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FINITE ELEMENT ANALYSIS OF CONCRETE BEAMS USING ANSYS SOFTWARE

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ABSTRACT

This research deals with the design of concrete shell structure based on finite element method using ANSYS software. Concrete shell is a very thin shell but very strong structure. There are many researches done to analyze concrete shell using finite element method. From the researches, all the steps of calculation that included formulas to analyze the concrete shell can be found. Using ANSYS software has resulted in considerable advances in the analysis and design of any structures. While by determining the design of concrete shell using Finite Element Analysis Method with the use of matrix equations consist of global displacement matrix and also strain displacement matrix. Because all of these methods are based on simplified analysis, they cannot provide the engineer with all the desired design information and only provide the engineer with all the desired design information and only provide very limited indications. Concrete shells have lots of different type of shapes which are folded plate, spherical domes and translation shell. To analyze the design of the concrete shell, ANSYS software will be used. The software consists of three stages of design process. The first stage is preprocessing which the steps of defining the problem that included define the material, element type, shell vertex, shell properties and geometry and also meshing the model. The second stage is solution. In this stage, it will be assigning loads, constraint and solving consists of specifying the load such as point and pressure, constraint the translational and rotational and finally solve the resulting set of equations. The third stage is postprocessing where it is further processing and viewing of the results. In this stage one may wish to see the shell reinforcement design, analyze the deflection, stress and strain of the model. The materials for the concrete shell are concrete and reinforcing steel.

ABSTRAK

Kajian ini memperkatakan dengan reka bentuk struktur shell konkrit berdasarkan kaedah unsur terhingga menggunakan perisian ANSYS. Konkrit shell adalah shell yang sangat nipis tetapi struktur yang sangat kuat. Terdapat banyak kajian yang dilakukan untuk menganalisis shell konkrit menggunakan kaedah unsur terhingga. Dari kajian, semua langkah-langkah pengiraan yang termasuk formula untuk menganalisis shell konkrit boleh didapati. Menggunakan perisian ANSYS telah menyebabkan kemajuan besar dalam analisis dan reka bentuk apa-apa struktur. Walaupun dengan menentukan reka bentuk shell konkrit menggunakan Analisis Kaedah Unsur Terhingga dengan penggunaan persamaan matriks terdiri matriks anjakan global dan juga ketegangan matriks anjakan. Kerana semua kaedah ini berdasarkan analisis dipermudahkan, mereka tidak boleh menyediakan jurutera dengan semua maklumat reka bentuk yang dikehendaki dan hanya menyediakan jurutera dengan semua maklumat reka bentuk yang dikehendaki dan hanya memberikan tanda-tanda yang sangat terhