. There were different in the size of opening and the location of the opening. According to Ashraf (2014),the overall reduction in the beam's capacity should not exceeding 10% of the capacity the beam without web opening, the diameter of the opening should not exceed 20% of the beam overall depth (0.2d). The size of the opening was set with diameter of 100mm, 130mm, and 160mm. The models are shown in Figure 1.1 and Figure 1.2 below. The size and location of the web opening on the deep beam is shown in Table 1.1.

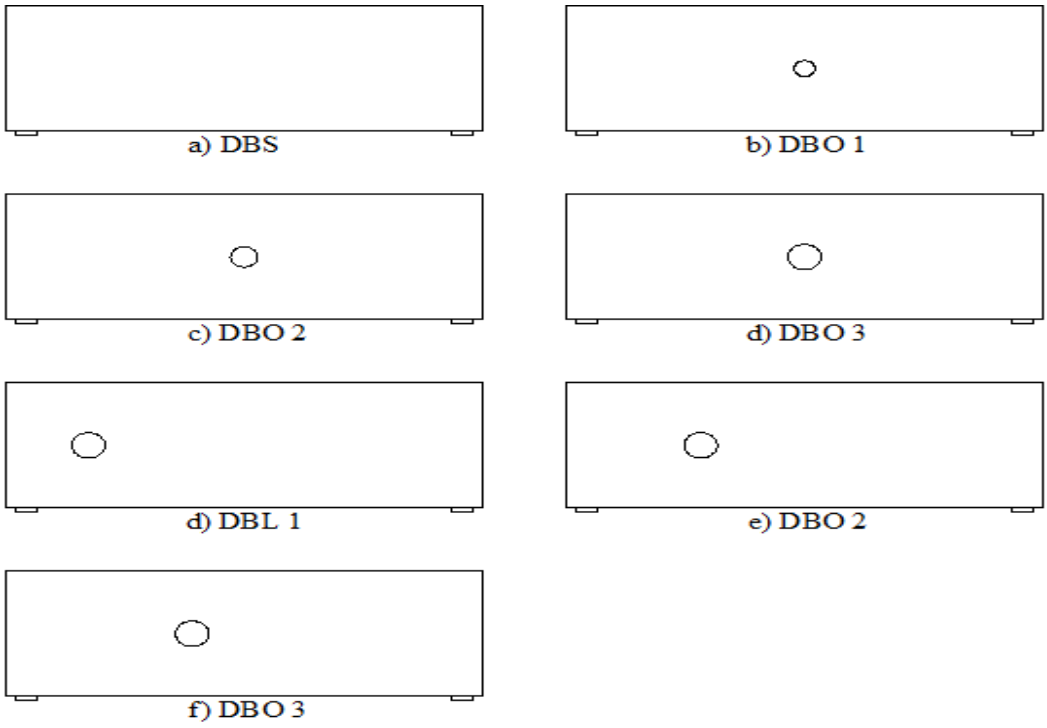

Figure 1.1: Models of the analysis

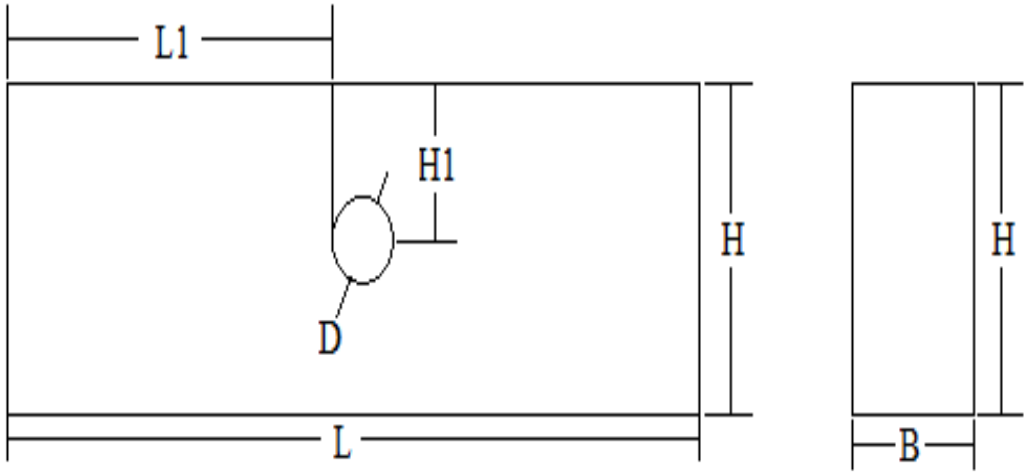

Figure 1.2: Location of the opening on the deep beam

Table 1.1: Dimension of the models and the detail of opening

BEAM	SIZE OF BEAM (B*H*L)	SIZE OF OPENING (D)	LOCATION OF OPENING	
			L1	H1
DBS	150x800x2300mm	-	-	-
DBO1	150x800x2300mm	100mm	1100mm	400mm
DBO2	150x800x2300mm	130mm	1085mm	400mm
DBO3	150x800x2300mm	160mm	1070mm	400mm
DBL1	150x800x2300mm	160mm	320mm	400mm
DBL2	150x800x2300mm	160mm	570mm	400mm
DBL3	150x800x2300mm	160mm	820mm	400mm

The tension longitudinal reinforcement used was 2H12mm and for the compressive longitudinal reinforcement was 2H10mm. The deep beam was reinforced vertically with shear reinforcements consisting of d8@200mm. The reinforcement bars configuration of the RC deep beam was shown in Figure 1.3. The section view of the reinforcement bars configuration also showed in the Figure 1.3.

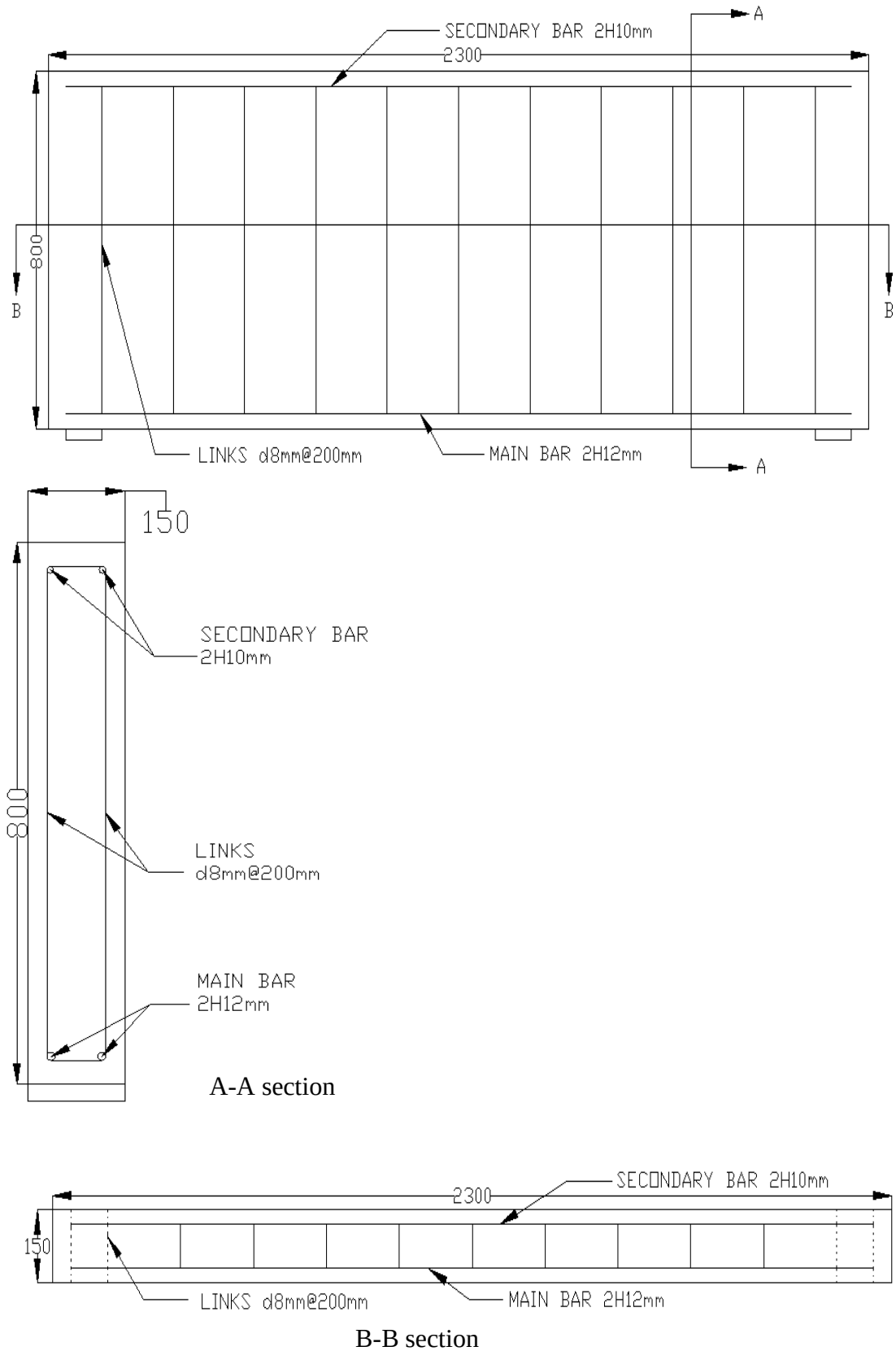

Figure 1.3: Reinforcement bars configuration and its section views

When the opening was located intersect with the shear reinforcement bars, the shear reinforcement bars was removed as shown in Figure 1.4. The red line showed the shear reinforcement bar that was intersecting with the opening.

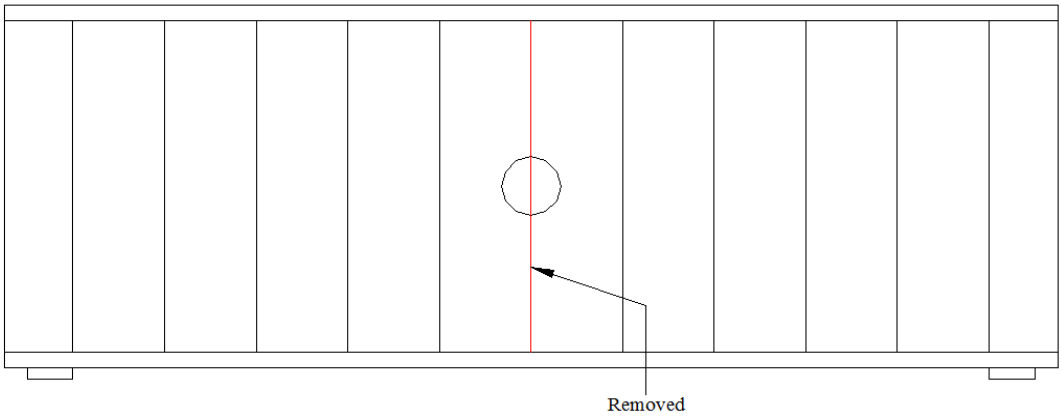

Figure 1.4: Reinforcement bar configuration when there is opening

This study was conducted by analyse the models by using the software called Civil FEM with ANSYS. To do the study on the flexure behaviour (deflection and the stress distribution) of the RC deep beam with web opening, the three-points bending test was conducted. The loading was put at the mid span of the deep beam. There are steel plates were placed at the supports. For the boundary condition for the deep beam model, the displacement was in the direction which is perpendicular to the plane is zero. For this study, one end was roller, while another end was fixed.

The input data for material properties of the concrete and the reinforcement bars in ANSYS were shown in the Table 1.2 and Table 1.3.

Table 1.2: Material properties of concrete in ANSYS

Material properties of concrete	
Elastic modulus, E_c	20,000 MPa
Poisson's ratio, v	0.2
Open shear transfer coefficient	0.5
Closed shear transfer coefficient	1
Uniaxial cracking stress	2.5MPa
Uniaxial crushing stress	25MPa

Table 1.3: Material properties of reinforcement bars in ANSYS

Material properties of reinforcement bars	
Elastic modulus, E_s	200,000 MPa
Yield stress, f_y	450 MPa
Poisson's ratio, v	0.3

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

A reinforced concrete deep beam is a common structural element used in high-rise building, off-shore structural and foundation structural. It is a load transferring structural component which is usually used to transferring a great amount of loads to supports.According to ACI 318, it stated that a beam with the clear span equal to or less than 4 times the overall member depth or a beam with concentrated loads within a distance equal to or less than two times the beam depth from the face of support is defined as deep beam.

2.2 ADVANTAGES OF DEEP BEAM

In construction of high rise building, a deep beam is used as transfer girder. By using deep beam, the number of columns below the deep beam can be reduced. This is because a deep beam has a higher ultimate load capacity compared to normal beam. It is a load transferring structural component which is usually used to transferring a great amount of loads to supports.

By using RC deep beam as the transfer girder, it can provide more space at lower floor. This is because of the high strength of the RC deep beam, it can carry higher loads from above, and thus the column below it can be removed. There will be more space below when the columns were removed.

2.3 APPLICATIONS OF DEEP BEAM

Reinforcement deep beams have many applications in buildings, bridges, offshore structures and foundations. Because of its high ultimate load capacity, it is commonly used in huge structural. In recent years, the deep beam is widely used in construction. Deep beams are usually used as transfer girder in high-rise building, pile caps, foundation wall as well as shear wall.

2.4 STRUT AND TIE METHOD

Strut and Tie method (STM) is a method used to design the reinforced concrete deep beam. By using this method the complex stress at the discontinuity region was simplified by theory in truss. Each uniaxial stress path is a member in STM. With this method, tension members are called tie, while compression members are called struts. The intersection points between struts and ties are called nodes. Ties are the location where reinforcement bars should be placed. The angle between the diagonal compression strut and the tension tie is limited to not less than 25 degree. Figure 2.1 showed the members in deep beam with STM.

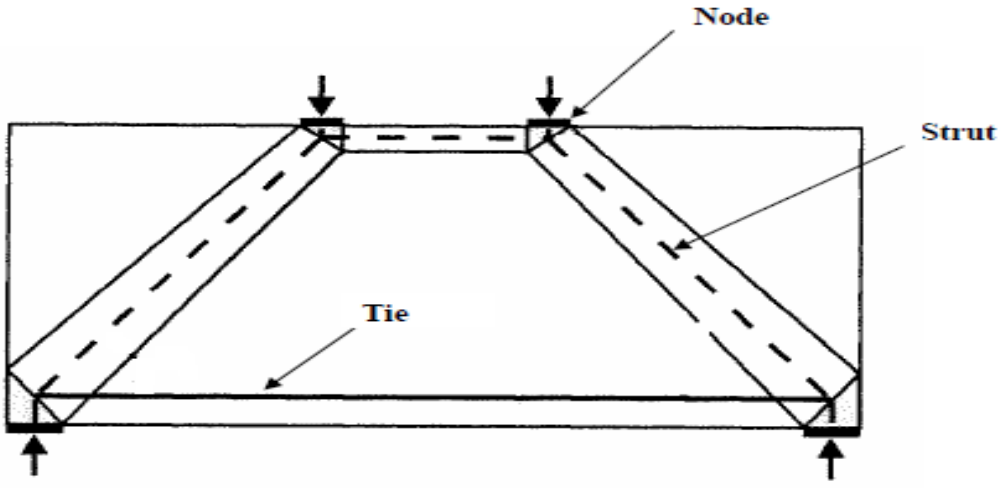

Figure 2.1: Members in Deep Beam with STM

Source: Barney 2007

Struts are compression members in a deep beam. According to study by J.Schlaich and K. Schlaich (1991), there are three types of struts which are bottle-shaped struts, prismatic struts, and compression fan struts. The different type of struts is caused by the force path in the deep beam. An illustration of the different geometric shapes of struts is shown in Figure 2.2.

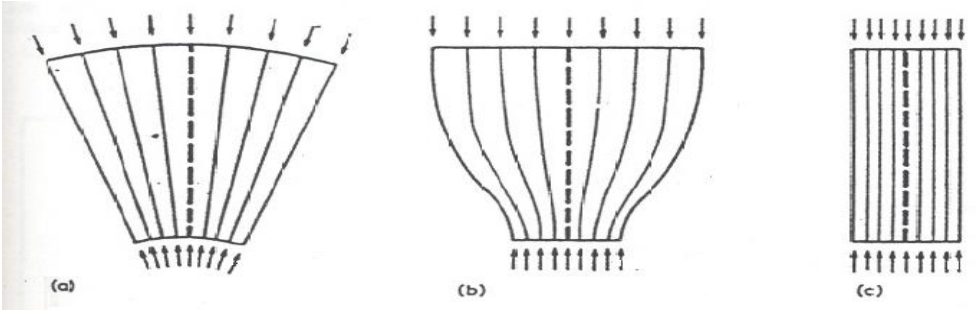

Figure 2.2: Geometric shapes of struts, (a) fan compression, (b) bottle shaped, (c) prismatic

Source: J.Schlaich and K. Schlaich 1991

"Structural behavior of RC deep beam with headed longitudinal reinforcements" by Soo (2004), this study showed that the STM Model was conservative and showed lowest standard deviation among several design methods in predicting shear strength of deep beam. Thus, it can conclude that the STM is a most desirable method for design of RC deep beam.

2.5 CODE PROVISION FOR STM

There are many reinforced concrete design codes including CSA A23.3, ACI 318 and Eurocode 2 accepted the STM after evaluating the model against experimental investigations.

2.5.1 CSA A23.3

According to CSA (2005), the STM is a suitable method to design deep flexural member. CSA A23.3-04 states that the deep flexural member is the flexural member with a clear span to overall depth ratio less than 2. The non-linear distribution of strains should be considered when design a deep flexural member.

The web reinforcement for deep flexural members should be not less than 0.2% of the gross concrete area in the horizontal and the vertical direction. There should be an orthogonal grid of reinforcement close to each face of the deep beam. This reinforcement should have spacing not more than 300mm in each direction.

2.5.2 ACI 318

The ACI 318 (2008) defined the deep beam as: (a) clear span equal to or less than four times the overall member depth; or (b) regions with concentrated loads within twice the member depth from the face of the support". According to ACI 318, the strength of the strut is depending on the geometry of the strut, and the presence of reinforcement bars and how they were distributed across the strut.

2.6 ANSYS MODELING AND ANALYSIS ON DEEP BEAM

ANSYS is software that can be used to solve variety problems. **ANSYS** is the most advanced, comprehensive and reputable finite element analysis and design software package available for civil engineering projects. The solid RC deep beam and the RC deep beam with opening are analyze by using the finite element model in ANSYS.

2.6.1 Concrete in ANSYS

"SOLID 65"in ANSYS is used for 3D modeling of the concrete with or without the reinforcement bars. It is used to model the concrete element. 8 nodes will be created, the nodes will be joining up by line and the volume will be defined as concrete. Each

node is having 3 degree of freedom. The concrete model is a solid concrete model without any rebar. “SOLID 65” is an element which is capable of cracking in tension and crushing in compression. Figure 2.3 showed the element with eight nodes.

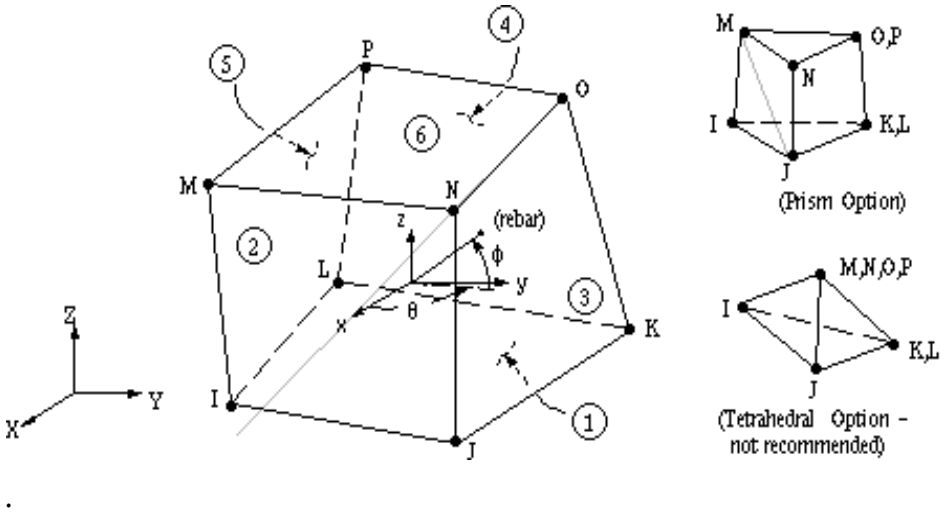

Figure 2.3: Geometry of SOLID 65

2.6.2 Steel Plate in ANSYS

“SOLID 185” in ANSYS was used to modeling the solid structures. In this study, it was used to define the steel plate of the model. In ANSYS modelling, the steel plates are used for the supports and loading. The purpose of steel plate is to distribute the stress evenly. The “SOLID 185” is defined as 8 nodes volume with 3 degree of freedom for each node. An illusion of element SOLID 185 is shown in Figure 2.4.

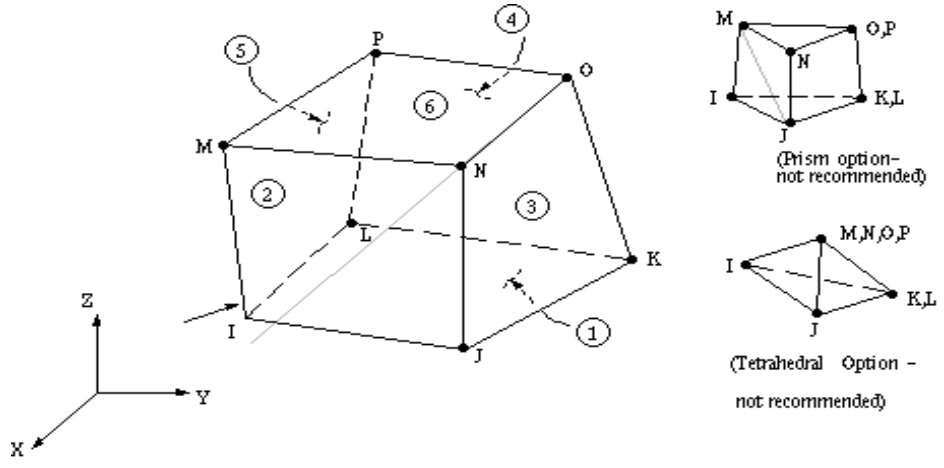

Figure 2.4: Geometry of SOLID 185

2.6.3 Reinforcement Bars in ANSYS

"LINK 180" is a spar which may be used in a variety of engineering applications. The reinforcement bar is defined by "LINK 180" in ANSYS CIVILFEM. The 3-D spar element is a uniaxial tension-compression element with three degrees of freedom at each node. The rebar and the concrete will automatic bonded perfectly when the node of rebar aligned with the node of concrete. Figure 2.5 showed the element, LINK 180, with two nodes.

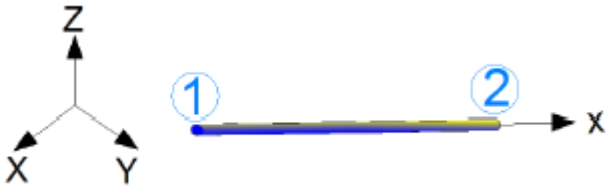

Figure 2.5: Geometry of LINK 180

2.7 EFFECT OF OPENING TO STRUCTURAL ELEMENT

Preetpal and Nasir (2014), an experiment was conducted to test the effects of static loading on RC beam with openings in the critical tensile zone. The concrete structural will reduce in strength when there is opening on it. This is because the load capacity reduces with the opening.

In the study made by Lee et al. (2008), there are total 5 deep beams with the circular web opening have been tested to evaluate the shear strength with the various location of web opening. They found that the deep beam with opening will has a steeper slope for the load-deflection curve when compared with the solid deep beam.

In the study conducted by Asraf et al (2014), there are three parts. One is three points test, and another one is four points test. The third is the test for continuous deep beam. The parameter of this study is the loading scheme, the location of web openings and the reinforcement distribution. There is about 35% reduction in load capacity of the

deep beam when the web opening located crossing the compression struts between the load and the support.

From the study done by Heather (2010), a doubly reinforced concrete beam with a circular opening at mid-span was modelled and analysis by using ANSYS. The main objective is to determine the stress distribution around the circular opening. The stress concentrates at the top and bottom of the circular opening before the deep beam cracks. The flexural cracks form at the bottom of the opening because of the stress concentration.

2.8 EEFECT OF THE SHAPE OF THE OPENING

A study made by Soroush and Reza (2011), the research is study on the effect of circular opening size on the behaviour of beam. The beam models were created with circular opening and equivalent square opening. From the result, they found that the beam with circular opening will has higher strength in ultimate load capacity when compared with the beam with equivalent square opening.

According to research done by Haider (2013), the effect of the opening shape on the structural behaviour of the reinforced concrete deep beam with openings has been investigated. The result of the research showed that the best shape to be made for the web opening is the narrow rectangular. It can save up 40% of structural strength of the deep beam. But in real case, the rectangular shape is not suitable.

2.9 EFFECT OF THE LOCATION OF THE OPENING

The study “effect of opening sizes and locations on the shear strength behaviour of RC deep beams without web reinforcement” has been done by HawrazKarim el at (2013). The results showed that the opening at shear zone will has a larger effect, while the opening at the mid-span will has small effect to the shear strength.

“Design of concrete deep beams with openings and carbon fibre laminate repair”, by Son (2002), in this research, there are 12 concrete deep beams with and

without openings were designed and then tested to validate the effectiveness of the design method. In the results obtained, the results showed that when the opening located at the place that did not interrupt the natural load path of the beam, the beam will behave like a solid deep beam.

According to the study done by Ashraf at el (2014), "prediction of the behaviour of reinforced concrete deep beams with web openings using the finite element method", the results of this study showed that when the opening was placed at the location where crossing the expected compression struts developed between the load and the supports, the beam's capacity was reduced more when compare the opening located at the place where it does not interfere with the load path.

2.10 FAILURE MODE OF BEAM

The concrete structures may be subjected to various loading during its service life. The cracks caused by loadings will affect the structural behaviour of the structural element.

2.10.1 Beam-Type Failure

In this type of failure mode, the failure plane is 45^{o}inclined. The failure plane is being cross the centre of the opening. It may be seen that the stirrups available to resist shear across the failure plane are those by the sides of the opening. An illusion of the beam-type failure is shown in Figure 2.6.

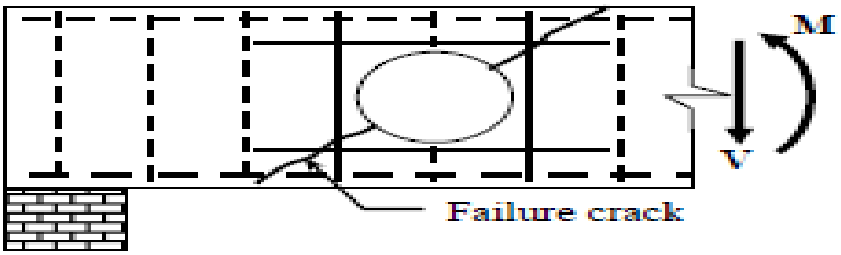

Figure 2.6: Beam-type failure

Source: Mansur 1998

2.10.2 Frame-Type Failure

In the frame-type failure, there 2 independent diagonal cracks formed, one above the opening and the another one below the opening. It seems that each member behaves independently similar to the members in a framed structure. An illusion of the frame-type failure is shown in Figure 2.7.

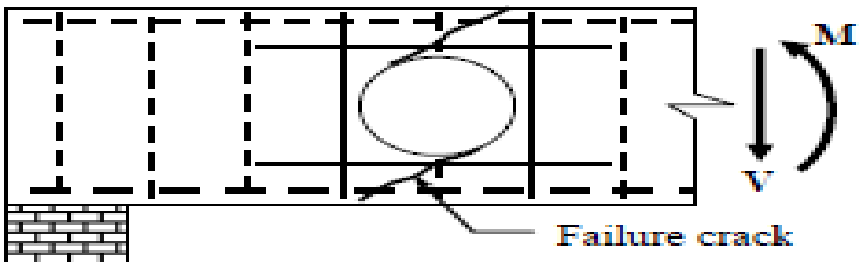

Figure 2.7: Frame-type failure

Source: Mansur 1998

2.11 TYPES OF CRACK

It was expected that the cracks will develop in a RC structural element under service loads. The cracks will develop once the stresses exceeding the tensile strength of the concrete. There were two types of crack usually are considered, flexural cracks and shrinkage cracks.

2.11.1 Flexural Cracks

A study done by Nicholas and James (1995), "Prediction of Cracking in Reinforced Concretes", the findings of this study showed that when the RC beam was subjected to bending moments, if the stresses in the tension zone was exceed the bending strength of the concrete, the flexural cracks will be develop. This kind of cracks will propagate from the tension face to the location of the neutral axis of the cross section.

There are two important factors affecting the crack width are the magnitude of the tensile strain in the reinforcement bars and the concrete cover over the reinforcement bars, size of bars, and the distribution of the steel in the tensile zone of a concrete structural element.

2.11.2 Shrinkage Cracks

According to Nicholas and James (1995), the drying and thermal contraction of concrete will caused shrinkage cracks. Restraint to shrinkage makes tensile stresses that caused the development of the cracks if the stresses exceed the tensile strength of the concrete. The simultaneous process of the shrinkage, creep, and stress relaxation was give effect to the induction of the stresses. Shrinkage cracks can be serious because it can extend through the full depth of the concrete element.

It was hard to predict the induced tensile stresses due to the restrained shrinkage because the potential drying shrinkage of the concrete element is depend on the geometry, composition of the concrete, curing period, and the ambient relative humidity.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

To do the analysis, the ANSYS was used. In industrial, ANSYS is widely used to do the engineering simulation work. There are 3 main parts in the process of analysis, which are preprocessor, solution, and general postprocessor. The three parts are including the process of modelling, analysis, and result data collect.

Preprocessor is the process of modelling. In this stage, the elements were chosen and the materials' properties were set. Every element had their different materials' properties. In this study, the elements used were "SOLID 65", "SOLID 185", and "LINK 180". The model consists of concrete, reinforcement steel bars, and steel plate.

Solution is the stage that the analysis was conducted. Before the analysis start, there are some parameters need to be considered. The boundary condition for the RC deep beam was set during this stage. Other than the boundary condition, the loading had to be set. In this study, for the analysis of a model, there are different loading. The loading is a manipulating data.

After the analysis was conducted, the next stage was the general postprocessor. This was the stage to collect the result data. In this study, there are two results were considered, which are the deflection and the crack pattern of the model. In ANSYS, the deflection can be obtained from the "deformed shape" of the model, while the crack pattern can be obtained from the "concrete plot".

3.2 FLOW CHART OF THE METHODOLOGY

Figure 3.1 showed the flow chart of the methodology.

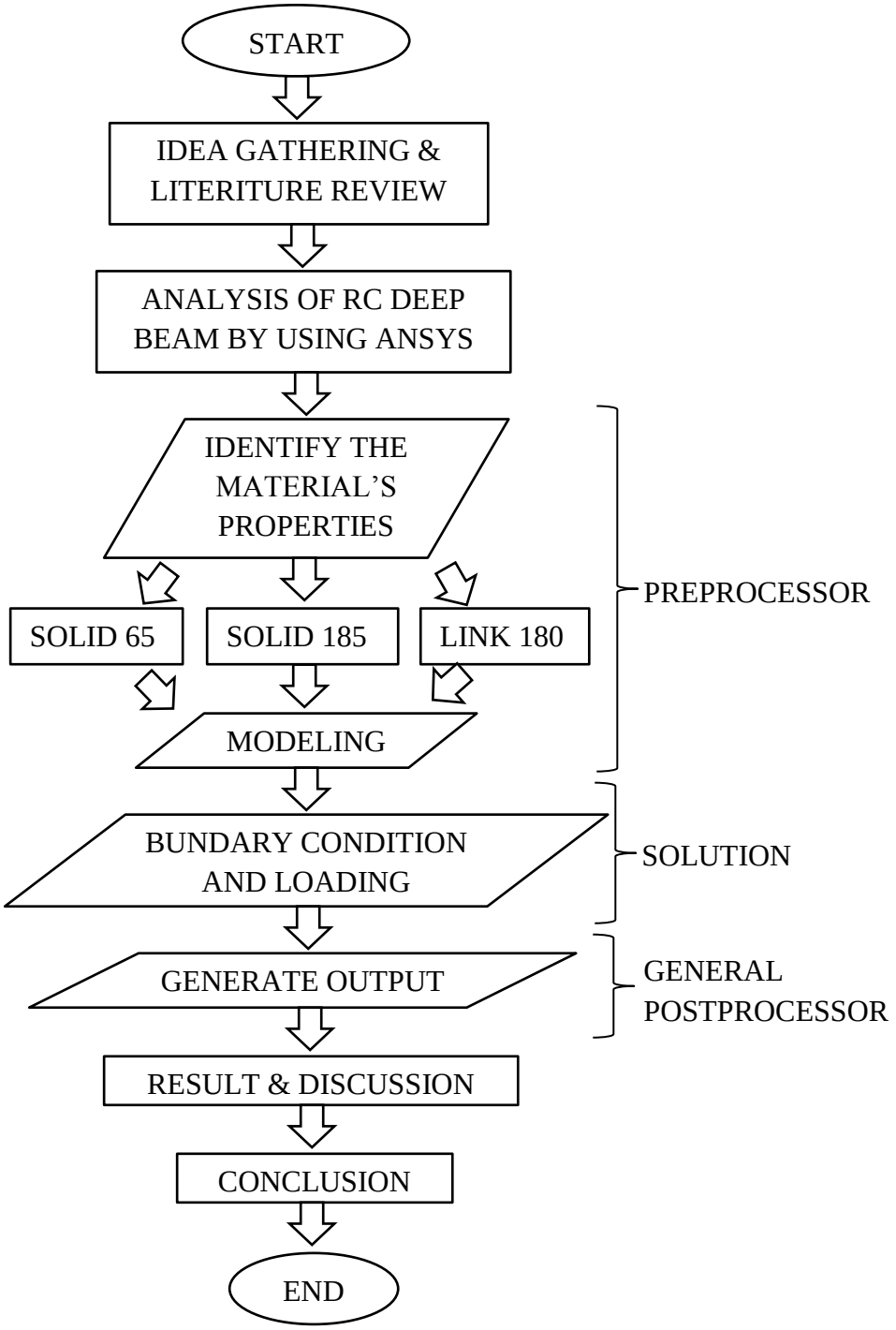

Figure 3.1: Flow chart of the methodology

3.3 PREPROCESSOR

In preprocessor, the model was created. To create the model, the elements and materials of the model was defined. Figure 3.2 showed the table for adding element types.

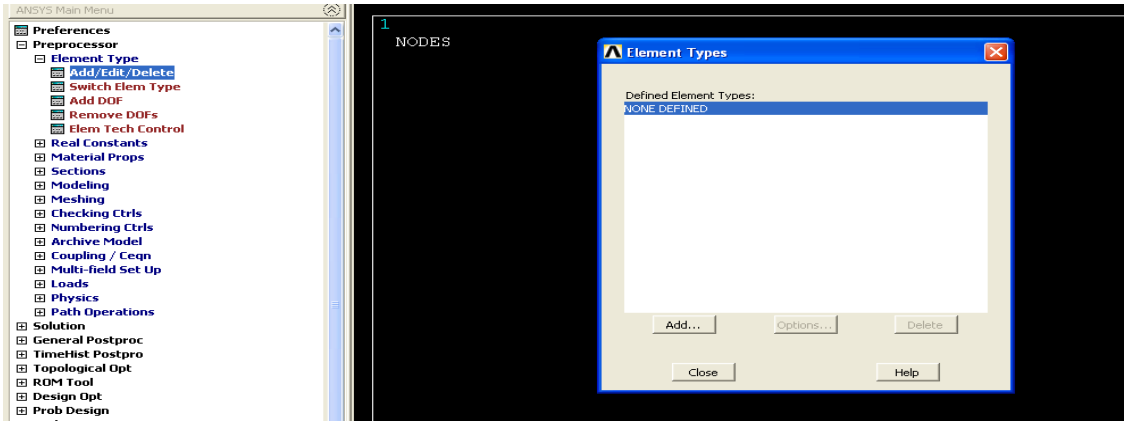

Figure 3.2: Window of add elements

Element Type in preprocessor is used to define the element of the model. In ANSYS, there are more than 100 types of elements in the library. In this analysis, the elements used were “SOLID 65”, “LINK 180”, and “SOLID 185”. “SOLID 65” was used to define the concrete, “LINK 180” was used to define steel reinforcement bars, and “SOLID 185” was used to define the steel plate which attached to the reinforced concrete deep beam.

The real constant is used to define the properties of the element. In real constant setting, the area of the reinforcement bars was set. For example as showed in Figure 3.3–Figure 3.5, the cross sectional area of “LINK 180” was set. In this analysis, the steel reinforcement bar sizes were 12mm, 10mm, and 8mm.

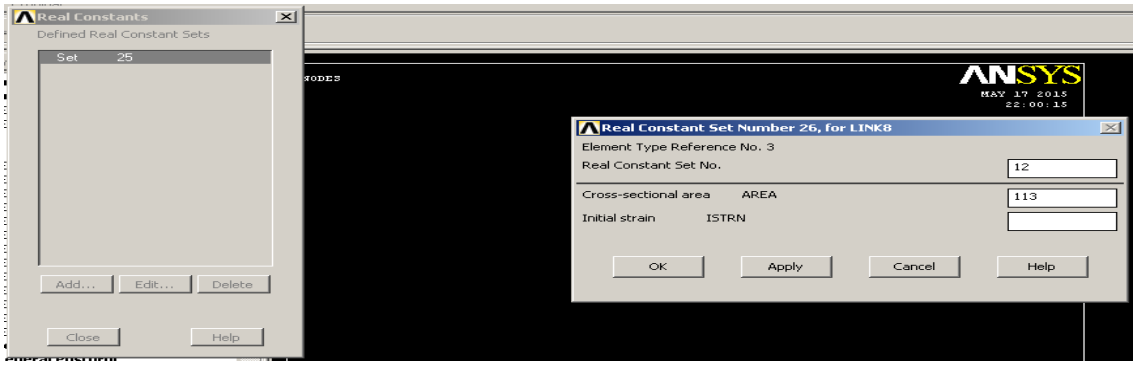

Figure 3.3: Real constant for steel reinforcement bar with diameter 12mm

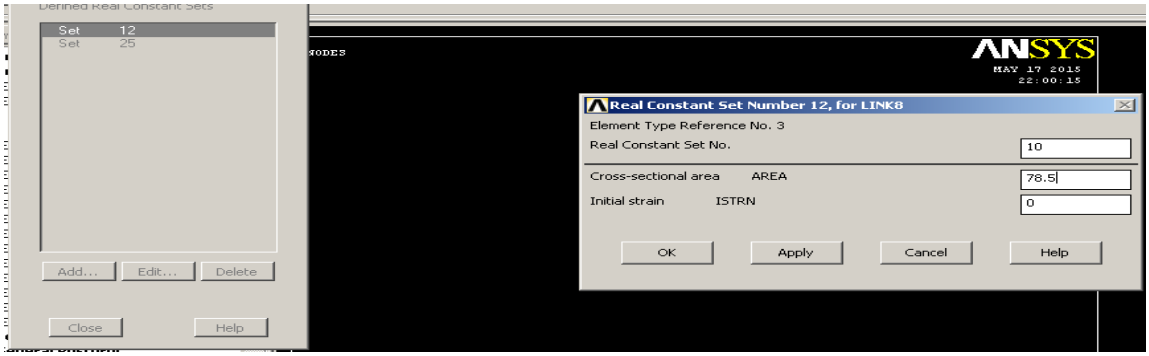

Figure 3.4: Real constant for steel reinforcement bar with diameter 10mm

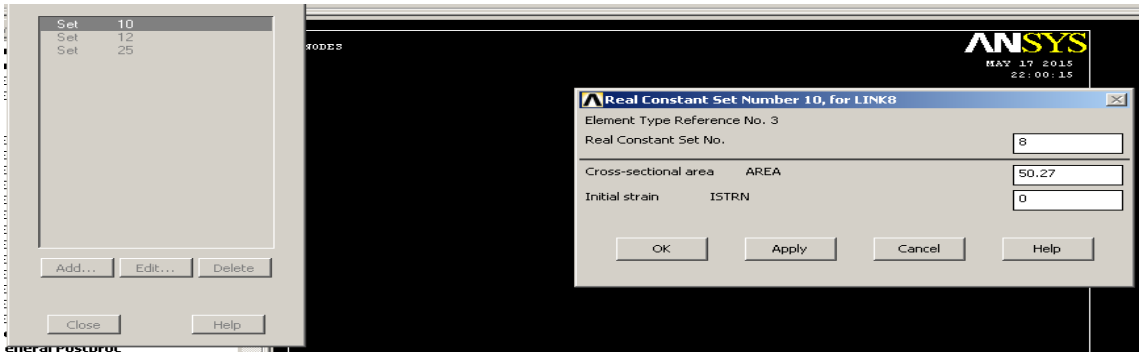

Figure 3.5: Real constant for steel reinforcement bar with diameter 8mm

Figure 3.6 showed the window of material models. The material properties were defined in this step. The material properties were set for the elements of the model. Different elements have different properties. In this analysis, the properties set were including the linear or nonlinear and isotropic.

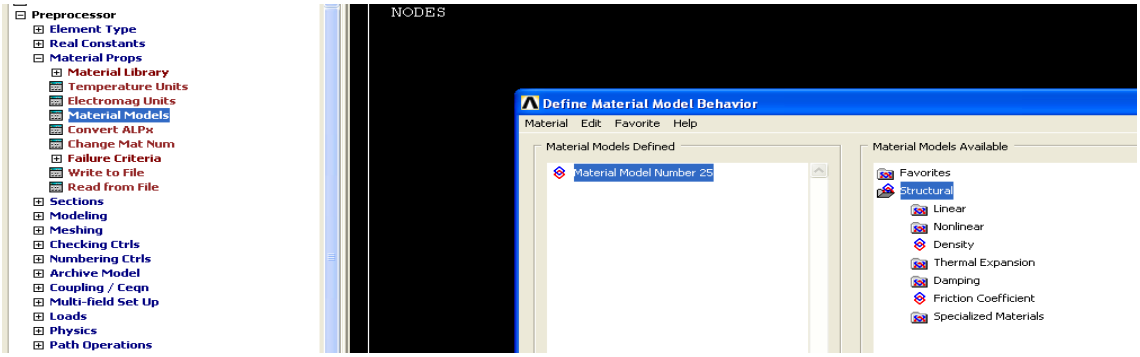

Figure 3.6: Window of material models

Figure 3.7 and Figure 3.8 were showed the window of create block and cylinder respectively. The block created in this analysis was a deep beam with dimension of 2300mm x 800mm x 150mm. There are two blocks with dimension of 100mm x 25mm x 150mm were created as steel plates which were placed at the bottom of the deep beam. A solid cylinder was created on the deep beam for the purpose of circular opening.

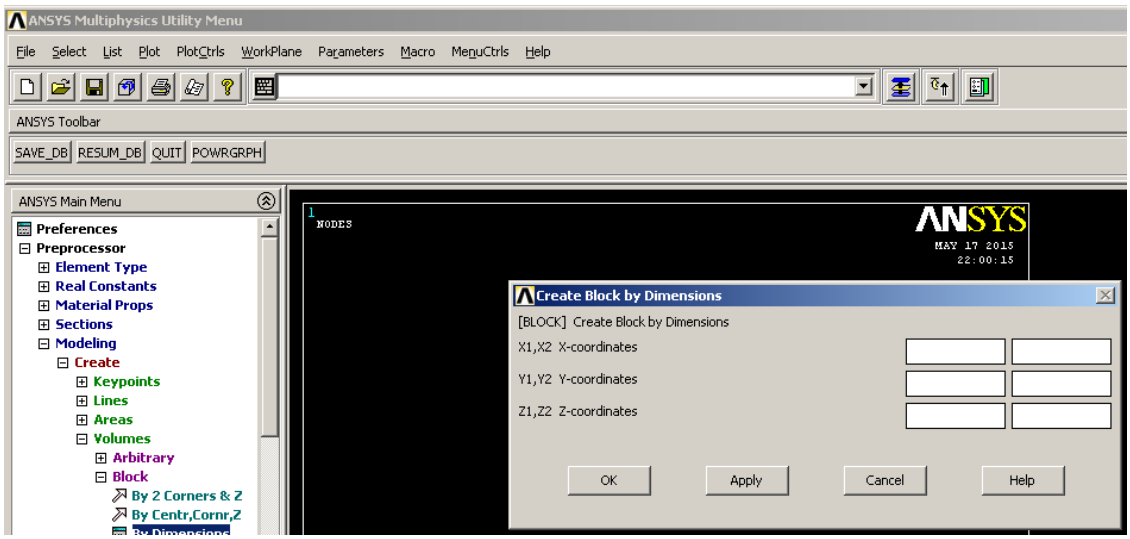

Figure 3.7: Window create block by dimensions

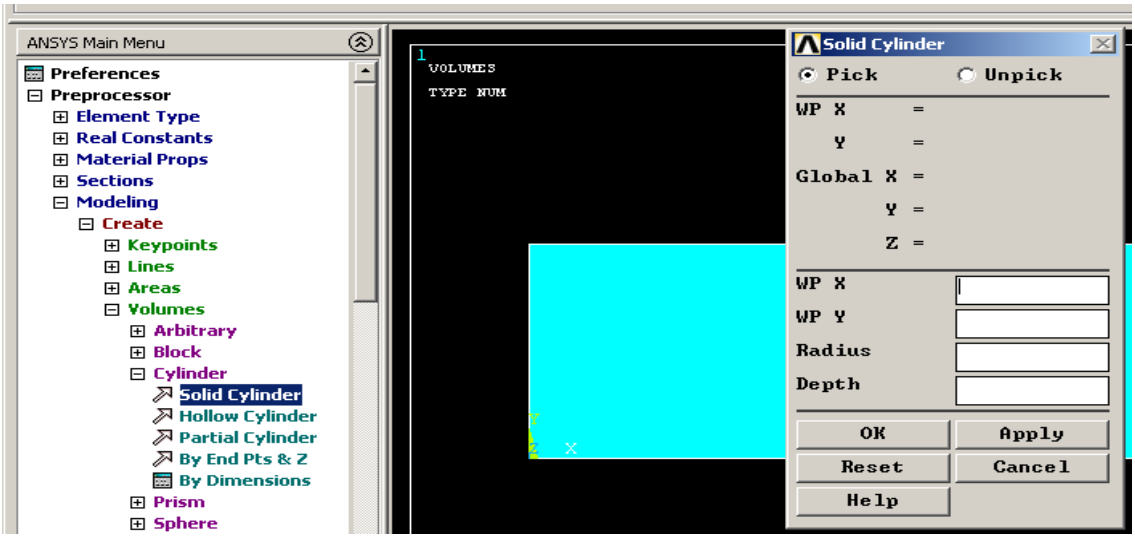

Figure 3.8: Window of create solid cylinder

Figure 3.9 showed the step for create opening on the beam. The opening was created by using "Subtract" in "Booleans". To created opening, the whole beam was selected first and then only the solid cylinder was selected.

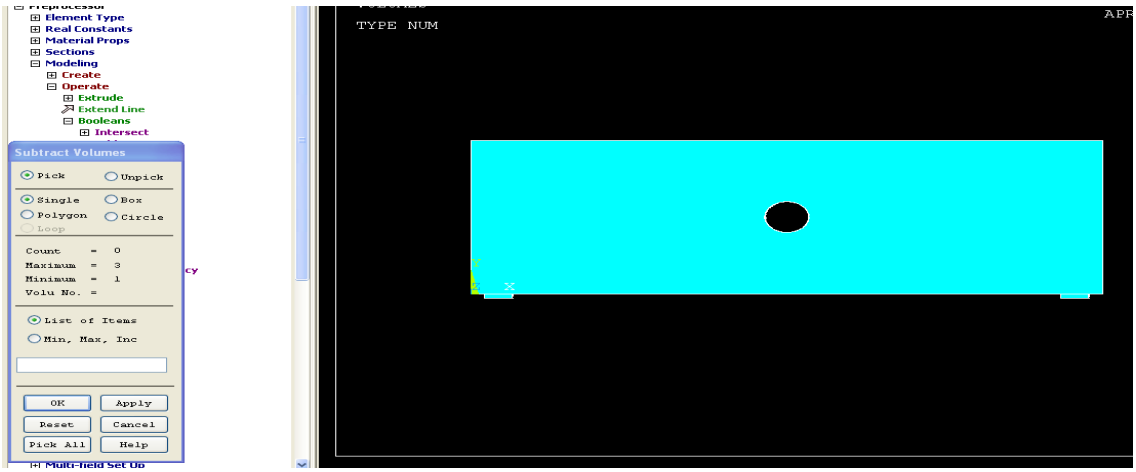

Figure 3.9: Window of subtract volumes

Figure 3.10 showed the window of Copy Area. In this window, the numbers of copy and the distance of offset were set. There are many ways to locate the steel reinforcement bars. In this analysis, the "define lines as elements" method was used. To

follow this method, the lines were created by copy areas. The areas were copy to the location of the steel reinforcement bars.

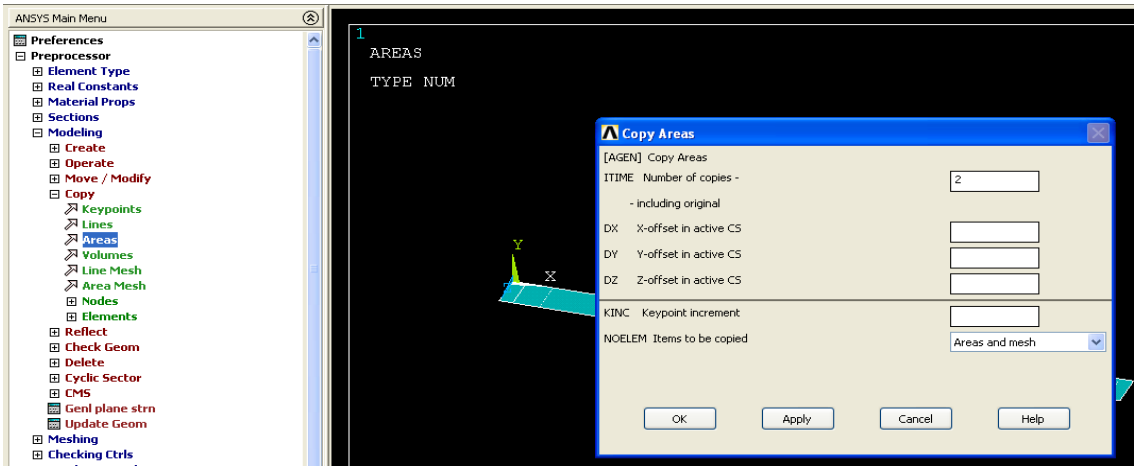

Figure 3.10: Window of copy areas

Figure 3.11 showed the window for divide the volume by the areas created in previous step. After the areas were copied, there are many unwanted excess areas. By dividing the volume by areas, all the unwanted excess areas will be trimmed.

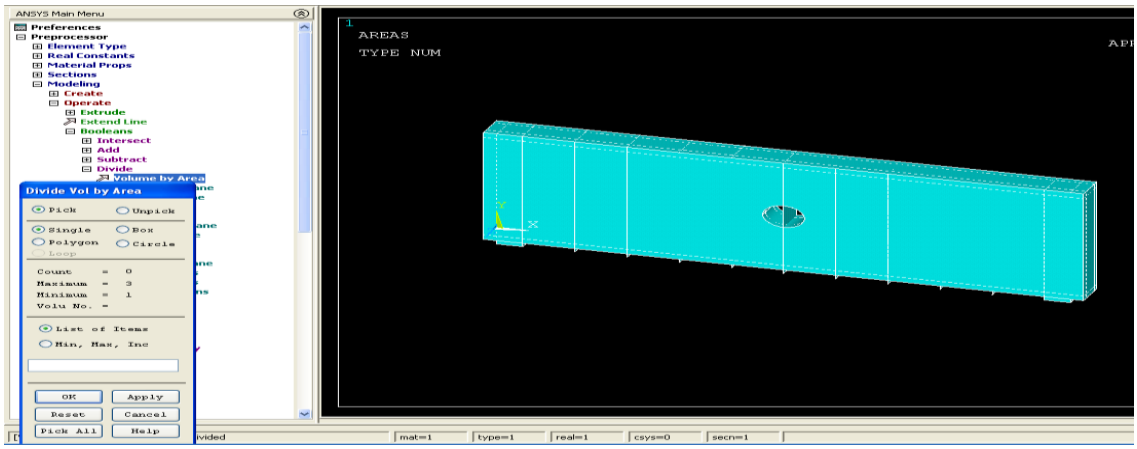

Figure 3.11: Window of divide volumes by area

The numbering of the elements, nodes, lines, volumes, and others entities that were created are coincident after the copy and divide step. Therefore, the numbering of these entities had to be merged. Figure 3.12 showed the step to merge all the coincident

items. By “merge items”, all the separated entities with the same location were merged together into a single entity, and the nodes with higher numbering were deleted.

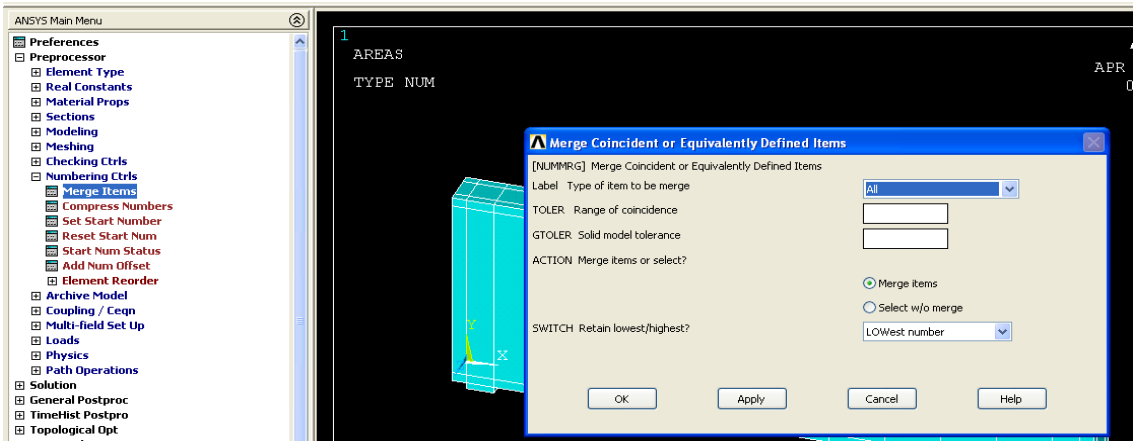

Figure 3.12: Window of merge item

Before placed the steel reinforcement bars, the lines at the desired location of the steel reinforcement bars were selected. The selected lines were created as a compartment. As shown in Figure 3.13, the lines selected were created as a compartment with name of “main bar”. There were other compartments were created and named as “secondary bar” and “links”. There compartments (lines) will be used in the next step which is “meshing”.

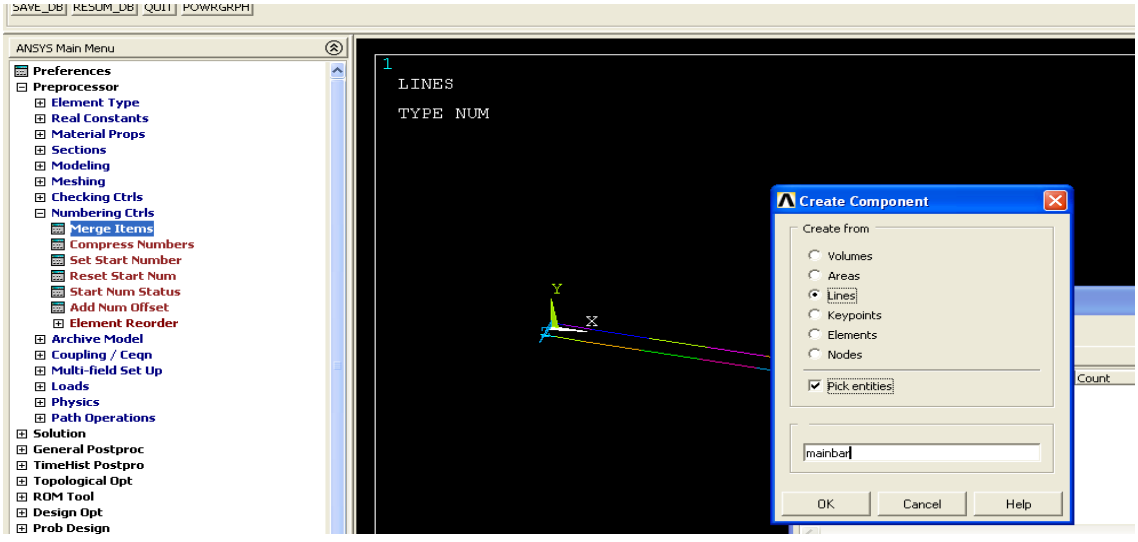

Figure 3.13: Window of select entities for lines

All the blocks and the selected lines were defined with the elements. Figure 3.14 showed the window of setting of the mesh. As shown in Figure 3.14, the [TYPE] is the element types (SOLID 65, SOLID 185, and LINK 180) which were selected at starting of the preprocessor. The [MAT] and [REAL] are the material models and the real constants respectively. In this analysis, the concrete deep beam was defined by "SOLID 65", the steel plate was defined by "SOLID 185" and the steel reinforcement bars were defined by "LINK 180". For the steel reinforcement bars, there are three different sizes, main bars with 12mm diameter, secondary bar with 10mm diameter, and links with 8mm diameter.

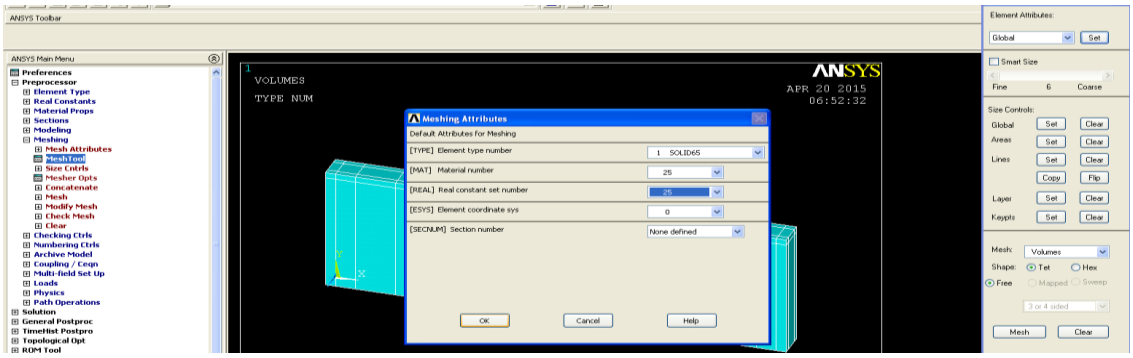

Figure 3.14: Window of meshing

Figure 3.15 showed the model after meshed. After meshing, the model was divided into small tiny elements. The larger the number of the elements, the higher the precision of the analysis result. But the analysis will take longer time if the number of elements is larger. After meshed the model, the modelling process was considered done.

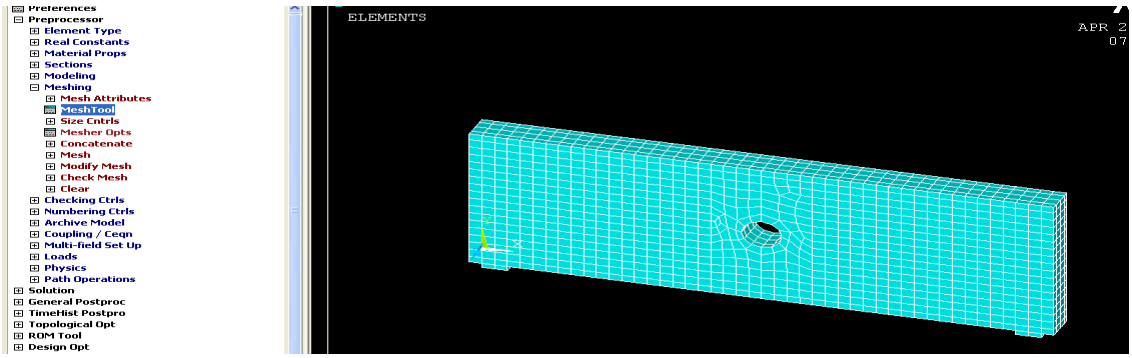

Figure 3.15: Meshed model

3.4 BOUNDARY CONDITION AND LOADING

In this section, the boundary condition for the model was set and the load was applied. The boundary condition was set after the modelling done. Figure 3.16 showed the window of setting for the boundary condition. To set the boundary condition, the nodes at the support which is at the steel plate were selected and applied with displacement (DOF's to be constrained).

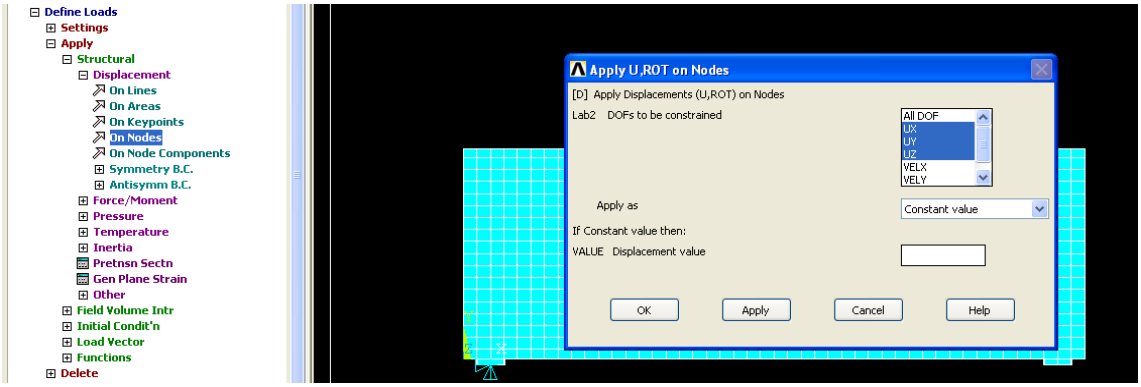

Figure 3.16: Window of apply displacements on nodes

For the fixed support, the UX, UY, UZ were constrained, while for the another support which is roller support, only the UY was constrained. Figure 3.17 is an illustration of the model with boundary condition fixed and pinned.

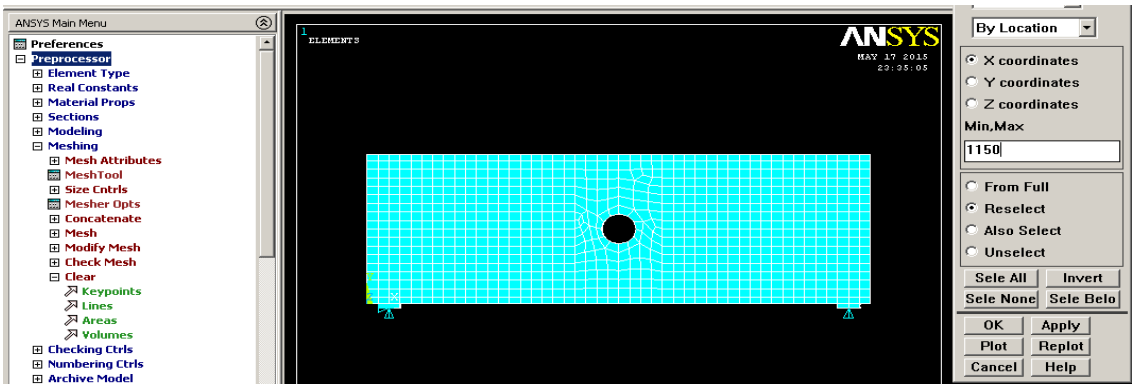

Figure 3.17: Boundary condition of fixed and pinned support

In the model, there are some special features that cannot be suite with the elements. Therefore, by using “Coupling / Ceqn”, the degrees of freedom in ways that elements can be suited. In this analysis, the loading was located at the mid span of the deep beam. The area at the mid span was selected and the coupled DOF was defined. The “NSET” was set to 1, while the “Lab” was set to UY as shown in Figure 3.18.

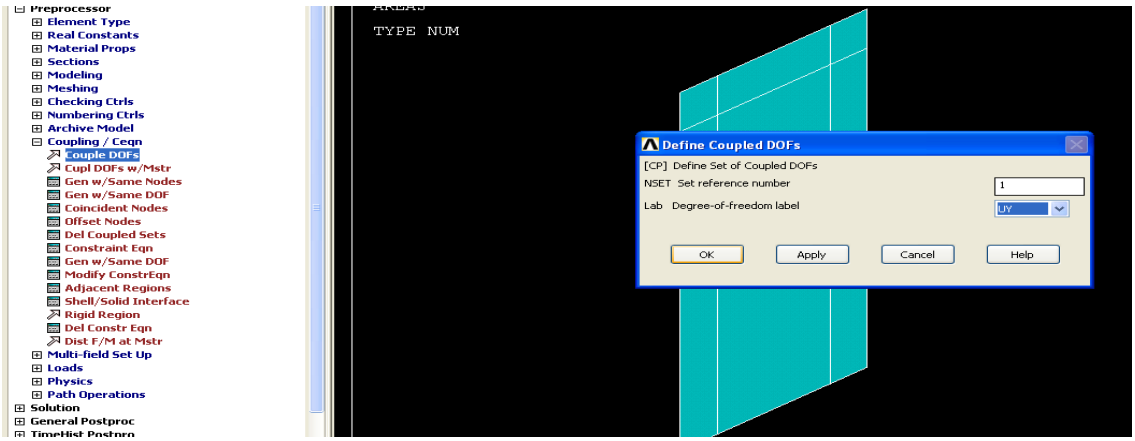

Figure 3.18: Window of define coupled DOF’s

There were many green lines occurred on the selected area. The load was applied at the node which is the node that joined all the green lines as shown in Figure 3.19. The direction of the force was set as” FY” which is in the direction of Y-axis, and the force value was set as negative value which is downward.

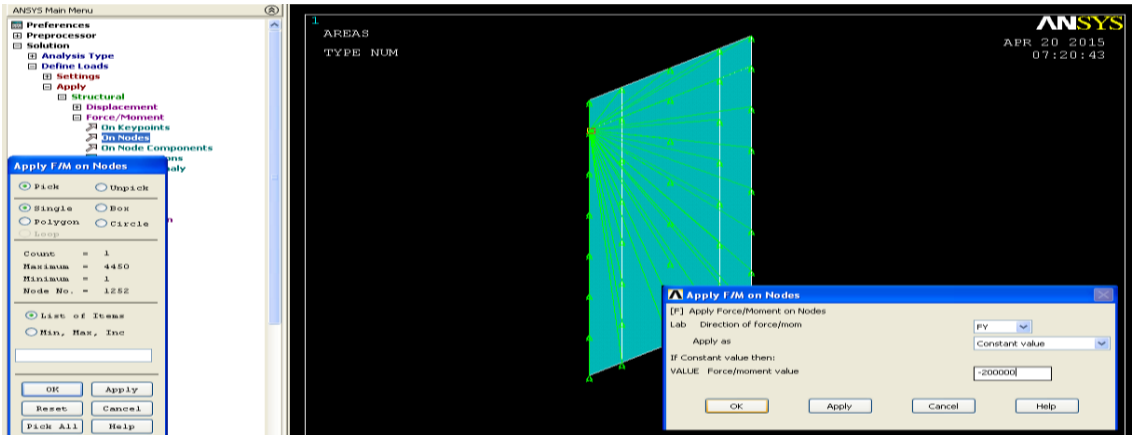

Figure 3.19: Window of apply force on node

There were many tabs in the window of the "Solution control", such as "basic", "sol'n control", "nonlinear", and "advanced NIL". Figure 3.20-Figure 3.23 showed the tabs in the solution control. There are several setting that needed to be take in account when conduct the analysis. It is depend on how the analysis being conduct. In this section, the number of iterations and substeps were set. The number of set of data was also depending on the setting in the section.

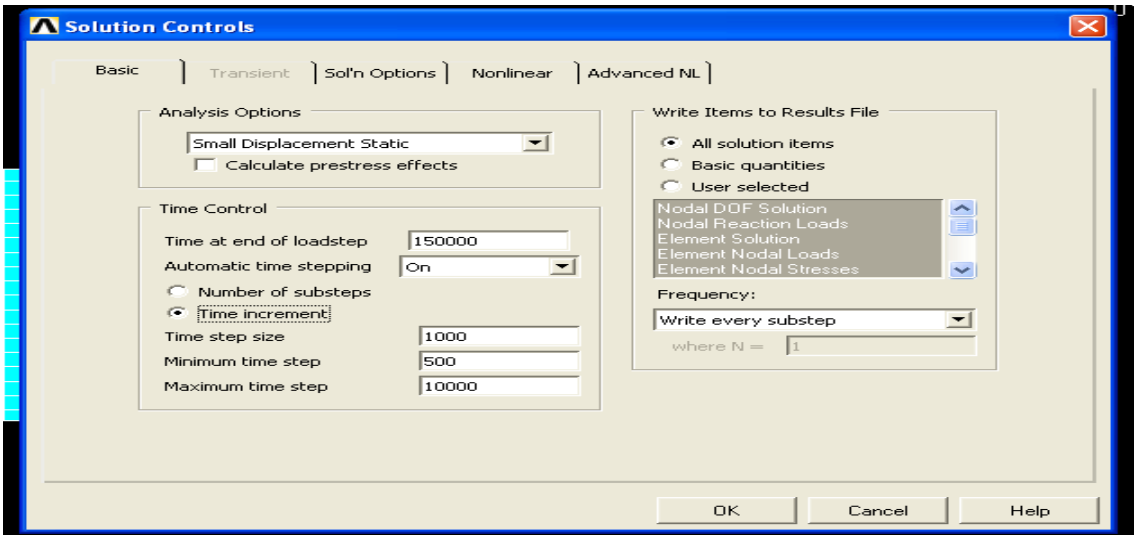

Figure 3.20: Tab of "Basic"

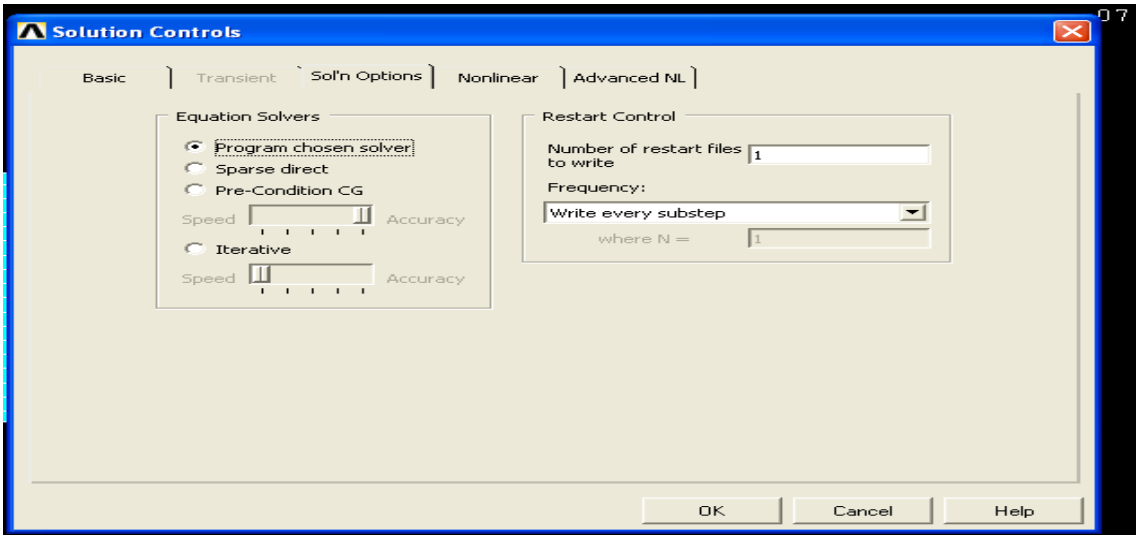

Figure 3.21: Tab of "Sol'n options"

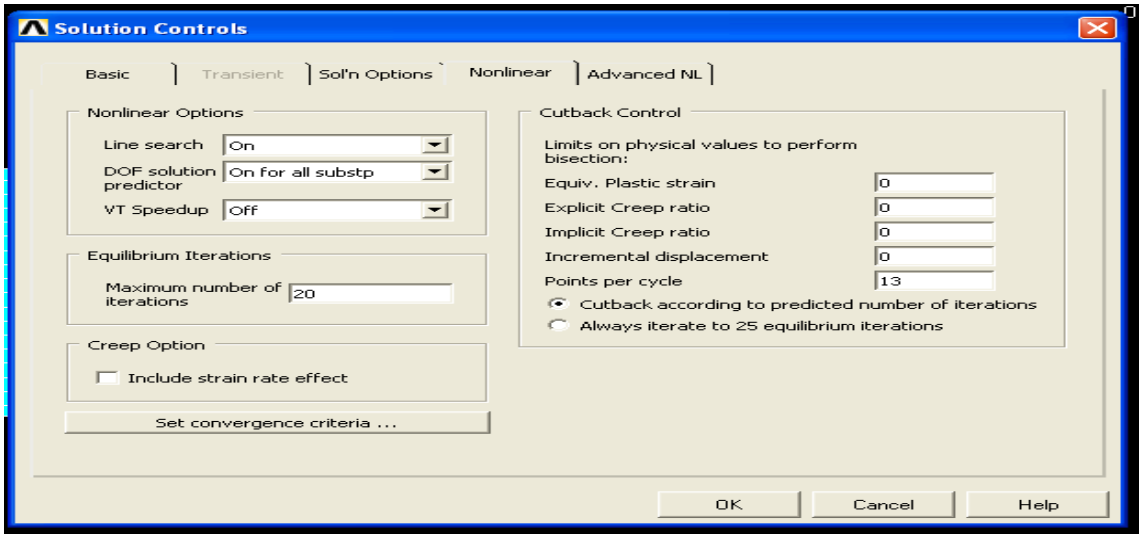

Figure 3.22: Tab of "Nonlinear"

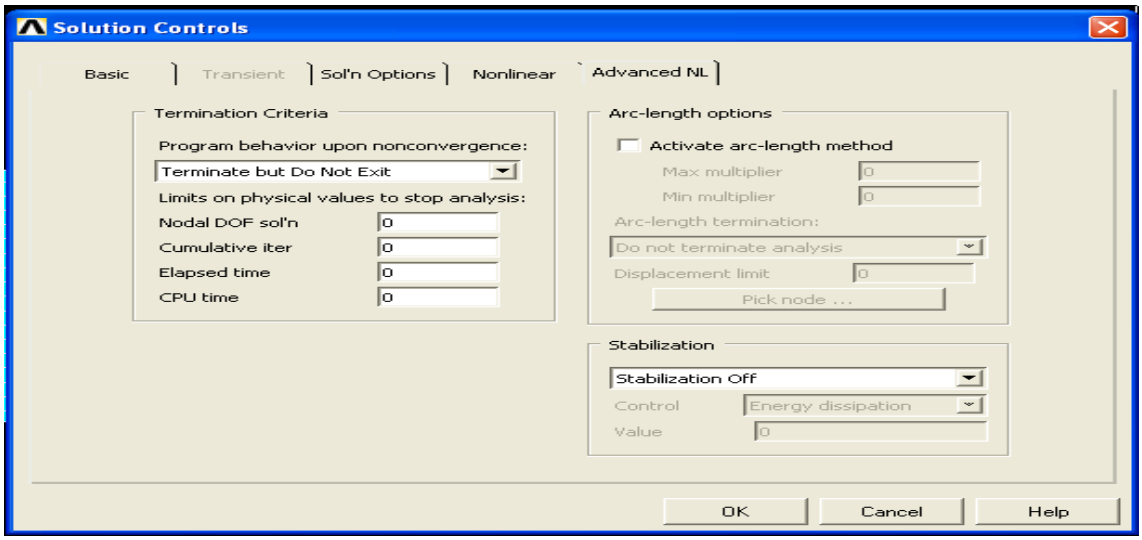

Figure 3.23: Tab of "Advanced Nil"

3.5 GENERAL PREPROCESSOR

This section is the last section for the whole analysis. After the analysis was done, continue with this section to collect the result data of the analysis. After the solution was done, the next step was read result. To read the result data, the result for the entire model at the last sub-step number was chosen. Figure 3.24 showed the window for choose the result to read.

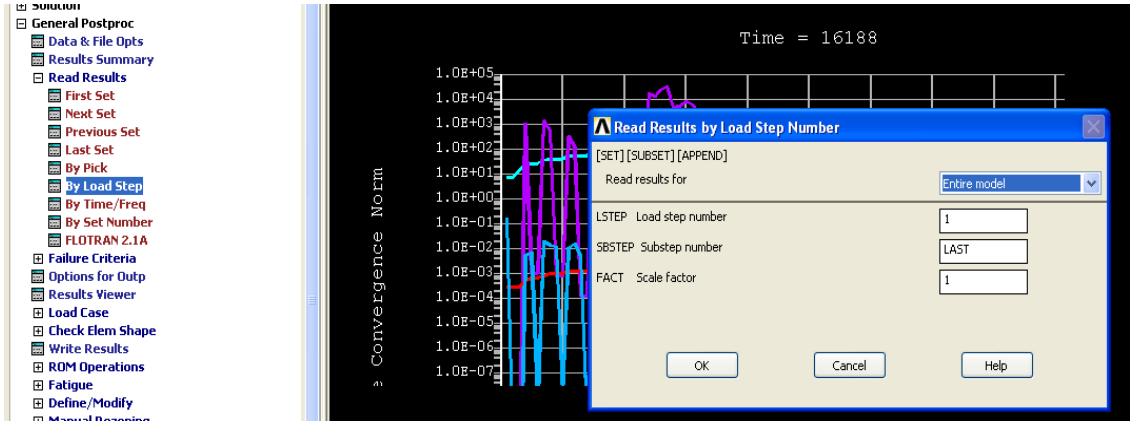

Figure 3.24: Window of read results by load step

The crack pattern of the concrete deep beam was viewed in this section. To view the crack pattern, the "crack/crush" in the "plot results" was selected. And then there is a window as shown in the Figure 3.25 will pop out.

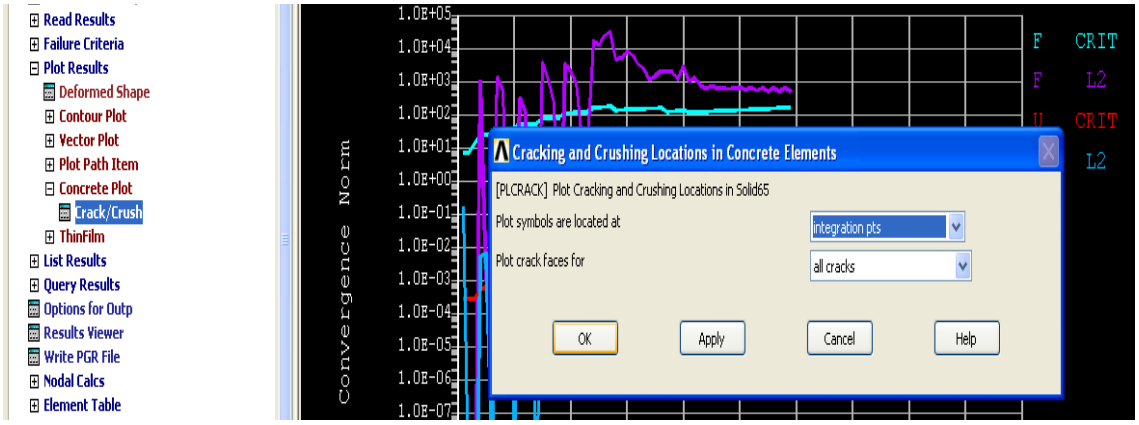

Figure 3.25: Window of cracking and crushing location in concrete elements

The crack pattern can be view in three stages; first crack, second crack, and third crack. In the diagram of the crack pattern, there are many colours. The red colour defined the first crack; the green colour defined the second crack, while the blue colour defined the third crack. Figure 3.26 is an illustration of the crack pattern obtained from ANSYS.

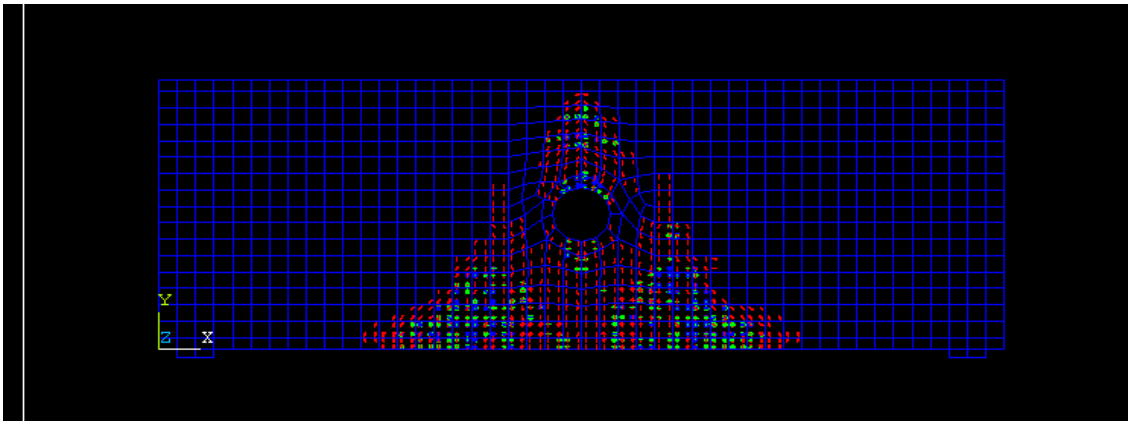

Figure 3.26: Sample of crack pattern

The deflection of the model was showed in the "deformed shape" under the "plot results". In the window as shown in Figure 3.27, there are options can be chose. Figure 3.27 showed the window of plot deformed shape. In this analysis, the "def shape only" was chosen.

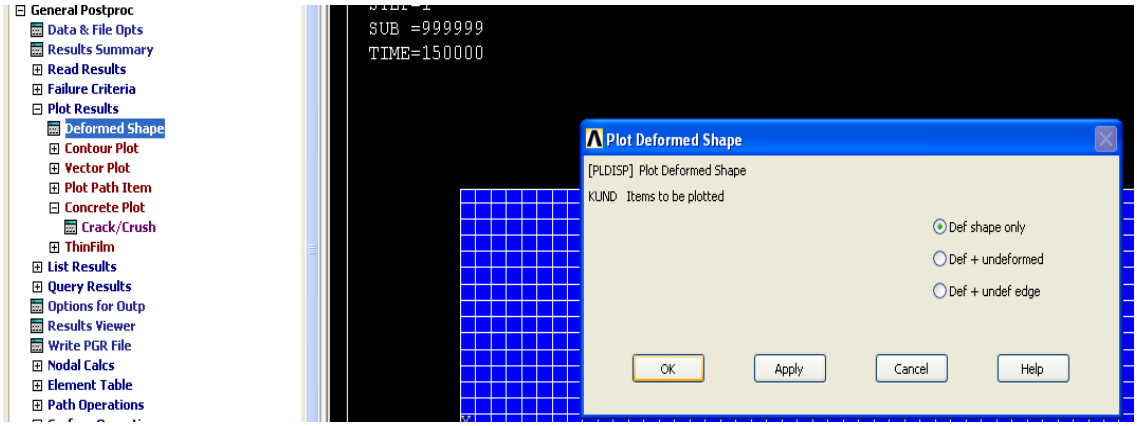

Figure 3.27: Window of plot deformed shape

In the deformed shape, it show that the sharp of the deep beam after deformed. The value of the maximum deflection was showed. Figure 3.28 showed the diagram of the deformed shape of the deep beam. The "DMX" value indicated the value of maximum deflection.

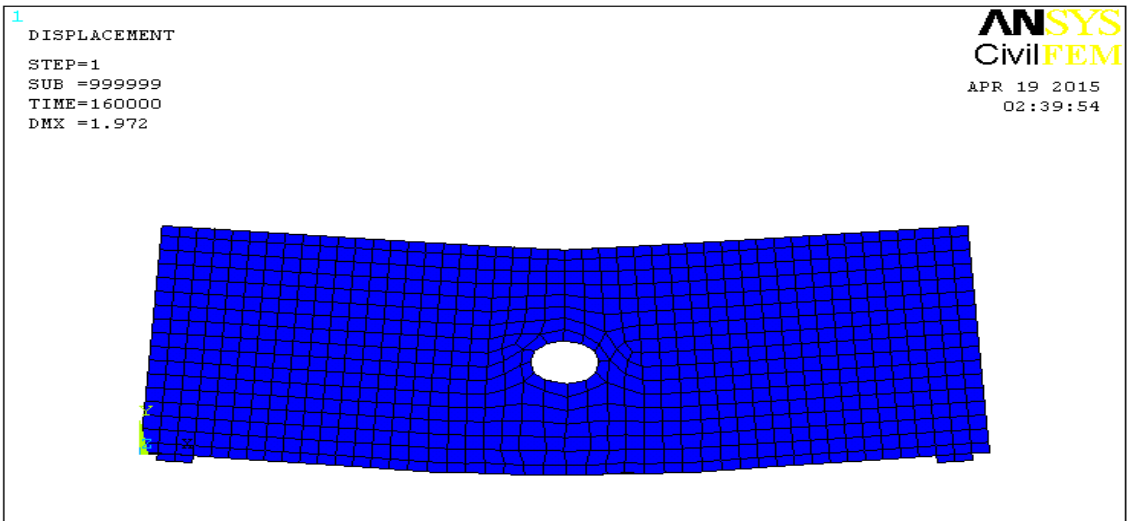

Figure 3.28: Deformed shape of the deep beam

CHAPTER 4

RESULTS AND DISCUSIONS

4.1 GENERAL

The analysis was conducted by using the software ANSYS 12.0. For each analysis, the load was applied from 4kN to 20kN, with the increment of 4kN. The diagram of the crack pattern and deformed shape were obtained from the result of the analysis. From the diagram of the crack pattern, the cracks were labelled with “first crack”, “second crack”, and “third crack”. These labels are made according to their order of occurrences. The crack in red color showed the first crack, green color showed the second crack, while the blue color showed the third crack. In the diagram of deformed shape, the deflection value was obtained. There is a DMX value which is the maximum deflection value for the model.

4.2 DEFLECTION

To determine the effect of opening on RC deep beam in term of deflection, the deformed shape from the analysis by using ANSYS was obtained. In the deformed shape, there is a DMX value. The DMX value is defined as the maximum deflection. The deflection at the mid span of the RC deep beam was taken in this study. There are two parameters were manipulated to determine the effect of the opening on RC deep beam in term of deflection. One is the opening size and another one is the location.

From the results obtained, for the effect of the opening size on RC deep beam, the larger the opening size, the higher the deflection. This kind of trend was expressed in various loads. The analysis was conducted with 4kN, 8kN, 12kN, 16kN, and 20kN

for all models. Refer to the Appendix A for the figures of the models' deflection obtained from the ANSYS.

When introduced the opening with diameter of 100mm at the center of the RC deep beam (DBO 1), under load of 20kN, the deflection of the RC deep beam had increased in about 22.8% when compared with the solid RC deep beam model (DBS). When the size of opening was increased to 130mm (DBO 2), the deflection was increased in about 22.5% when compared with the DBO 1. For the DBO 3, its opening was 160mm; the result showed that the deflection was increased in about 7.2% when compared with DBO 2. According to the result, it was obviously showed that the opening give a significant effect to the RC deep beam. The deflection of DBO 3 was increased in about 61.2% compared with DBS. The results from the analysis on the effect of the opening size on RC deep beam were tabulated in Table 4.1 and visualized in Figure 4.1-Figure 4.5.

Another parameter was the location of the opening on the RC deep beam. The results showed that located an opening at the center of the RC deep beam will give greater effect in term of deflection. Under the same amount of load, as the opening move toward the side of the RC deep beam, the deflection was become smaller. The trend can be seen by the results obtained from the analysis of the DBO 3, DBL 1, DBL 2, and DBL 3. Under the load of 20kN, the deflection of the DBL 1, DBL2, and DBL 3 were 1.496mm, 1.558mm, and 1.581mm respectively. The deflection of DBL 1 was smaller than DBO 3 in a percentage of 24.1%. For DBL 2, the opening was located at 570mm from the side of RC deep beam. Its deflection was increased in 4.4% when compared with DBL 1. DBL 3 has an opening at 820mm from the side of the RC deep beam. When compared DBL 3 and DBL 1, the deflection of DBL 3 was increased in about 6%. For the DBO 3, its opening was located at center where the location that affect the deflection the most. The deflection of DBO 3 was the greatest among the other models in this analysis. Its deflection was 1.972mm. Table 4.2 and Figure 4.6-Figure 4.9 showed the analysis results of DBL1, DBL 2, and DBL 3.

In the analysis of the effect of the opening size on RC deep beam, from the result, it showed that there was a trend which is the deflection increased as the opening

size increased. The finding of this study was agreed by the study done by (Nilesh and Patel, 2013), the result showed that the increasing of the opening size has caused the deflection increases. The opening was made in two different sizes, which is 0.45d and 0.55d. The result showed that there was an increment about 30% in the deflection as the opening size increased from 0.45d to 0.55d.

There was a research done by (Soroush and Reza, 2011) showed that there is no much effect on the RC deep beam if the opening size not more than 48% of the depth of the deep beam. In this study, the maximum size opening was set to 20% of the depth of the beam which is less than 48% of the depth of the deep beam. This has caused the deflection in this study increased only in small scale, which is not more than 1mm.

According to the result from this study, as the location of the opening move toward the center, where the loading act, the deflection becomes higher. This result was agreed by the study done by (Haider, 2013). The finding by (Haider, 2013) stated that the best location of the opening is far from the loading and the flexure region. The ultimate strength of the RC deep beam was decreases in 36% when the opening moves toward to the loading from a distance of 600mm to 300mm.

Table 4.1: Deflection of the RC deep beam model with different opening size

LOAD (kN)	**DEFLECTION (mm)**			
	DBS	**DBO 1**	**DBO 2**	**DBO 3**
0	0	0	0	0
4	-0.492	-1.042	-1.044	-1.153
8	-0.624	-1.296	-1.345	-1.388
12	-0.776	-1.398	-1.592	-1.743
16	-1.004	-1.475	-1.65	-1.766
20	-1.223	-1.502	-1.84	-1.972

Table 4.2: Deflection of the RC deep beam model with opening at different location

LOAD (kN)	DEFLECTION (mm)			
	DBL 1	DBL 2	DBL 3	DBO 3
0	0	0	0	0
4	-0.494	-0.492	-0.471	-1.153
8	-0.802	-0.814	-0.79	-1.388
12	-0.956	-0.959	-0.982	-1.743
16	-1.003	-1.402	-1.302	-1.766
20	-1.496	-1.558	-1.581	-1.972

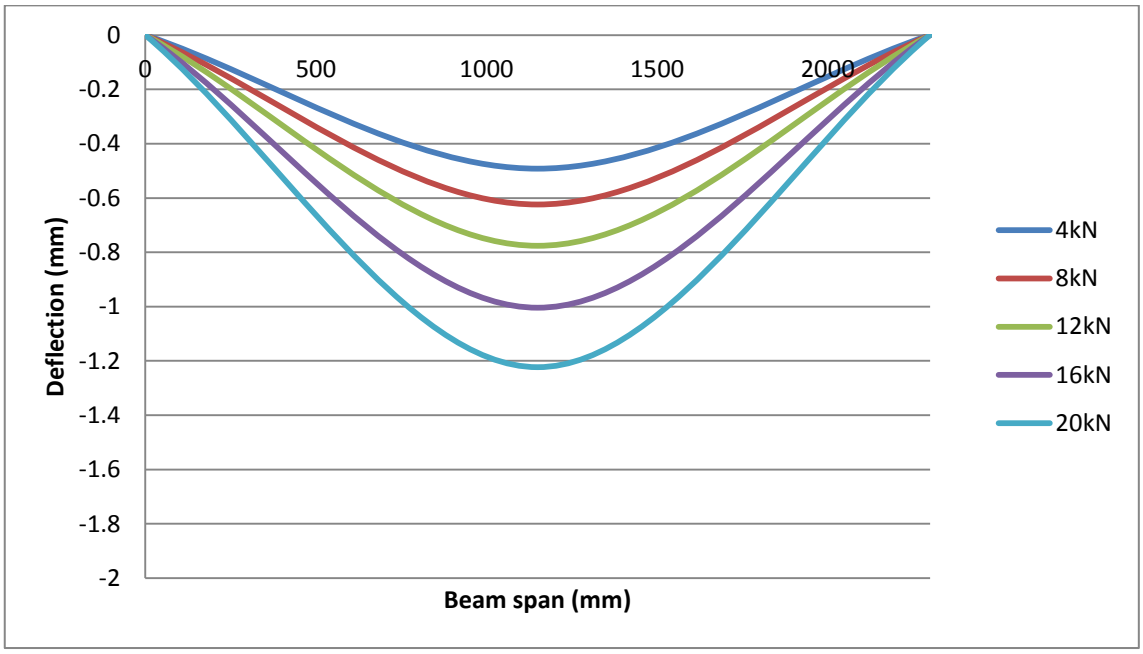

Figure 4.1: Deflection profile of the DBS under various loads

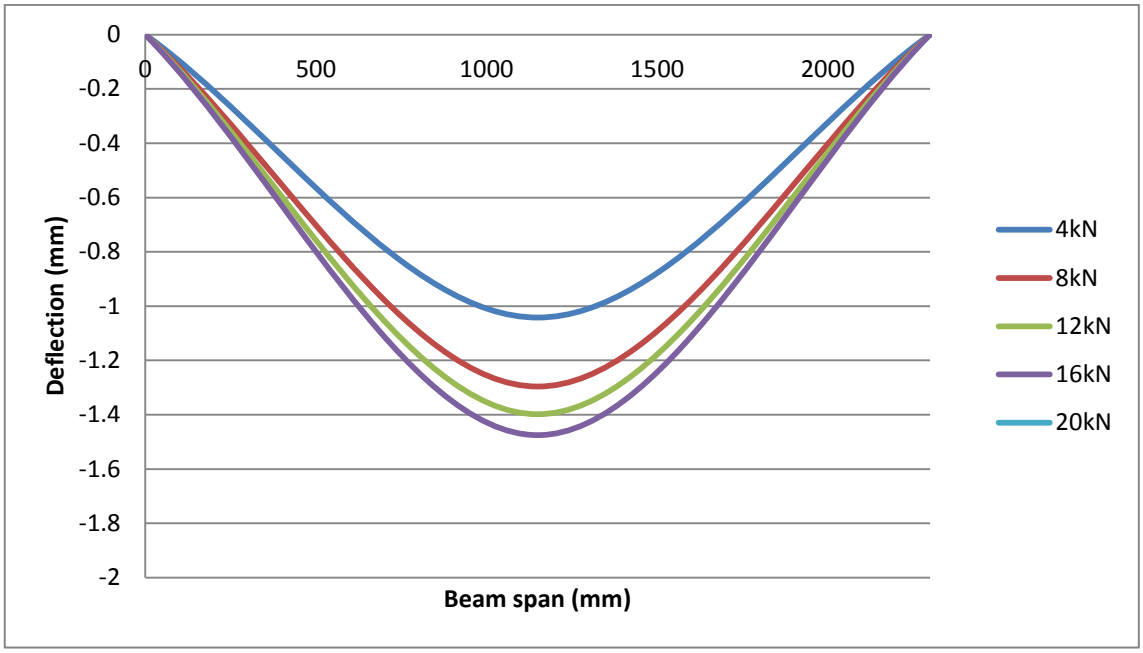

Figure 4.2: Deflection profile of the DBO 1 under various loads

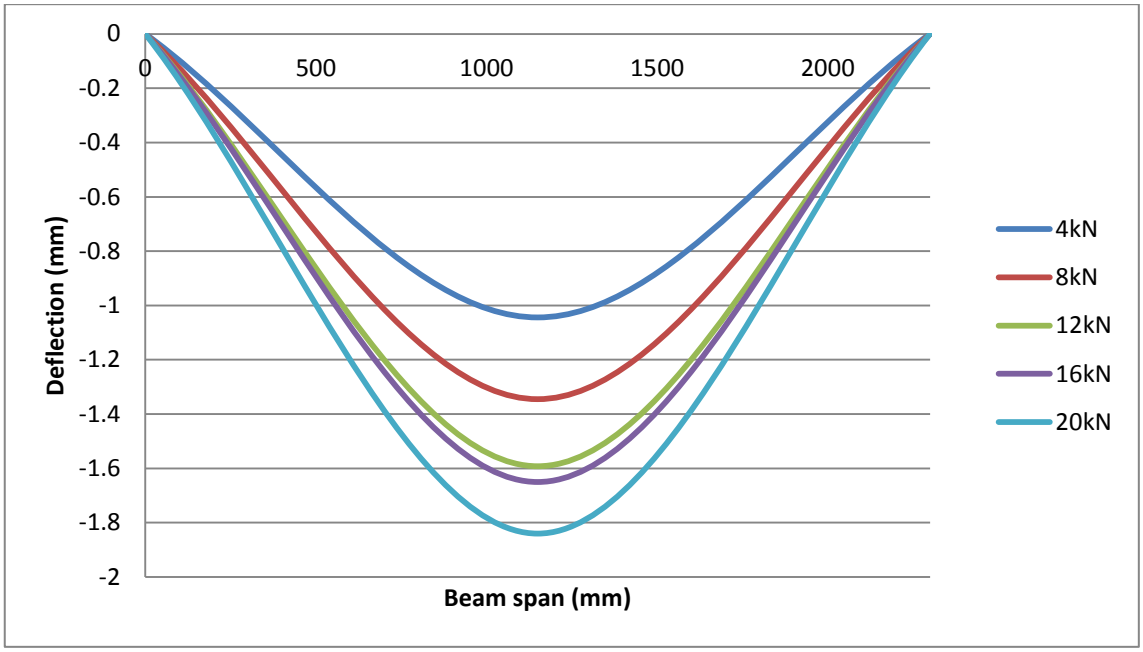

Figure 4.3: Deflection profile of the DBO 2 under various loads

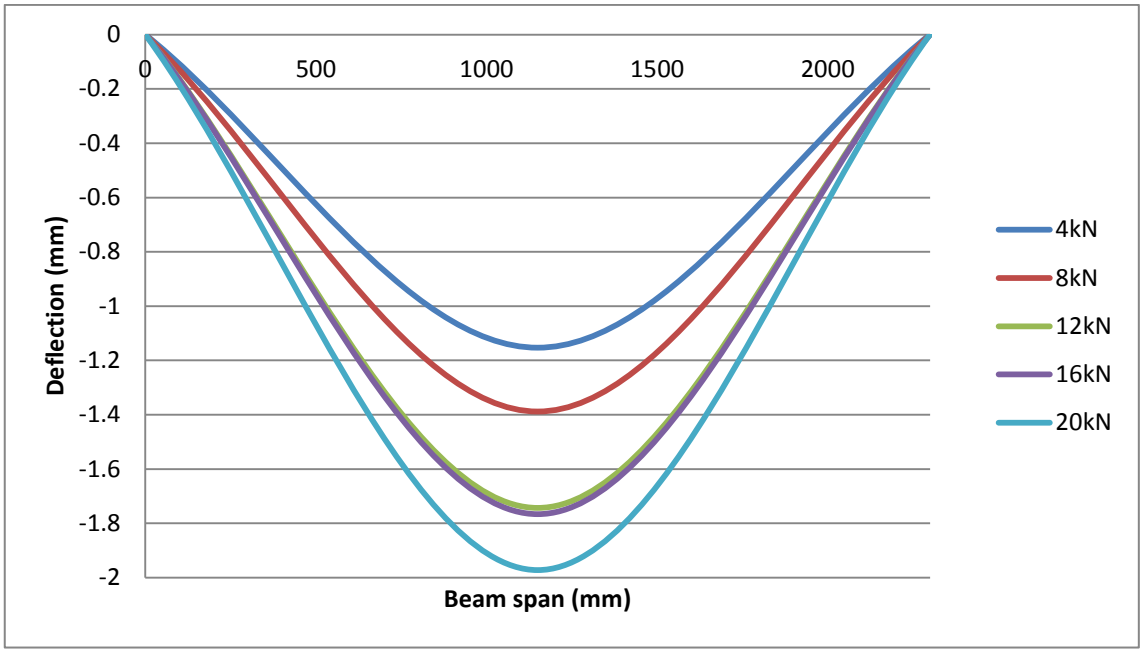

Figure 4.4: Deflection profile of the DBO 3 under various loads

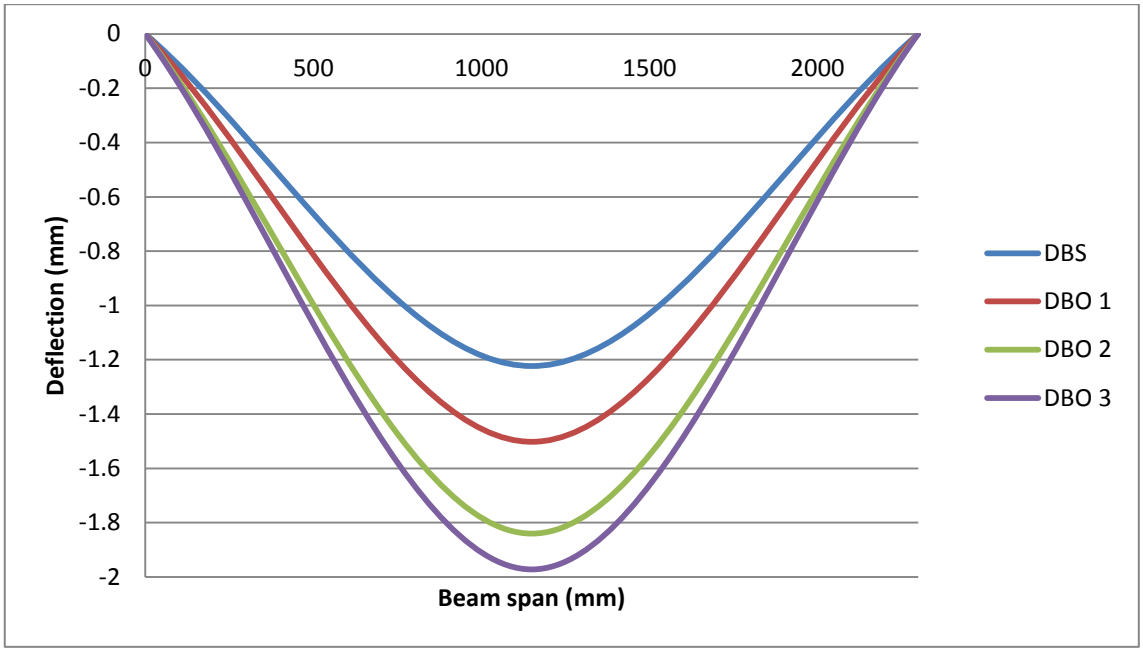

Figure 4.5: Combination of deflection profile of the DBS, DBO 1, DBO 2, and DBO 3

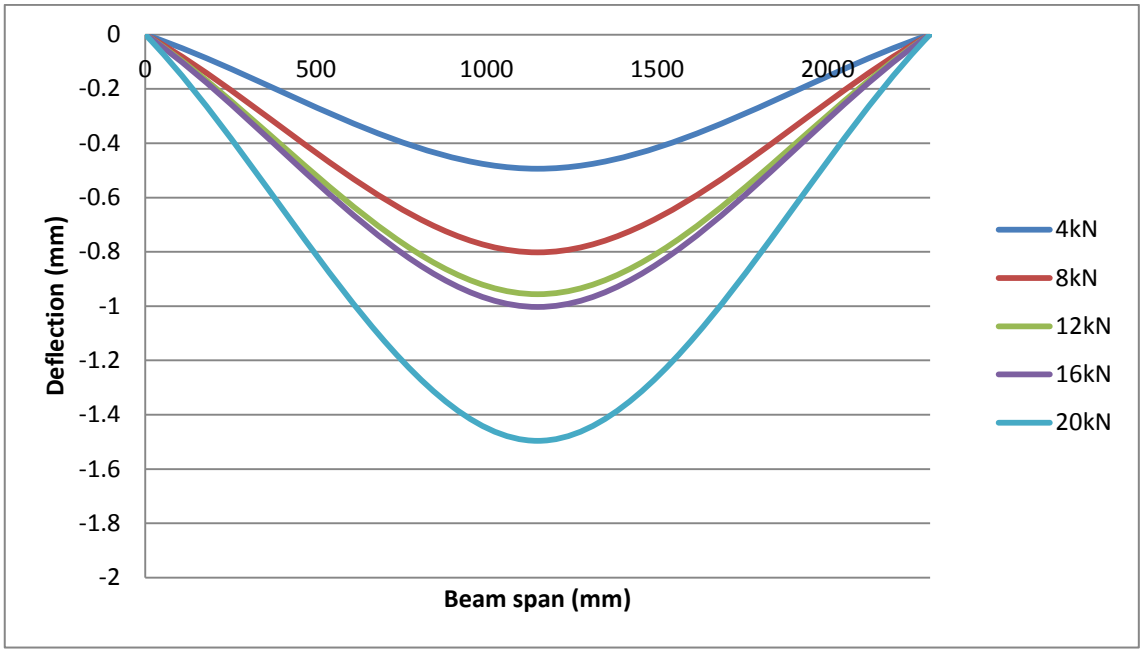

Figure 4.6: Deflection profile of the DBL 1 under various loads

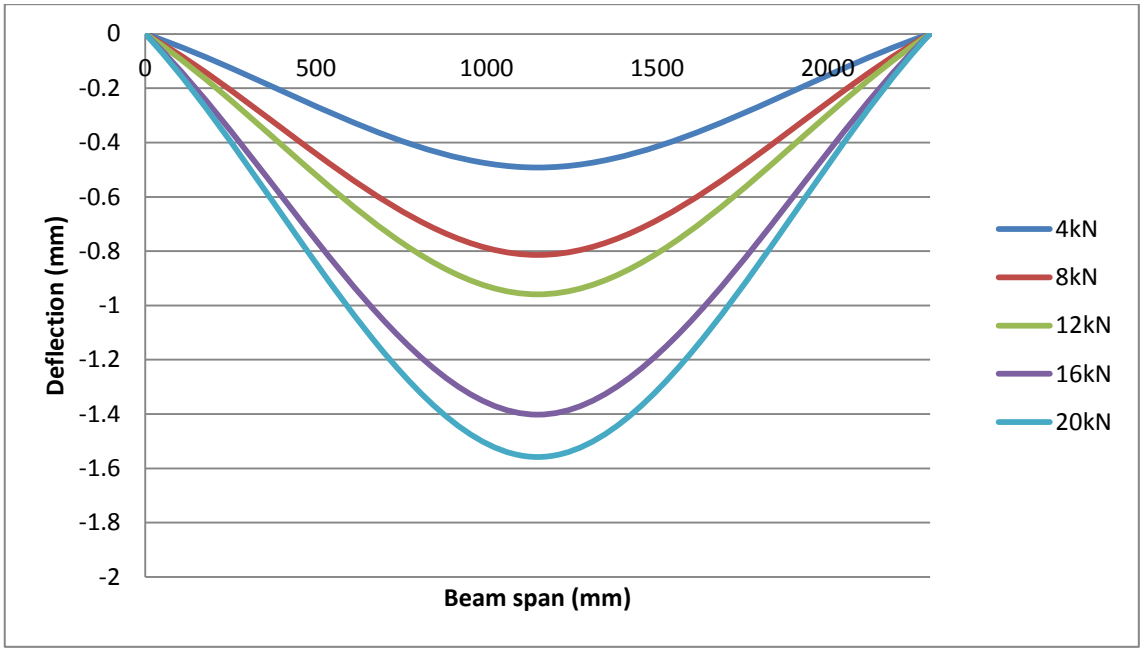

Figure 4.7: Deflection profile of the DBL 2 under various loads

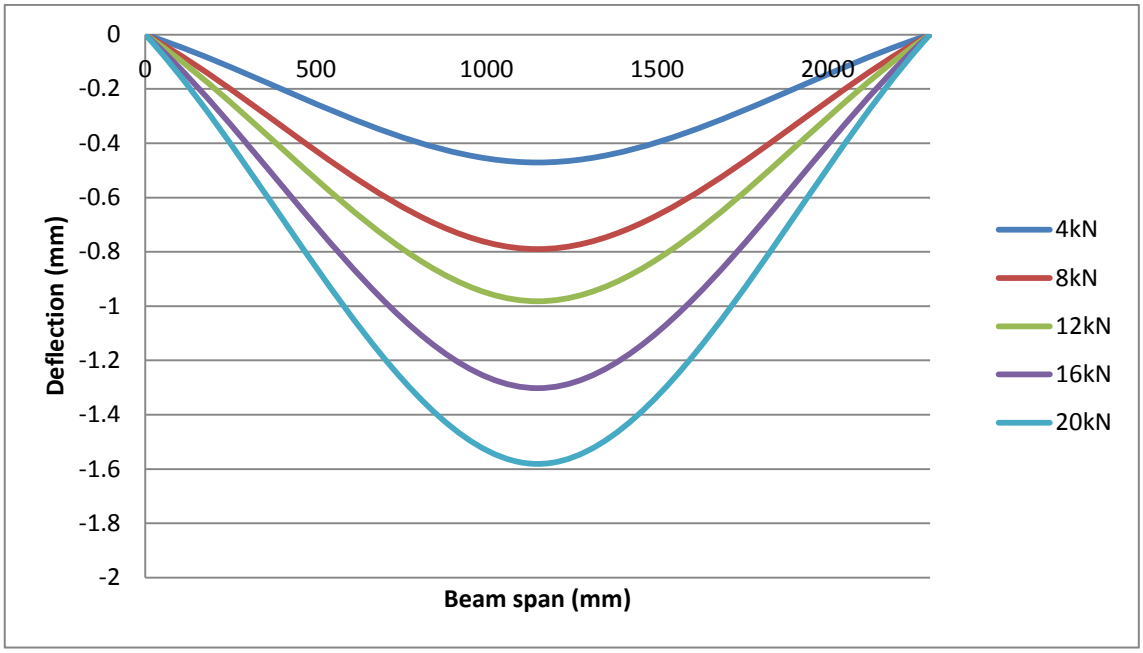

Figure 4.8: Deflection profile of the DBL 3 under various loads

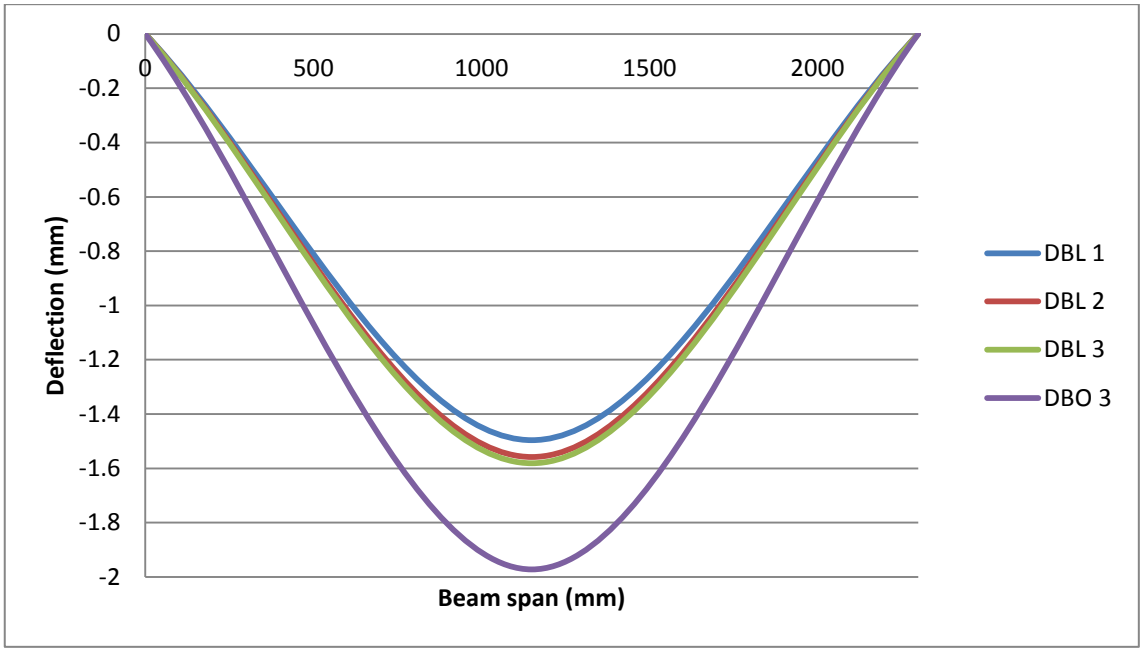

Figure 4.9: Combination of deflection profile of DBL 1, DBL 2, DBL 3, and DBO 3

4.3 CRACK PATTERN

From the results obtained, for the solid RC deep beam (DBS), the flexural crack was occurred at the first stage. The crack was occurred at the bottom of the deep beam. As the load increased, the crack was propagated at the bottom of the RC deep beam. When come closer to the loading point which is the top of the RC deep beam, the crack was propagated slowly. The crack converged to the loading point when it comes closer to the loading point. Figure 4.10-Figure 4.14 are the diagrams of the crack pattern of the DBS obtained from the analysis. It showed the crack pattern of the DBS with different loads, which 4kN, 8kN, 12kN, 16kN, and 20kN.

There are some effects on the RC deep beam when the opening was introduced to it. Introducing the opening at the center of the RC deep beam had reduced the strength of the deep beam. The crack was occurred below and above the opening. The flexural cracks were occurred at the bottom of the deep beam. The cracks propagated from the bottom to the opening. Once the cracks reached the opening, the cracks were continued to propagate above the opening. There is less or even no crack occurred at the both sides of the opening, the cracks were occurred below and above the opening. The analysis was conducted with different size of the opening. There are three models with opening at the center of the RC deep beam, which are DBO 1, DBO 2, and DBO 3. The diameter of the opening was increased by 30mm from diameter of 100mm. From the result of this analysis, the cracks were propagated faster as the opening size increased. The diagrams of the crack pattern for the DBO 1, DBO 2, and DBO 3 under different loads were showed in Figure 4.15-Figure 4.29.

The study also conducted to determine the effect of the location of the opening of the RC deep beam. The model DBO 3, DBL1, DBL2, and DBL 3 were used in this study. The location of the opening from the edge of the deep beam for models DBL 1, DBL 2, DBL, and DBO 3 were 320mm, 570mm, 820mm, and 1070mm respectively. According to the result obtained, for DBL 1, when the opening was introduced at the location where farthest from the loading point, it caused little effect on the crack pattern and it act like the solid RC deep beam. From the result obtained from the model DBL 2 and DBL 3, it was significantly showed that as the opening getting closer to the loading

point, the diagonal cracks occurred and propagated earlier. The length of the diagonal cracks at the opening increased as the loading increased. Figure 4.30-Figure 44 showed the crack pattern of the models with opening at different location plot by ANSYS.

According to (Mansur, 1998), he labeled the failure at opening which is similar to the solid beam as beam-type failure. For this type of failure, there are two diagonal cracks occurred and caused a 45 ° inclined failure plane. From the results of this study, this type of failure was happened in the models DBL 1, DBL 2 and DBL 3. The opening in these models is made at the location where is away from the loading point. There are two diagonal crack occurred at the opening.

From overall, the cracks pattern of all the models is almost the same. The different can be seen when the opening was introduced to the RC deep beam. The RC deep beam was failure with the diagonal cracks. As the load increased, the diagonal crack was slowly propagated from the supports toward the loading point. With the opening on the RC deep beam, it had reduced the strength of the RC deep beam and caused the crack occurred at earlier stage and propagated faster.

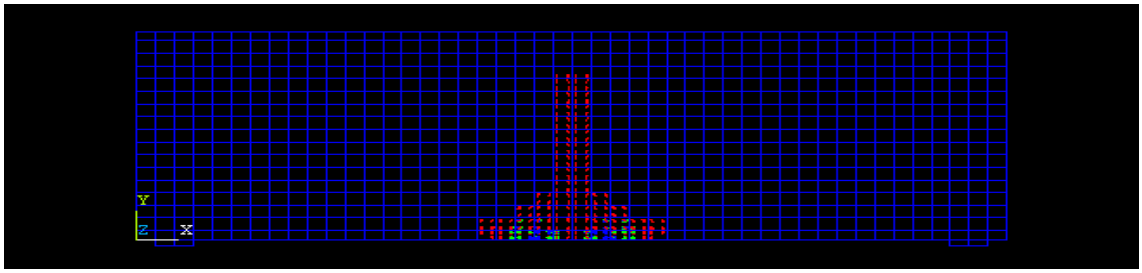

Figure 4.10: DBS under load of 4kN

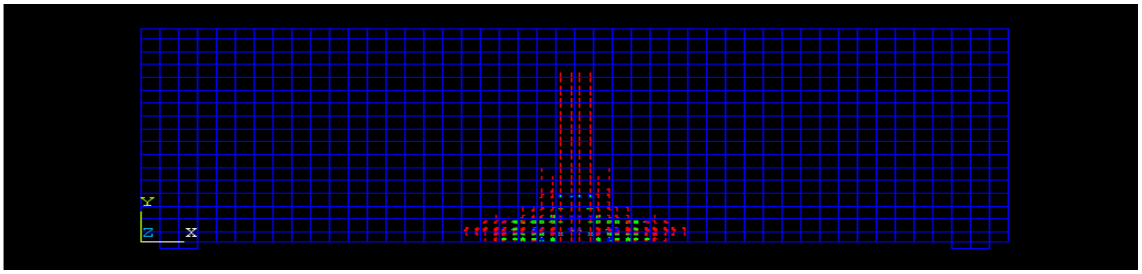

Figure 4.11: DBS under load of 8kN

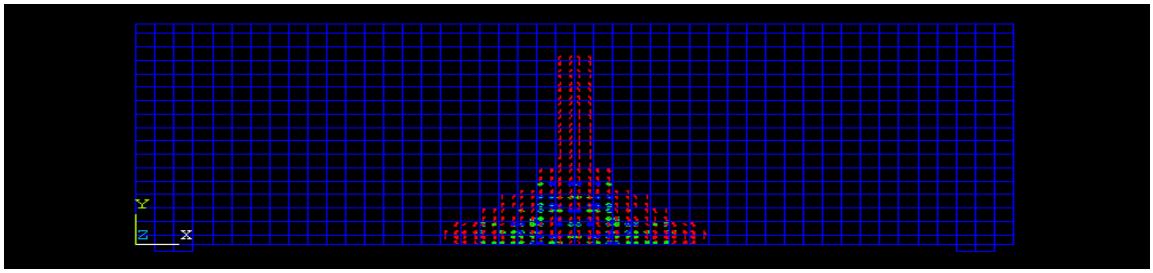

Figure 4.12: DBS under load of 12kN

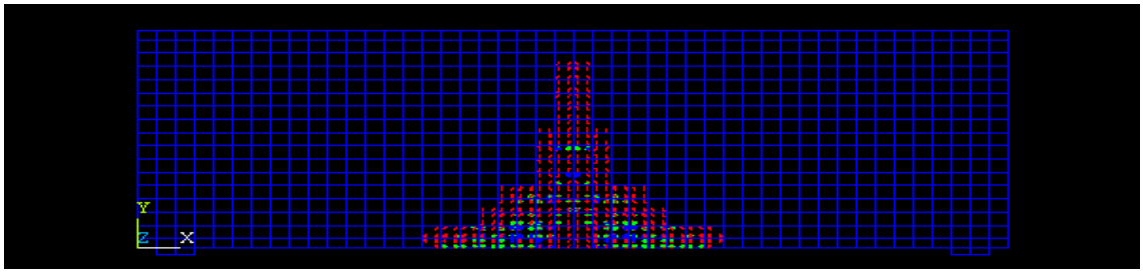

Figure 4.13: DBS under load of 16kN

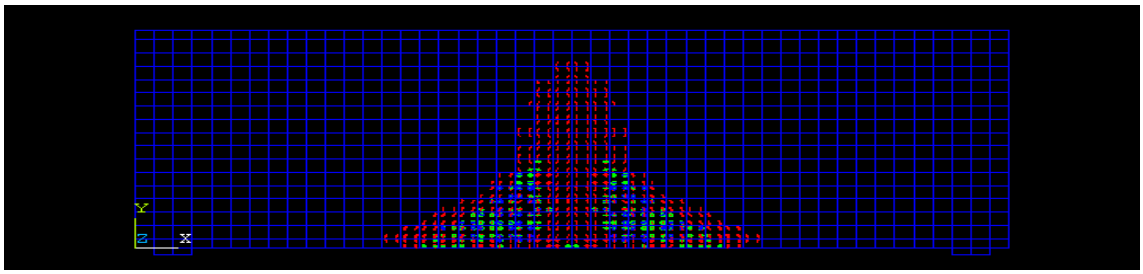

Figure 4.14: DBS under load of 20kN

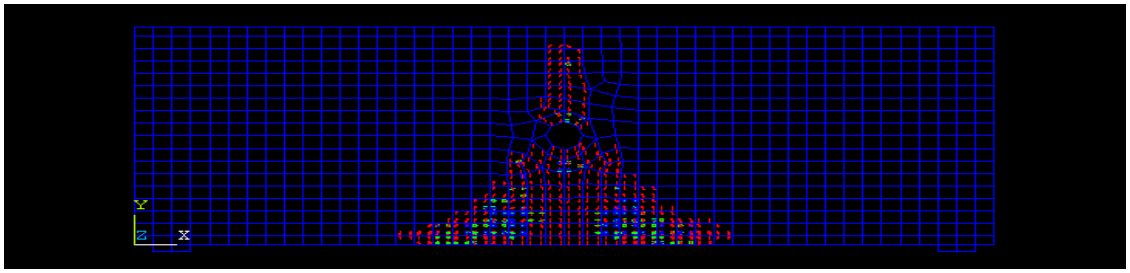

Figure 4.15: DBO 1 under load of 4kN

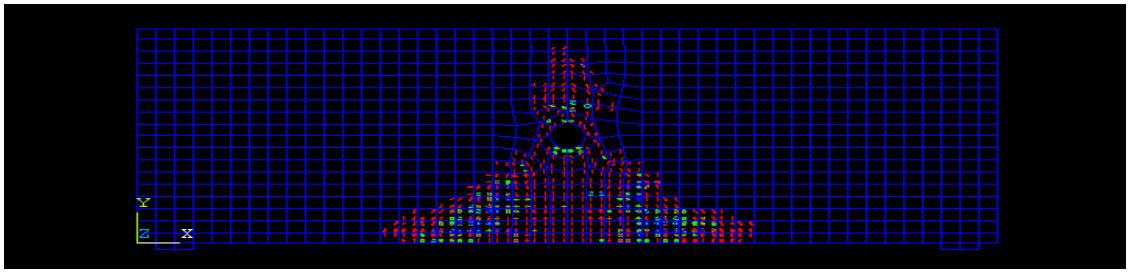

Figure 4.16: DBO 1 under load of 8kN

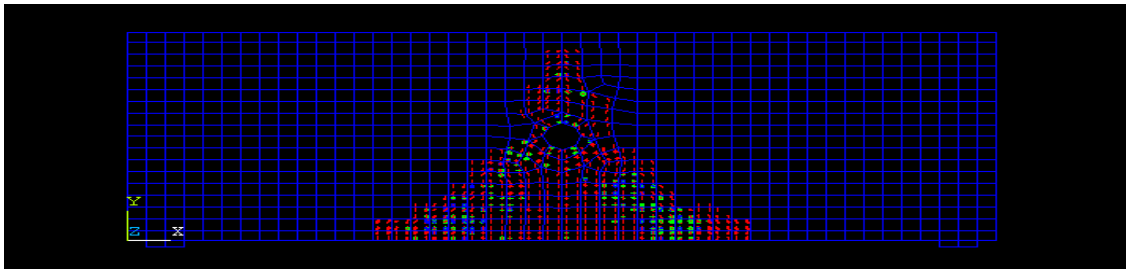

Figure 4.17: DBO 1 under load of 12kN

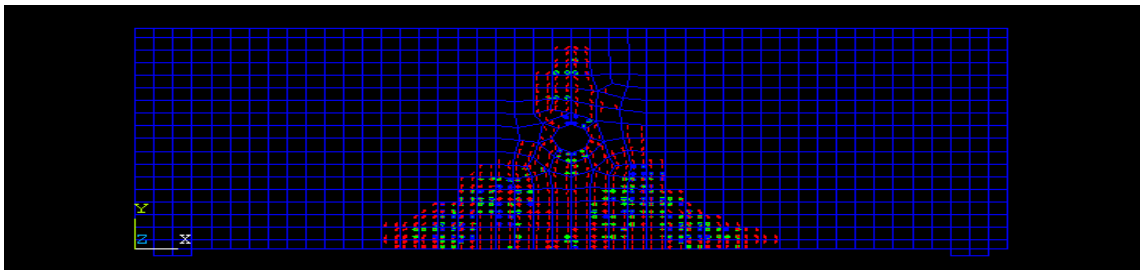

Figure 4.18: DBO 1 under load of 16kN

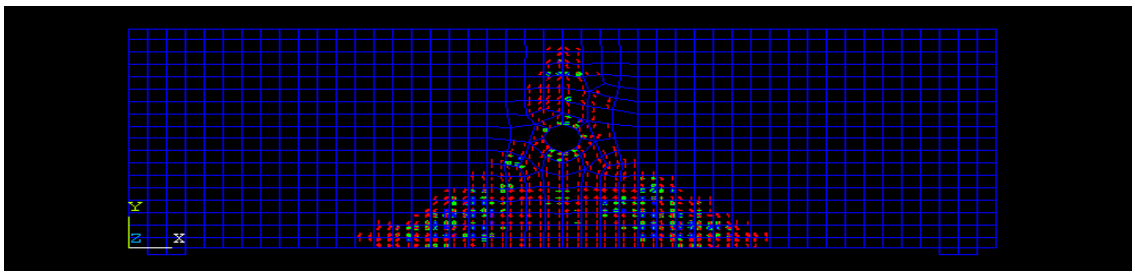

Figure 4.19: DBO 1 under load of 20kN

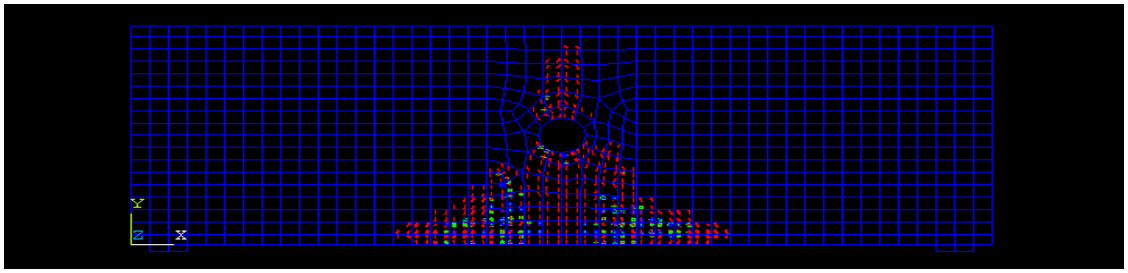

Figure 4.20: DBO 2 under load of 4kN

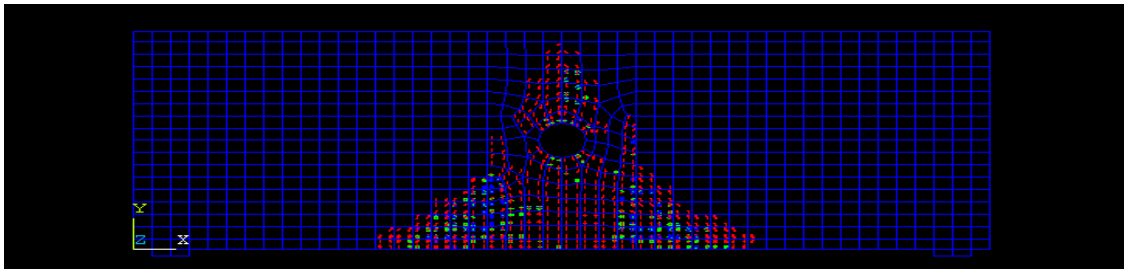

Figure 4.21: DBO 2 under load of 8kN

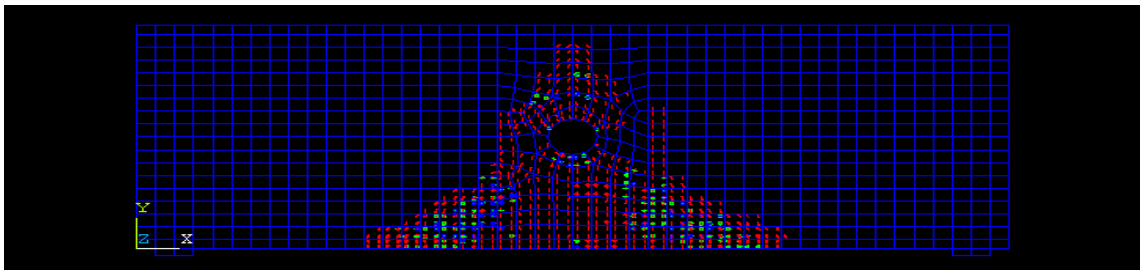

Figure 4.22: DBO 2 under load of 12kN

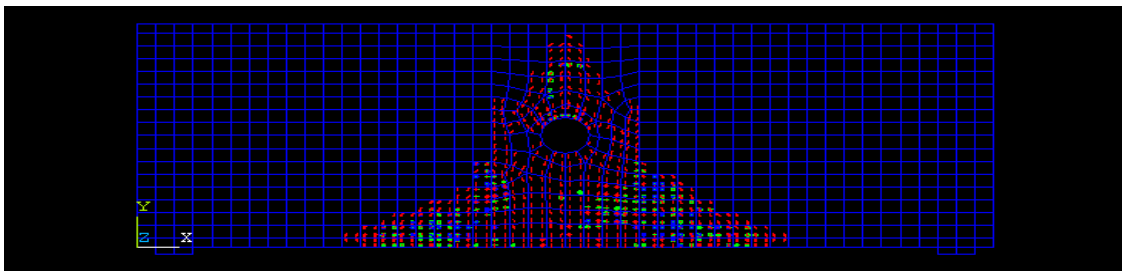

Figure 4.23: DBO 2 under load of 16kN

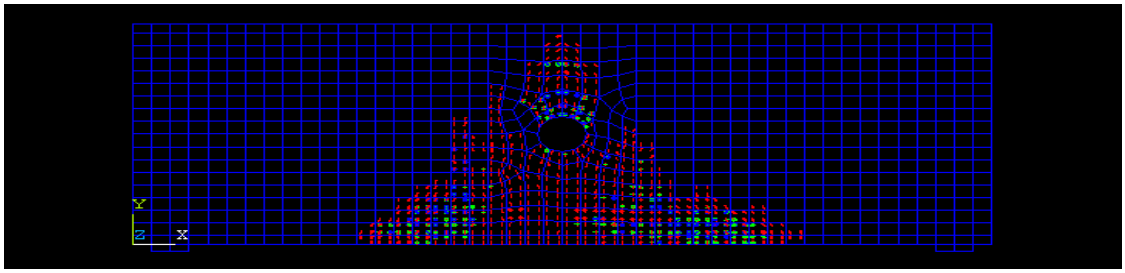

Figure 4.24: DBO 2 under load of 20kN

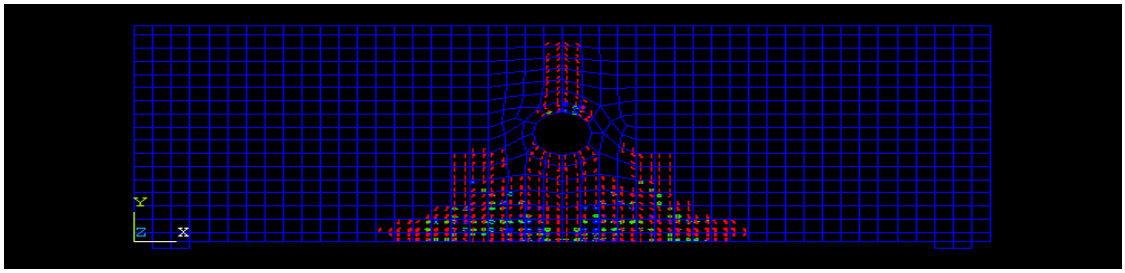

Figure 4.25: DBO 3 under load of 4kN

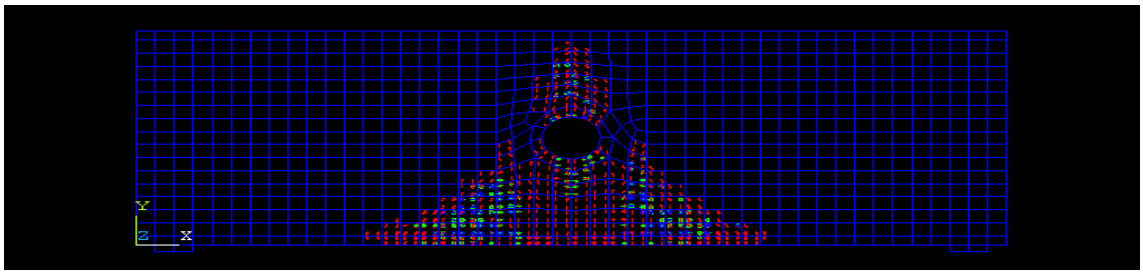

Figure 4.26: DBO 3 under load of 8kN

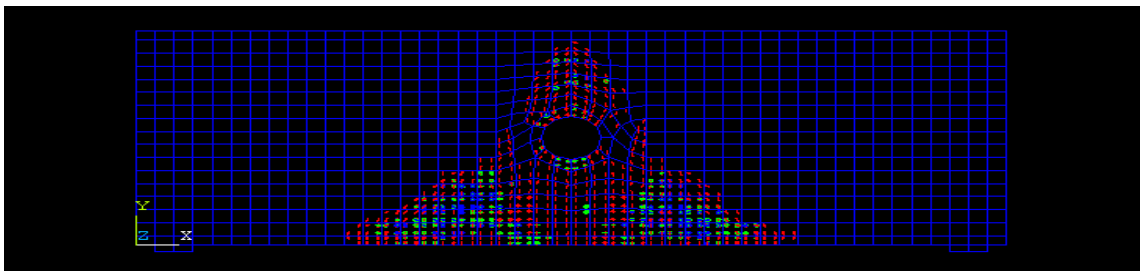

Figure 4.27: DBO 3 under load of 12kN

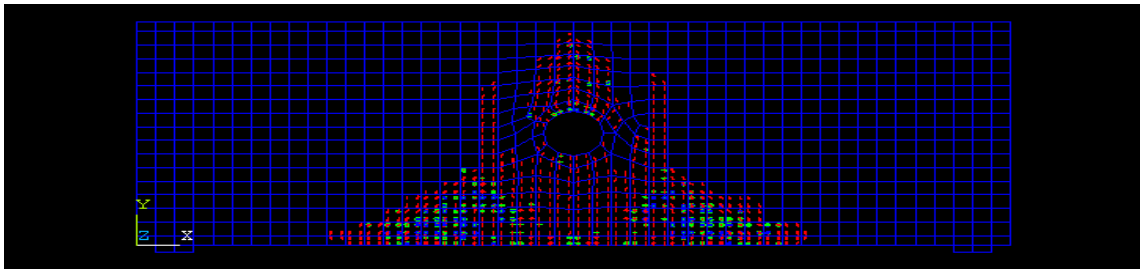

Figure 4.28: DBO 3 under load of 16kN

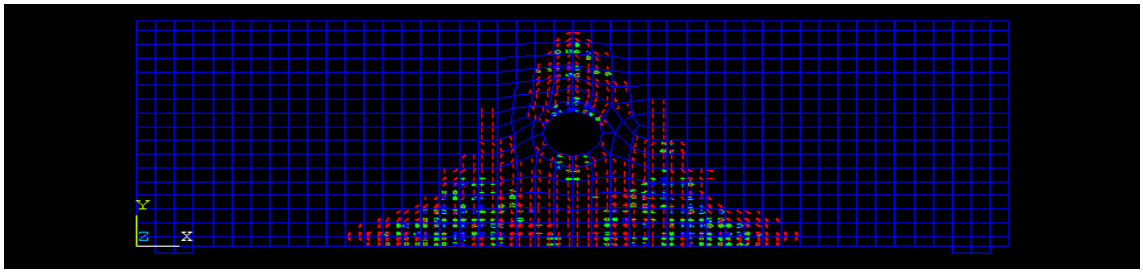

Figure 4.29: DBO 3 under load of 20kN

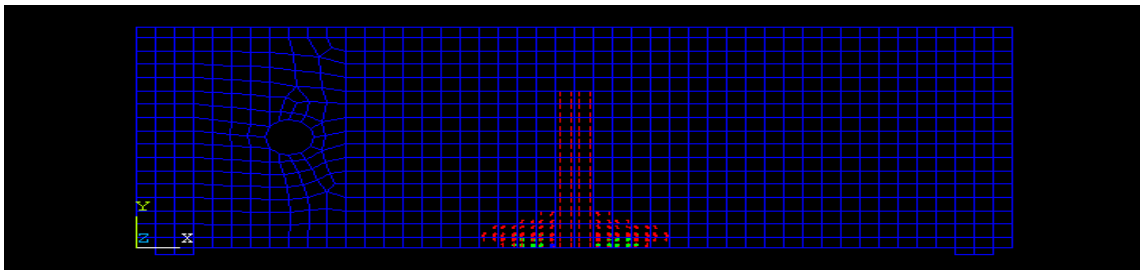

Figure 4.30: DBL 1 under load of 4kN

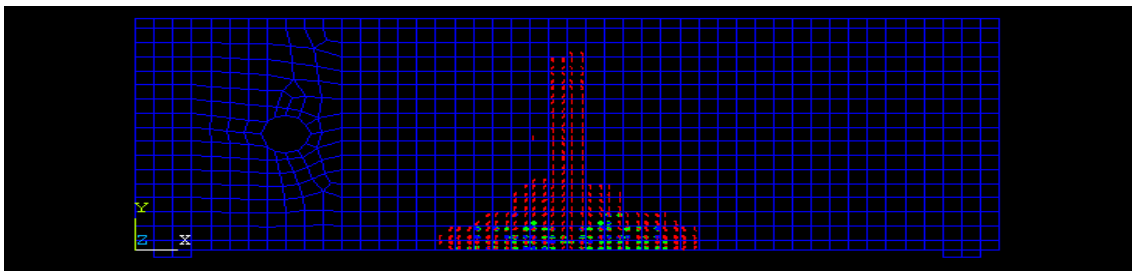

Figure 4.31: DBL 1 under load of 8kN

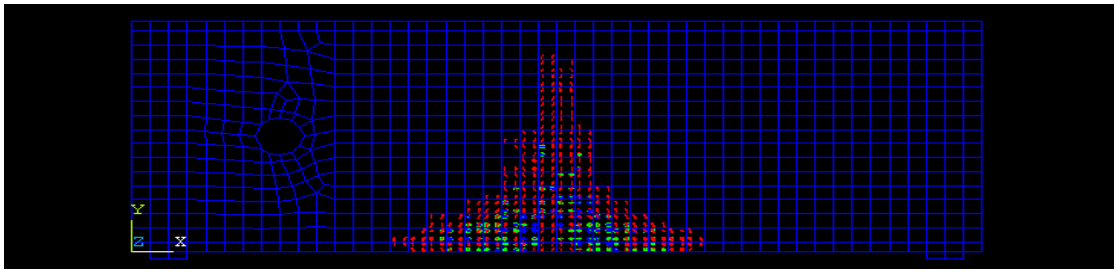

Figure 4.32: DBL 1 under load of 12kN

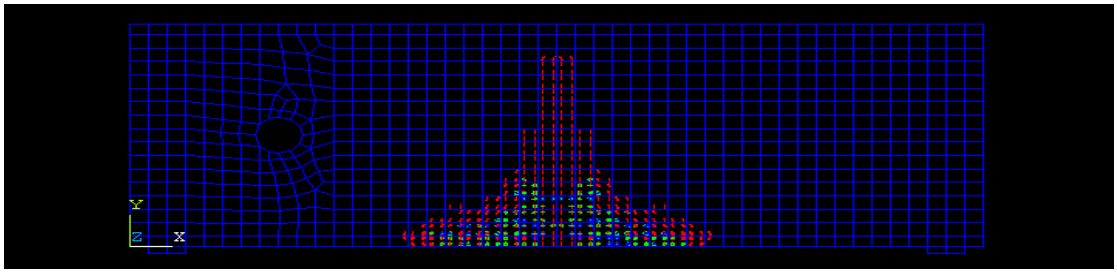

Figure 4.33: DBL 1 under load of 16kN

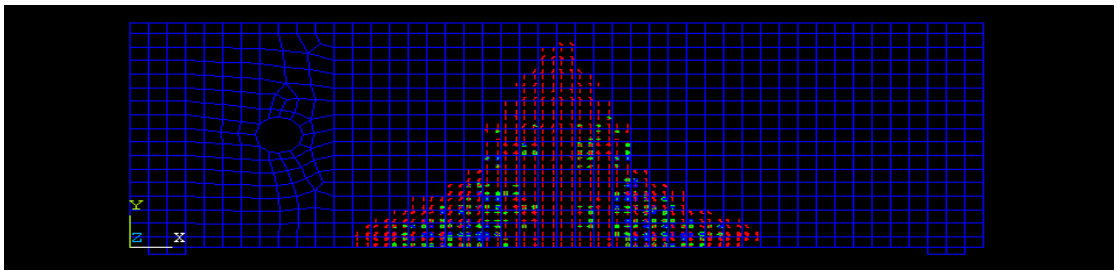

Figure 4.34: DBL 1 under load of 20kN

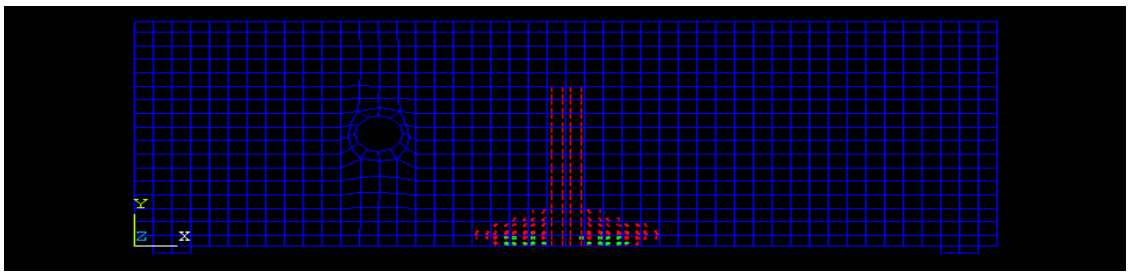

Figure 4.35: DBL 2 under load of 4kN

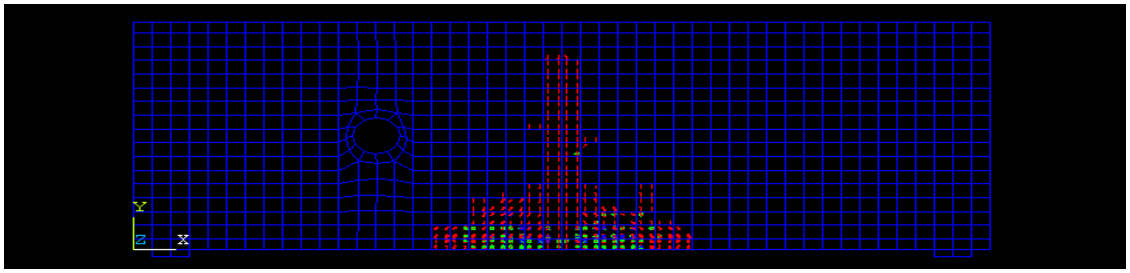

Figure 4.36: DBL 2 under load of 8kN

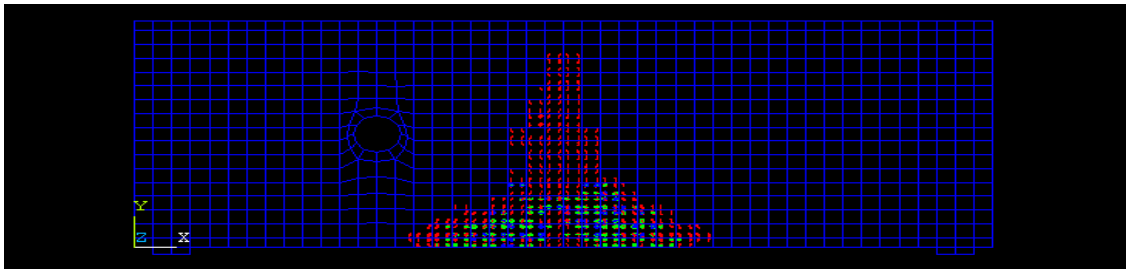

Figure 4.37: DBL 2 under load of 12kN

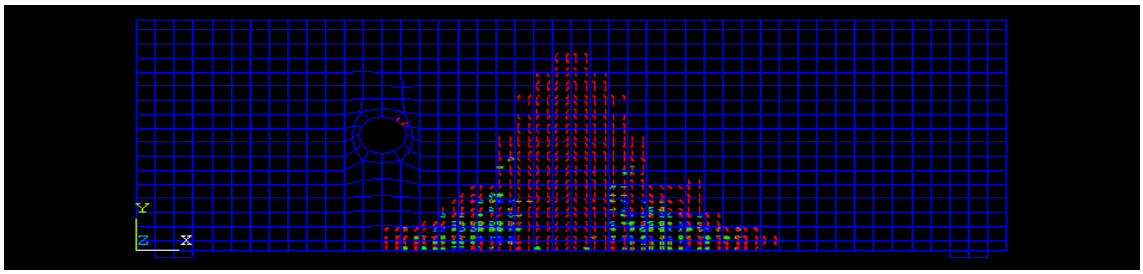

Figure 4.38: DBL 2 under load of 16kN

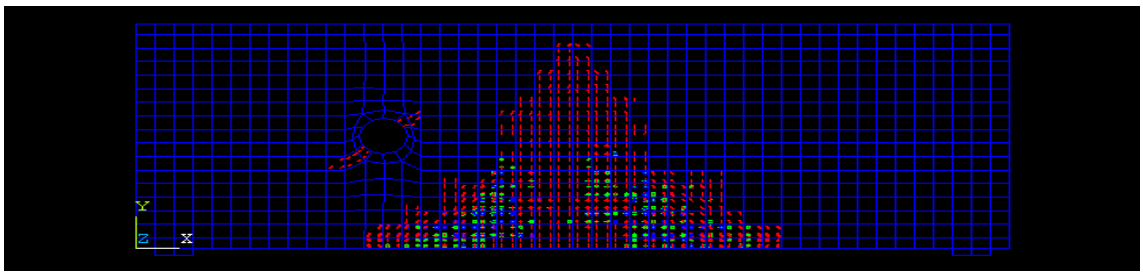

Figure 4.39: DBL 2 under load of 20kN

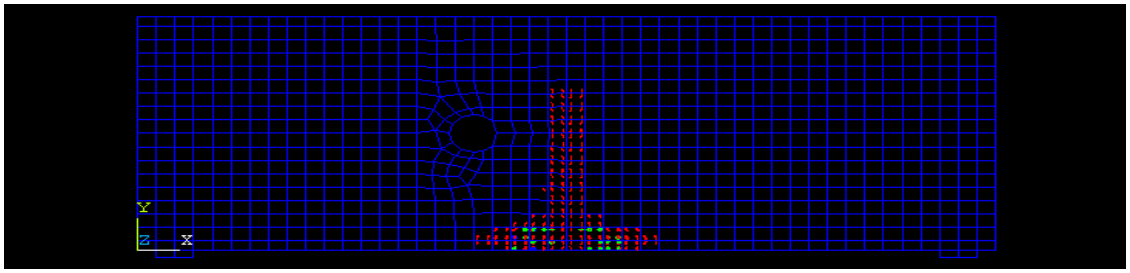

Figure 4.40: DBL 3 under load of 4kN

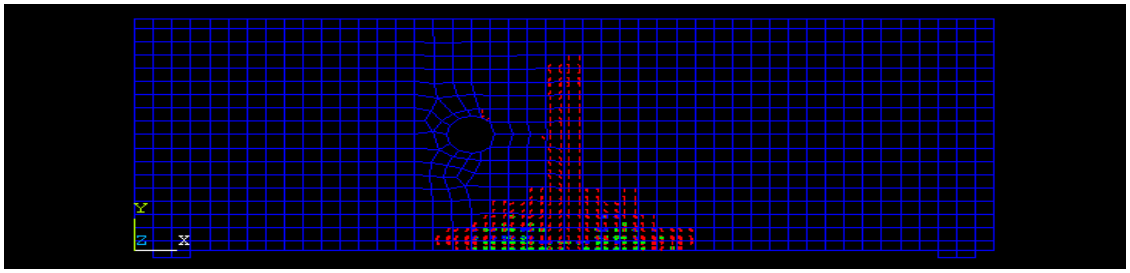

Figure 4.41: DBL 3 under load of 8kN

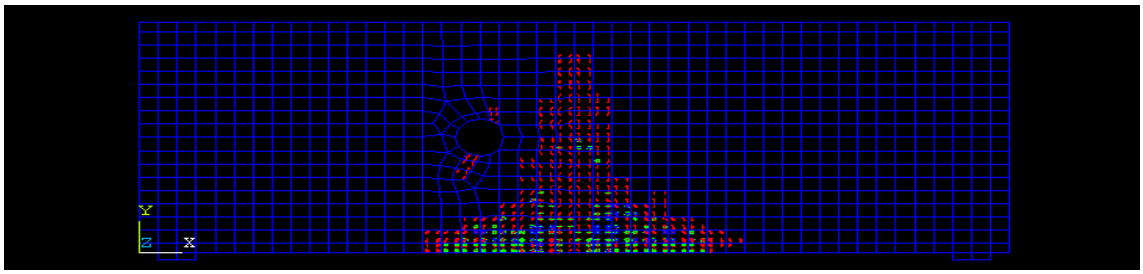

Figure 4.42: DBL 3 under load of 12kN

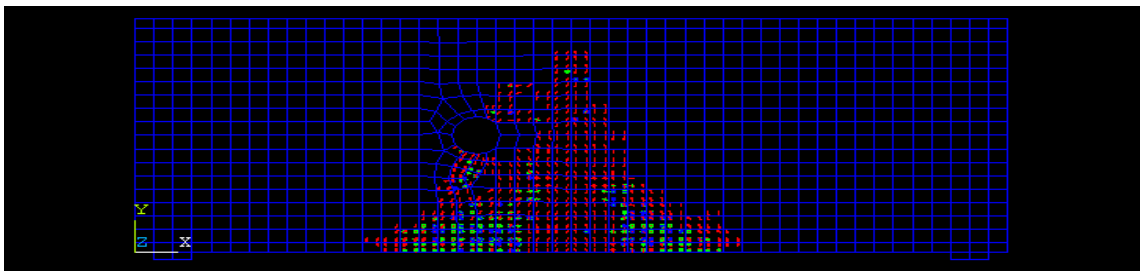

Figure 4.43: DBL 3 under load of 16kN

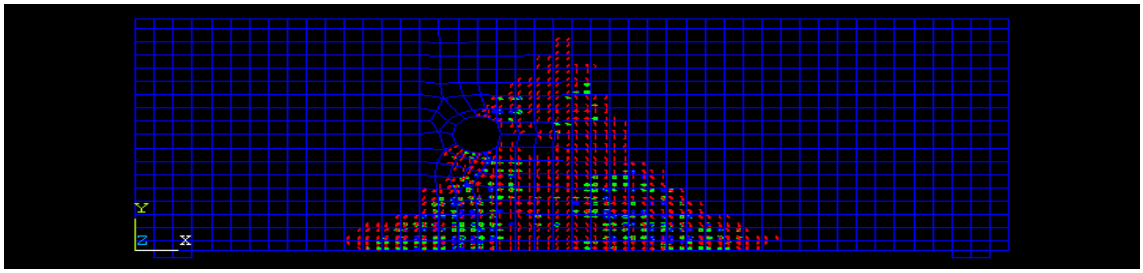

Figure 4.44: DBO 3 under load of 20kN

CHAPTER 5

CONCLUSION

5.1 CONCLUSIONS

This study is focused on the effect of the opening on RC deep beam. The opening was made with different size and different location. The results of deflection and crack pattern were taken to study on the effect of opening on RC deep beam.

The following was the conclusion made based on the finding of the study:

(i) Introducing the opening with diameter of 100mm at the centre of the RC deep beam had increased the deflection in 22.8% compared with solid RC deep beam.

(ii) When the size of opening at the centre of the RC deep beam was increased in 30%, the RC deep beam had increased the deflection in 50.4% compared with solid RC deep beam.

(iii) The deflection of the RC deep beam increased in 61.2% compared with solid RC deep beam when the size of opening at the centre of the RC deep beam increased in 60%.

(iv) As the opening introduced at 350mm from the edge of the RC deep beam, its effect on the deflection and crack pattern is small.

(v) As the opening located at the distance close proximity to the load, the cracks at the opening were become critical.

(vi) The best location to provide opening is the location farther with the load.

5.2 RECOMMENDATIONS

The following areas of research concerning effect of opening on RC deep beam that could form the basis of future research:

(i) Similar RC deep beam should be analyse with bigger size of the opening
(ii) By using the different type of loading to analyse the same RC deep beam
(iii) Different type of reinforcement arrangement can be consider in future study
(iv) More laboratory testing should be carried out on various sizes and location for the RC deep beam.
(v) Analyse the same RC deep beam by using the other engineering software.

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APPENDIX

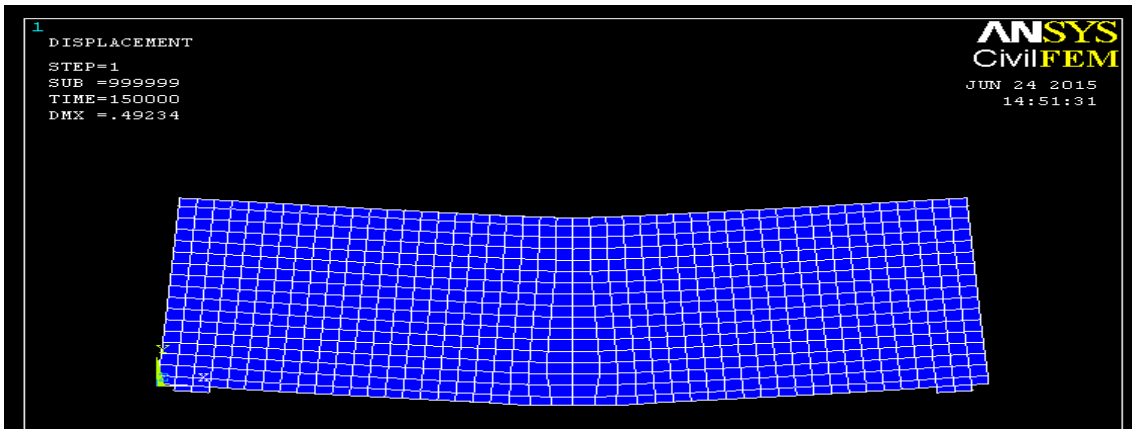
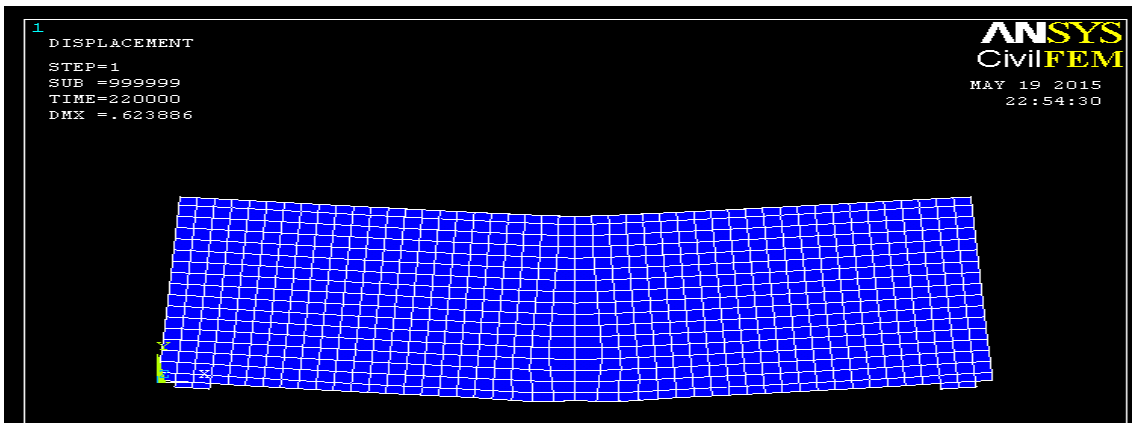


Figure 1: Deflection of DBS under load 4kN



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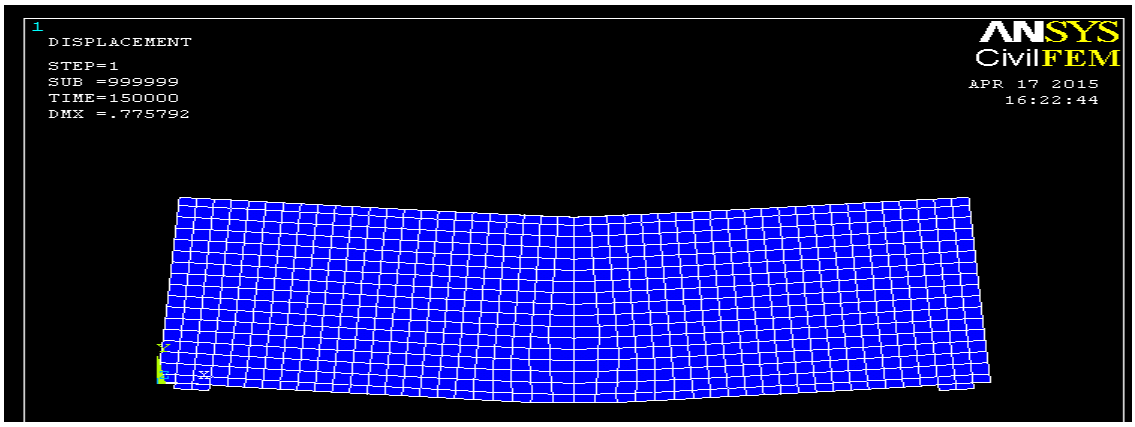


Figure 3: Deflection of DBS under load 12kN

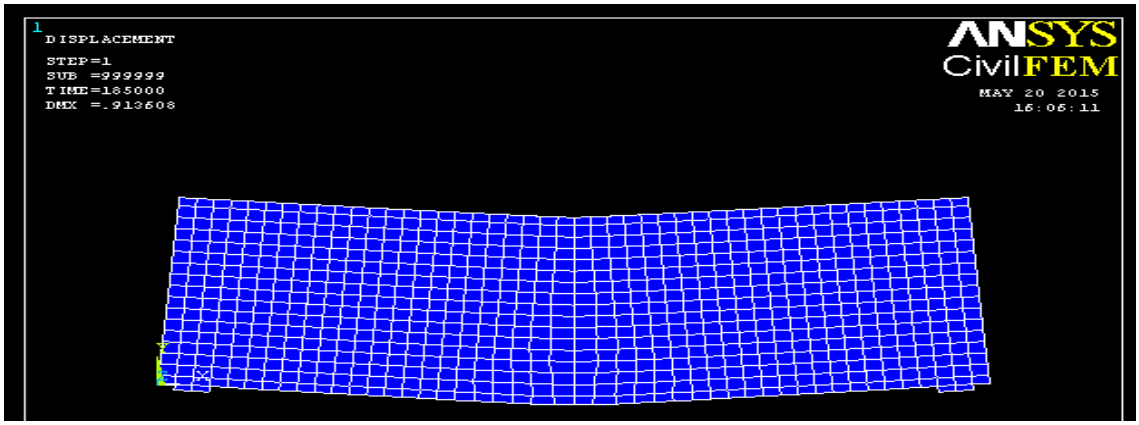


Figure 4: Deflection of DBS under load 16kN

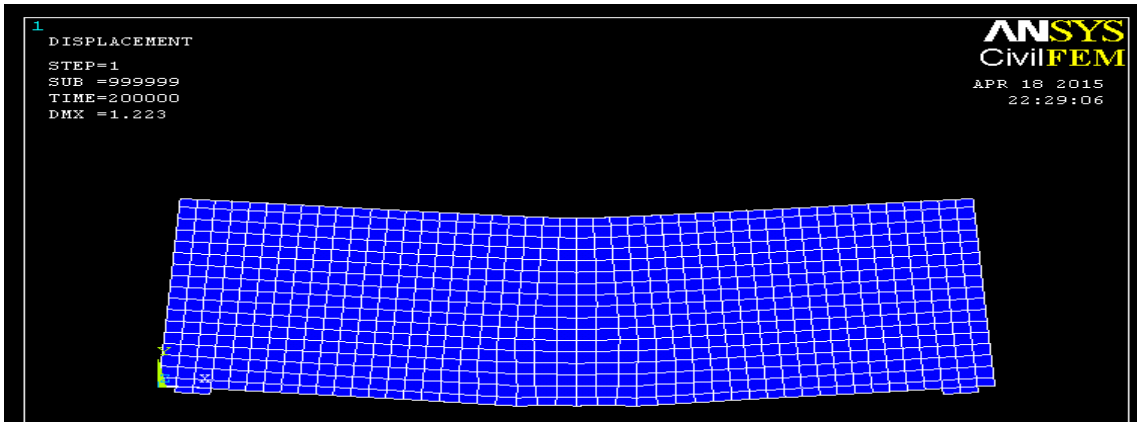
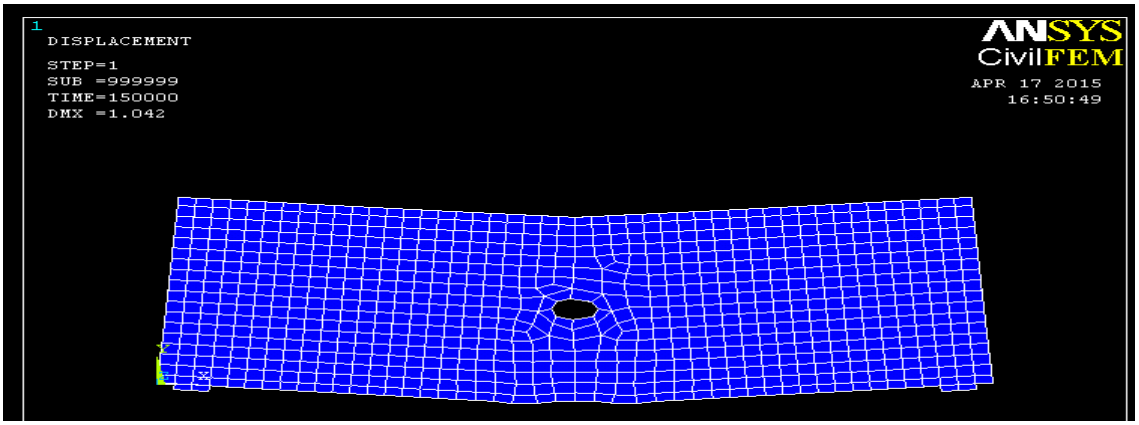


Figure 5: Deflection of DBS under load 20kN



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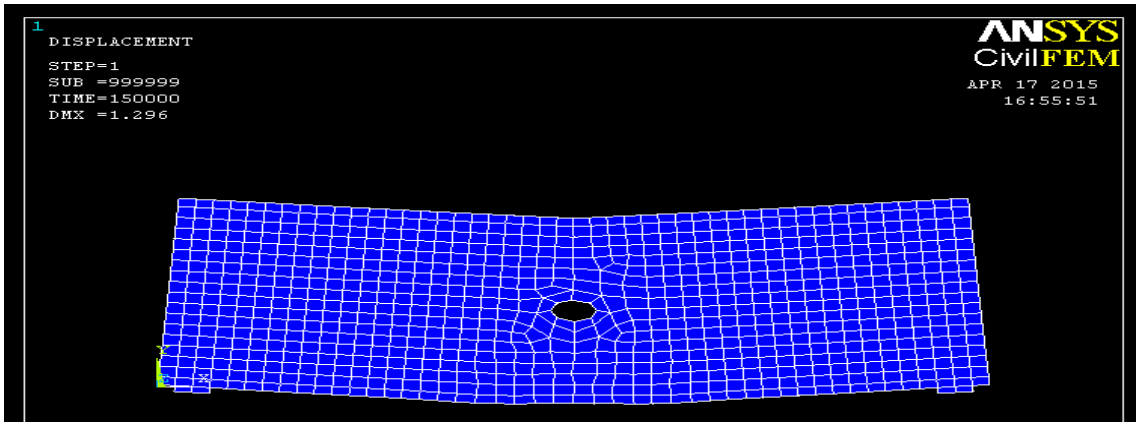

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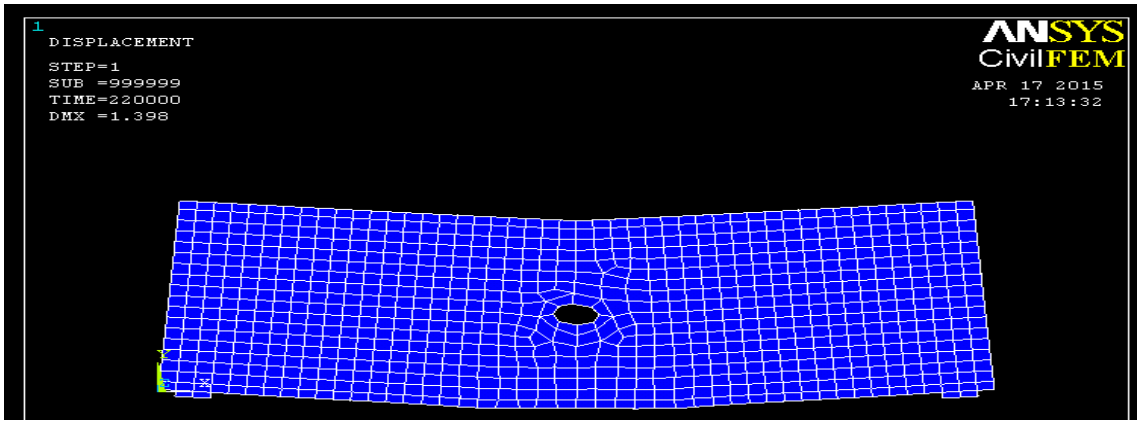

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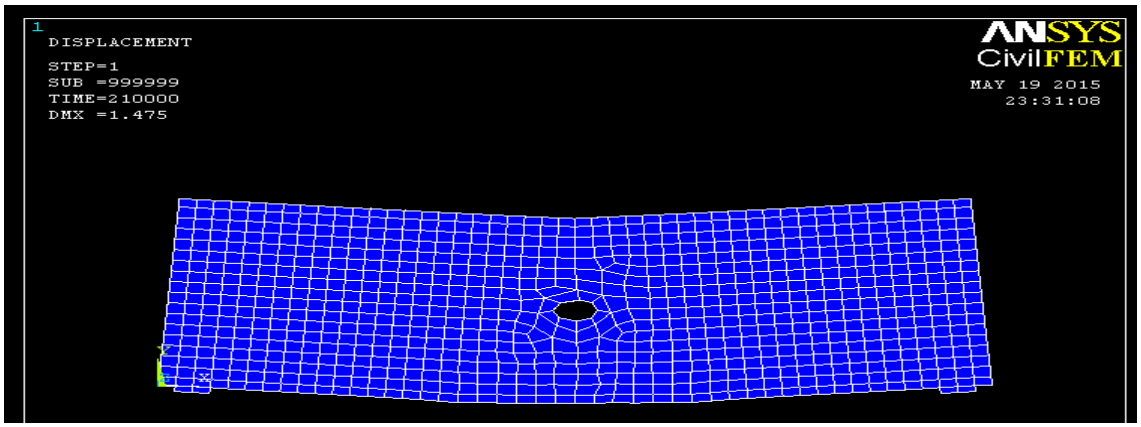

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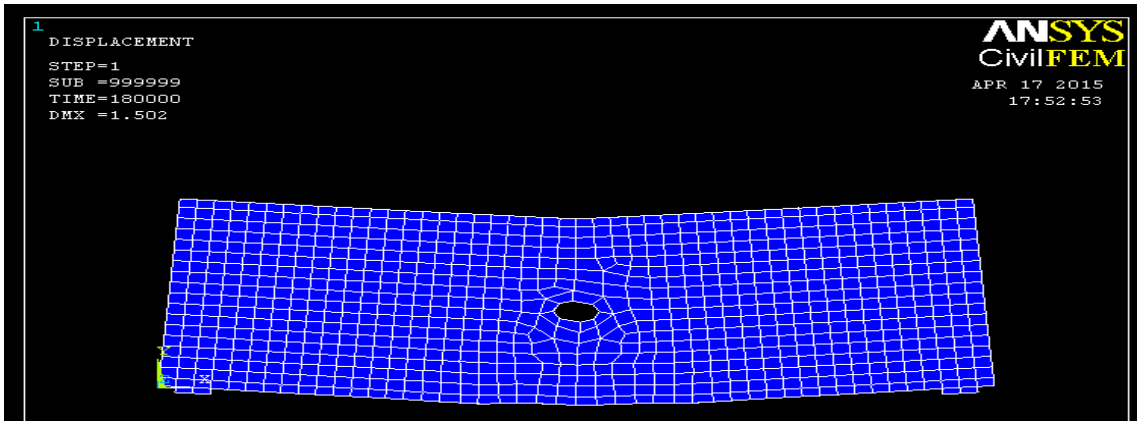

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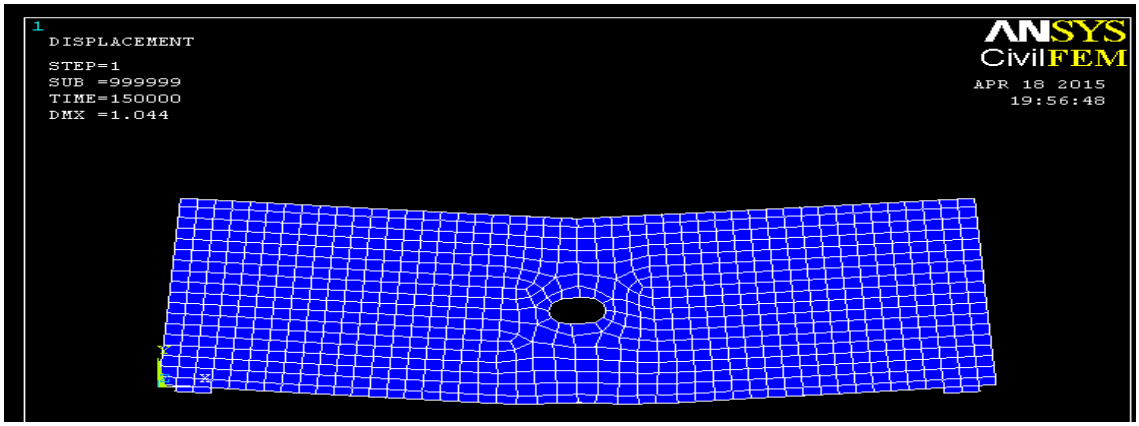

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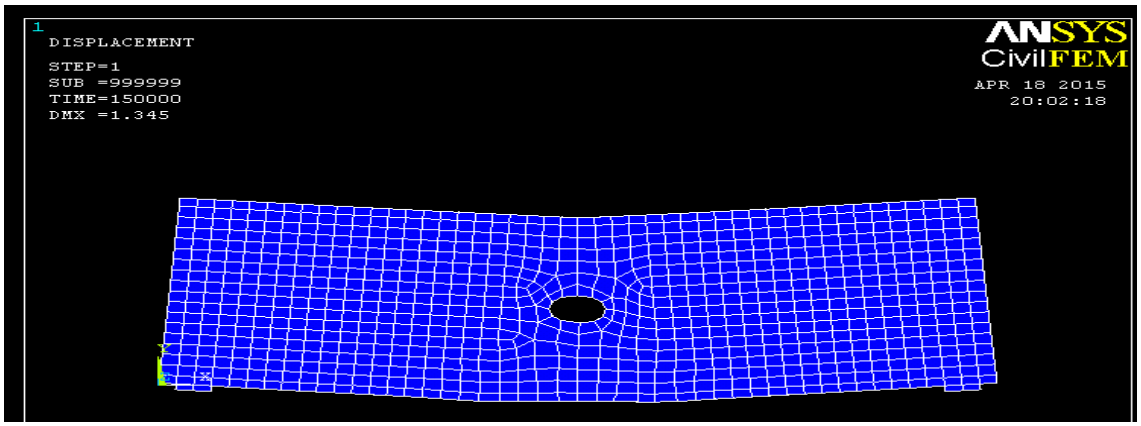

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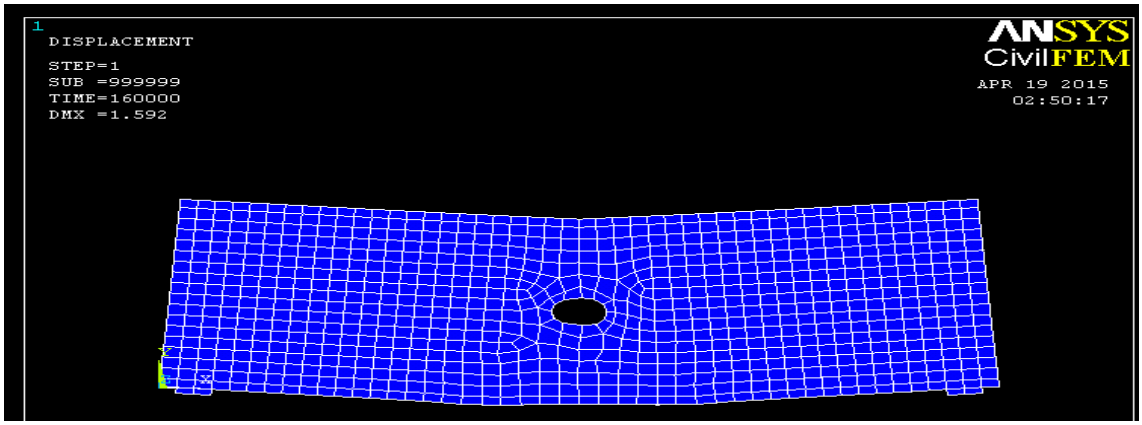

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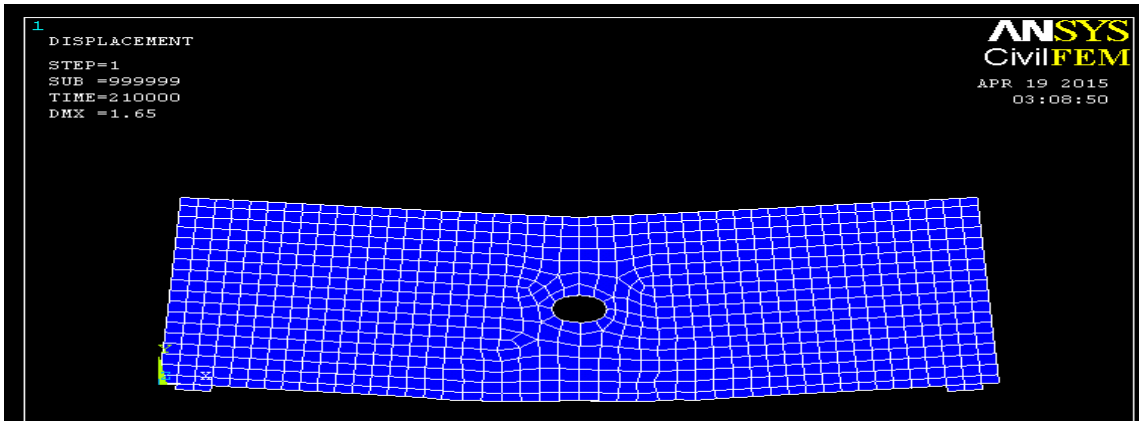

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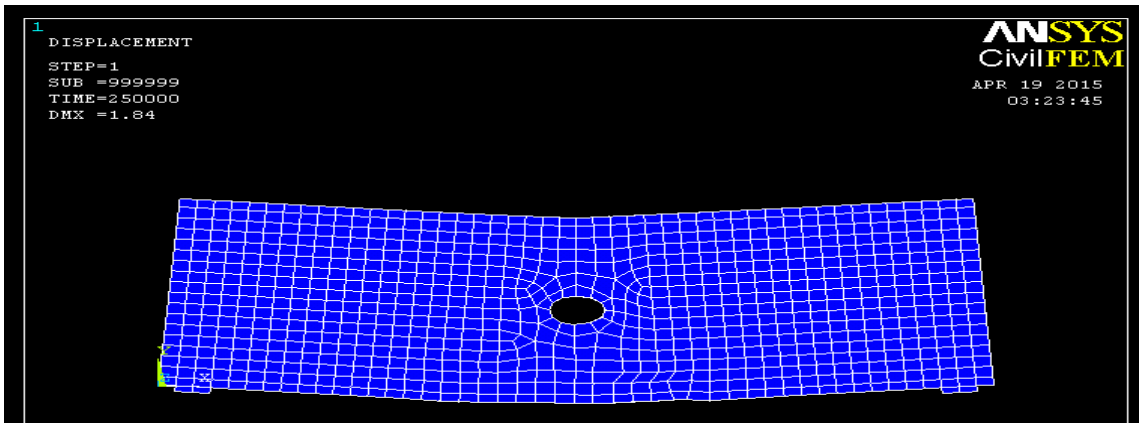

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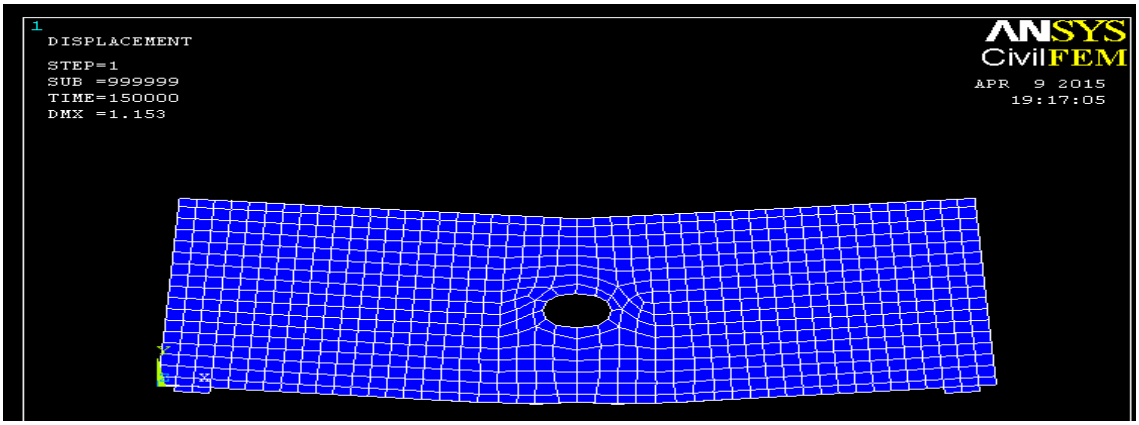

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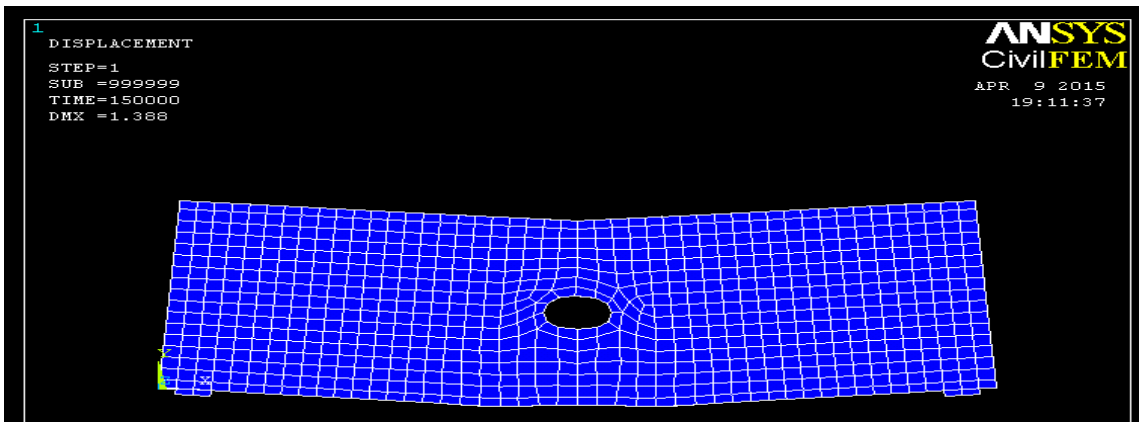

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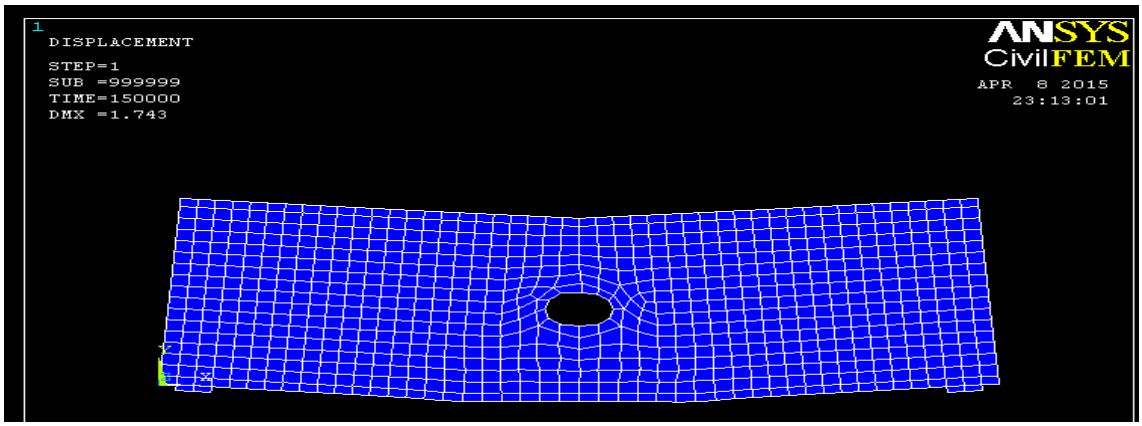

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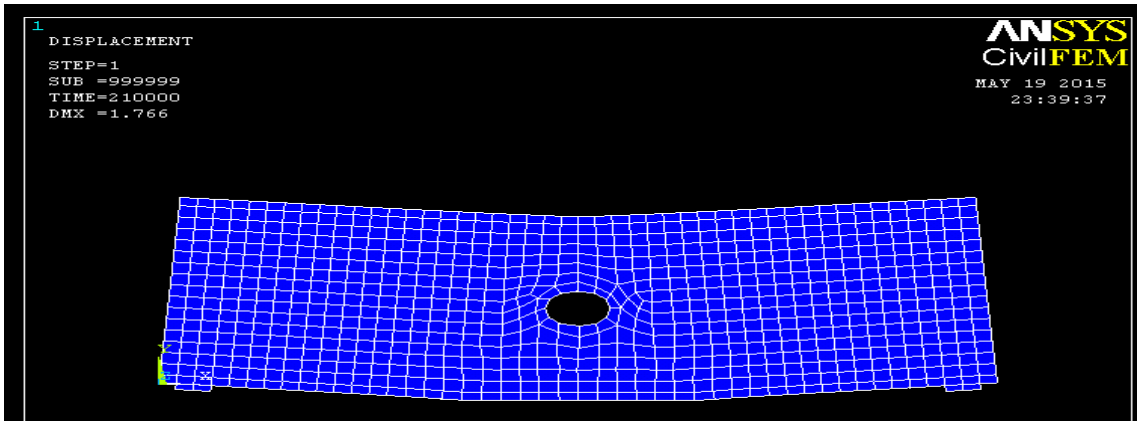

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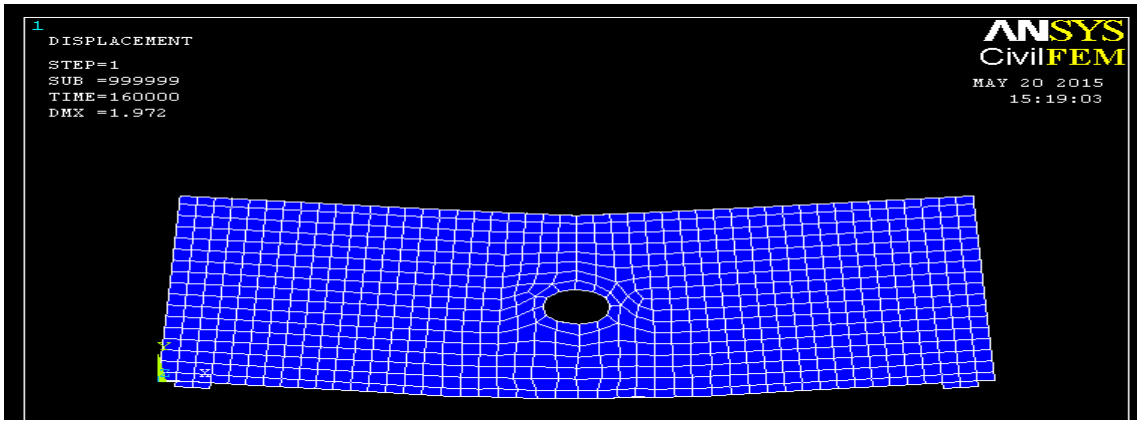

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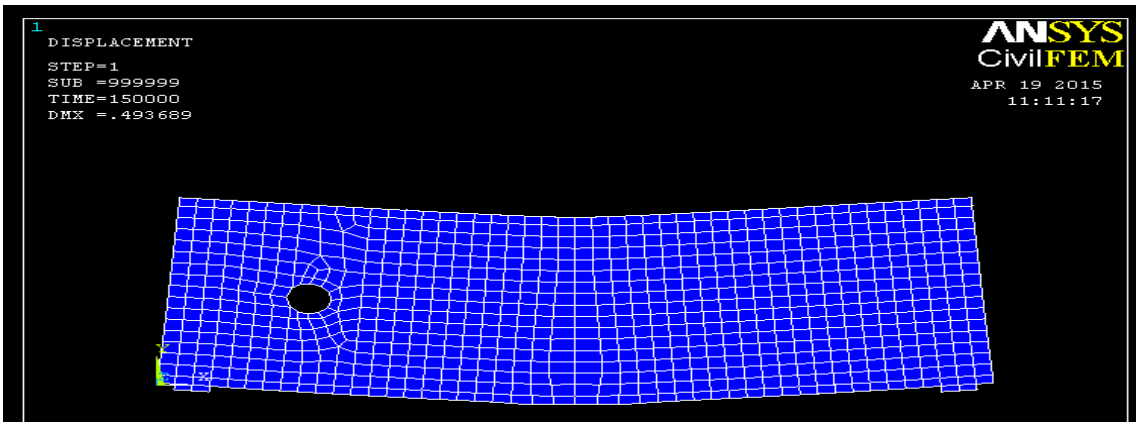
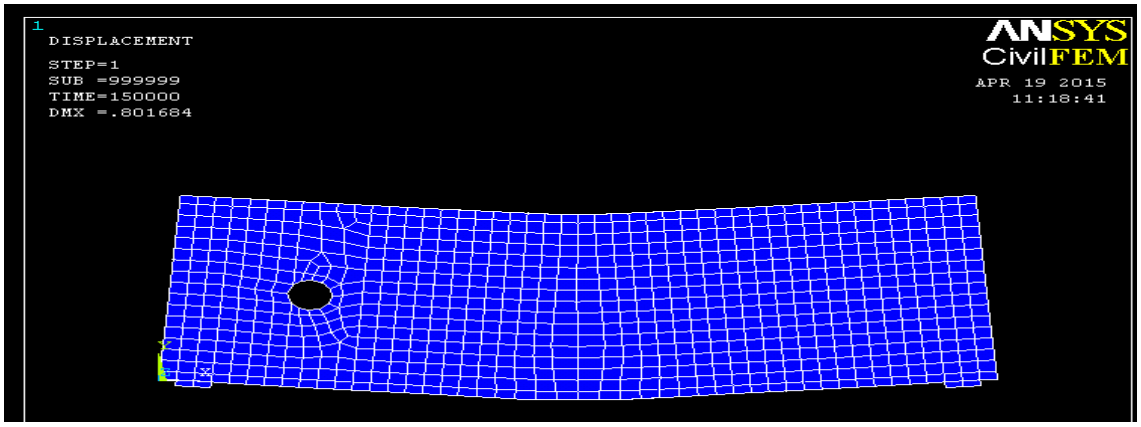


Figure 21: Deflection of DBL 1 under load 4kN



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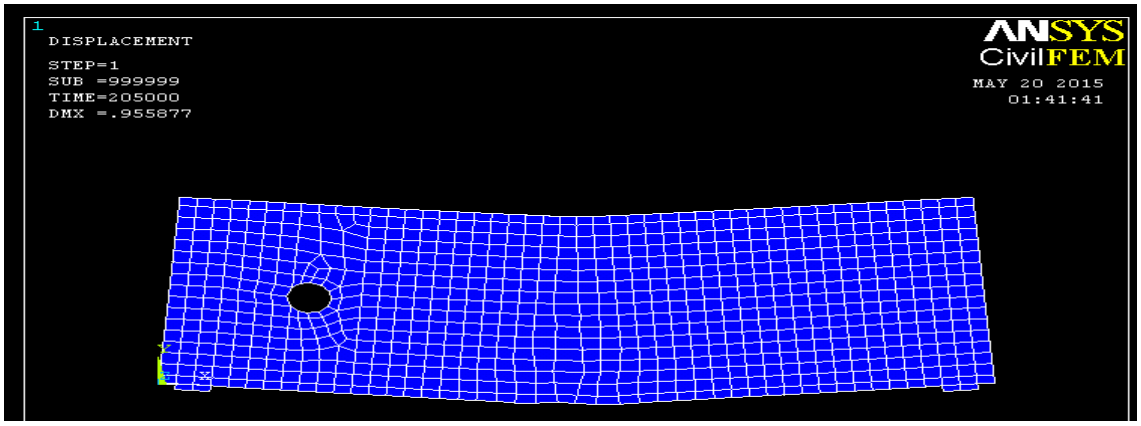

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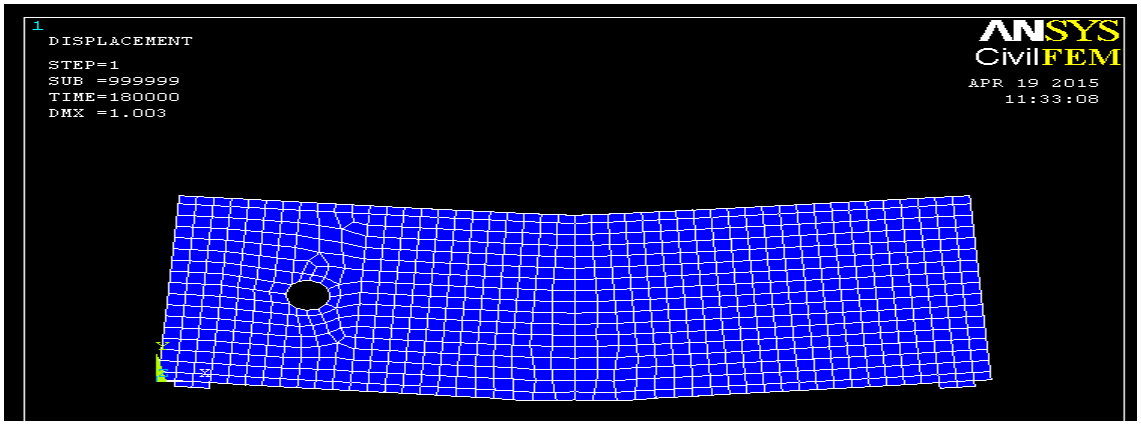

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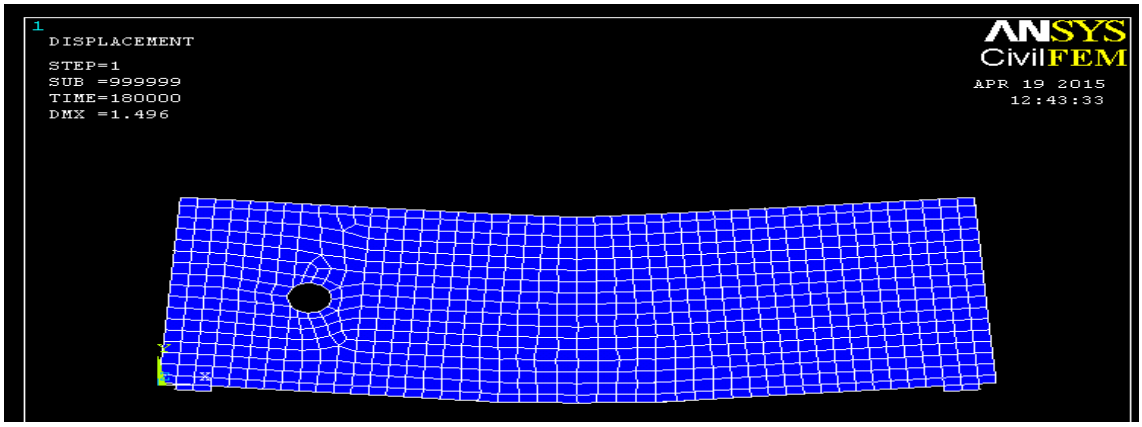

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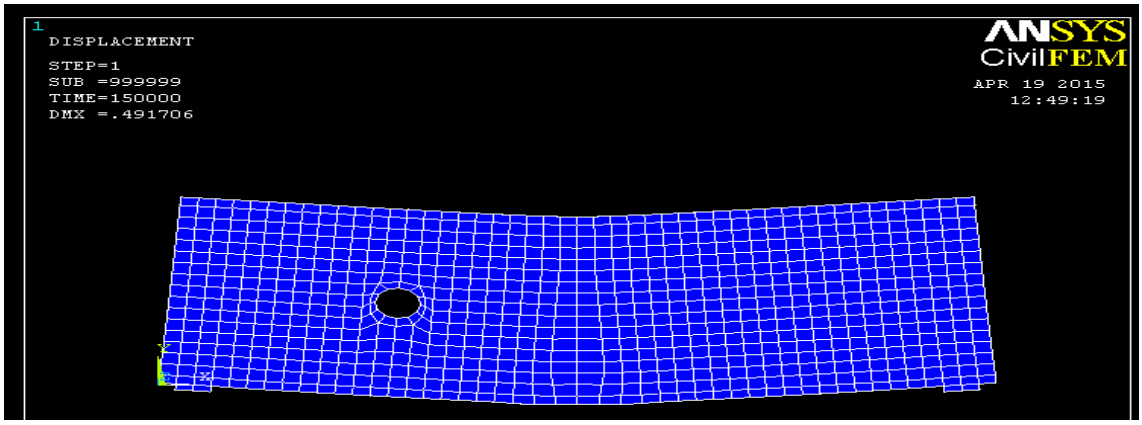

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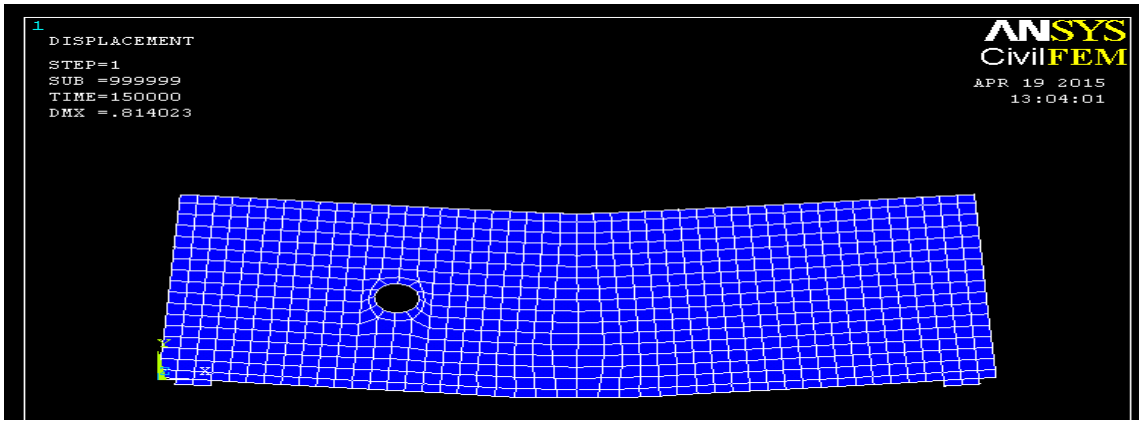

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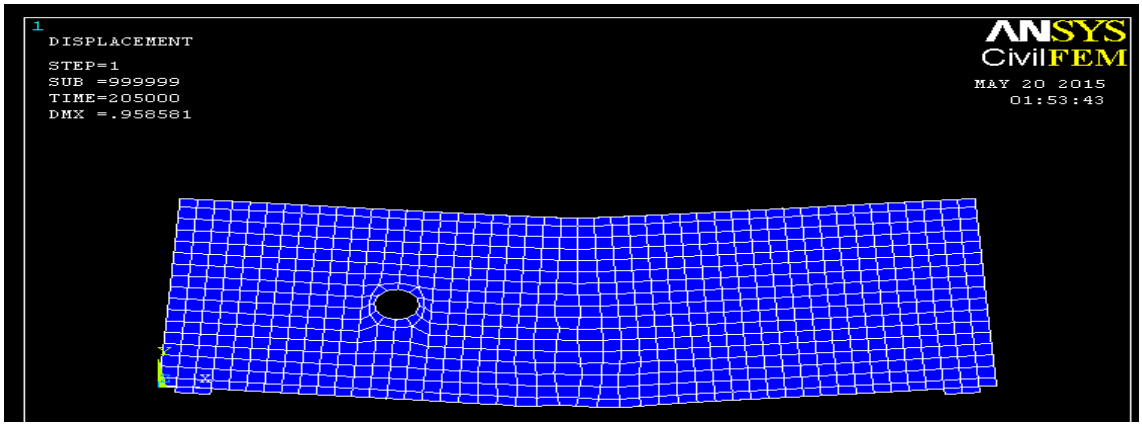

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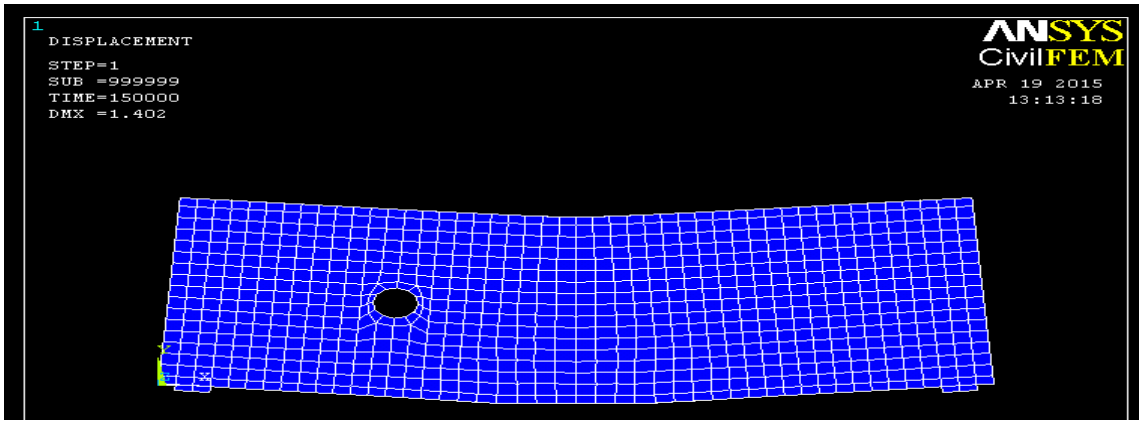

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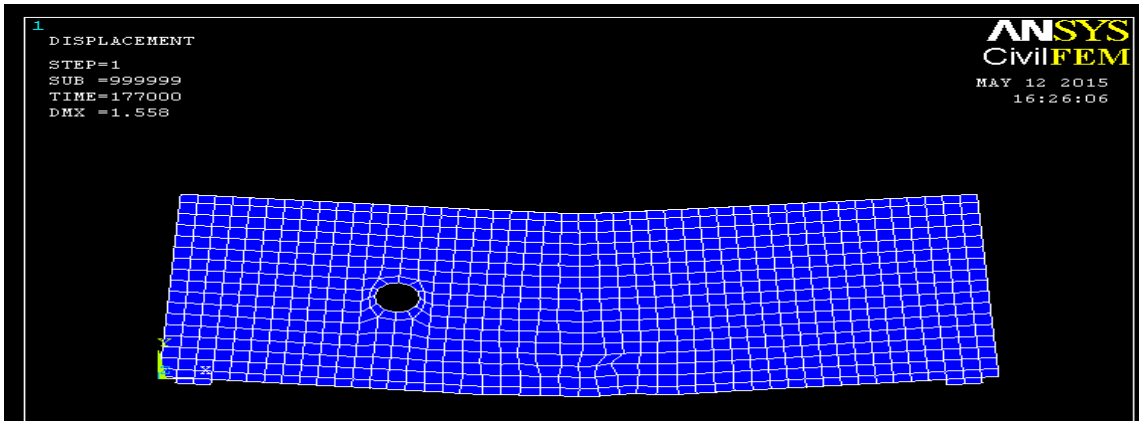

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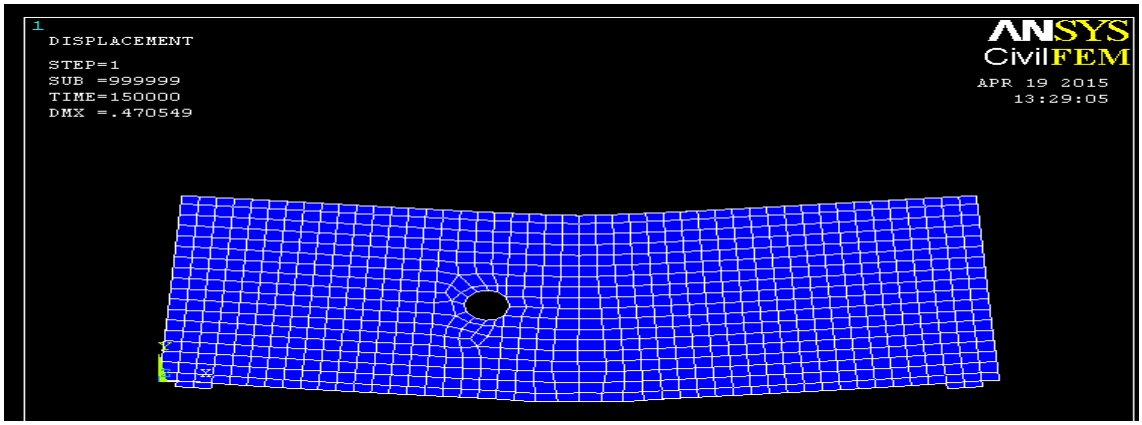

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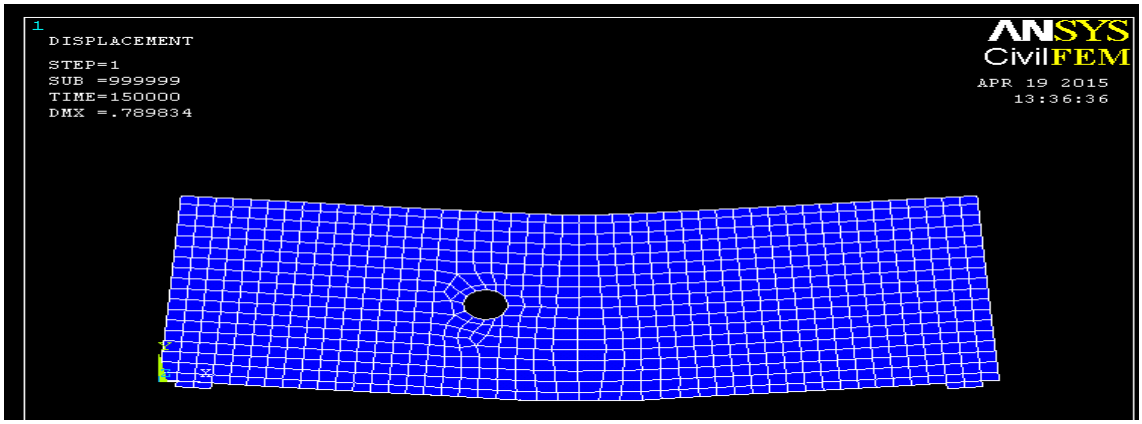

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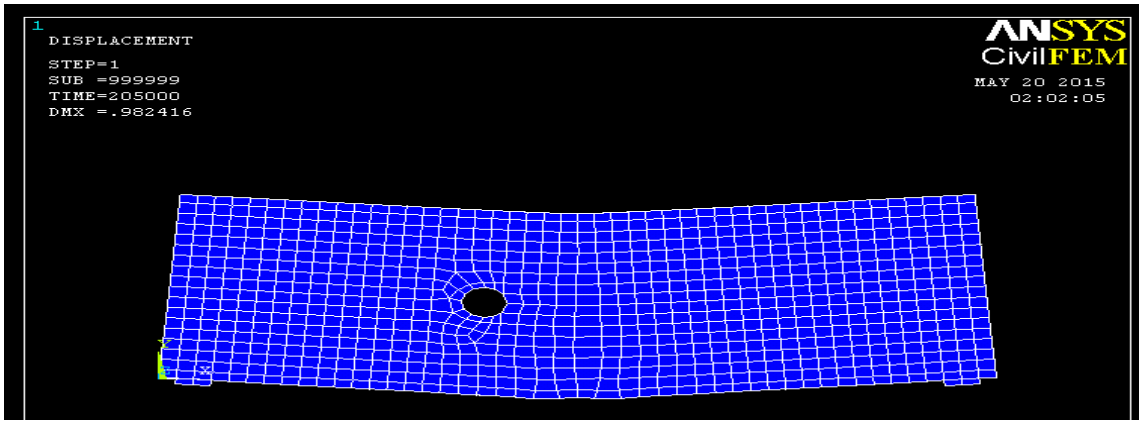

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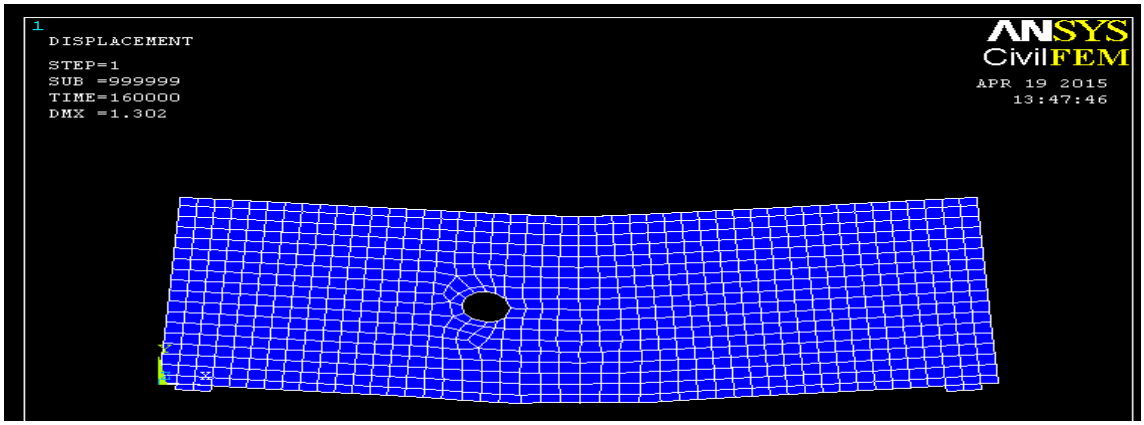

Figure 34: Deflection of DBL 3 under load 16kN

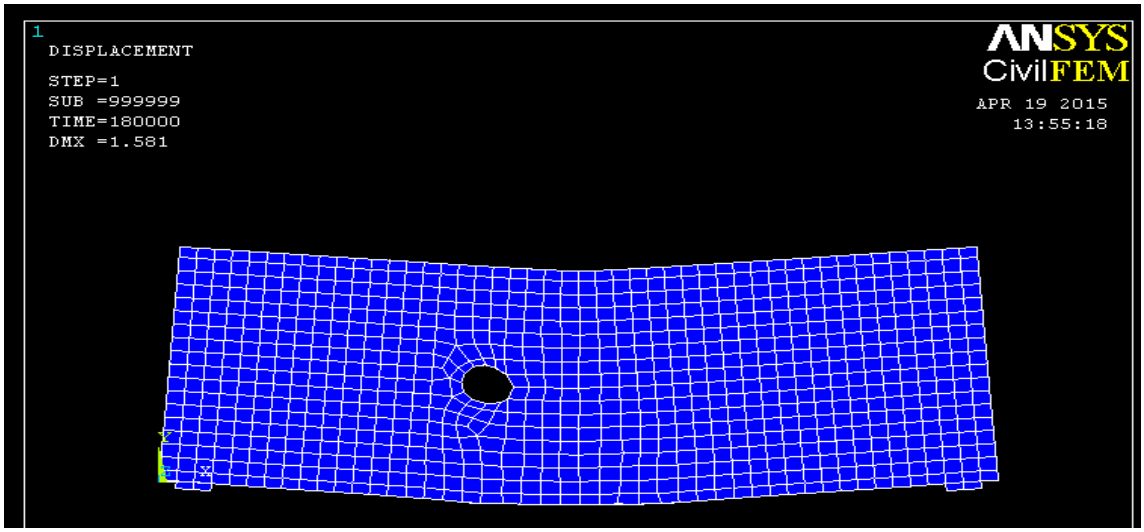

Figure 35: Deflection of DBL 3 under load 20kN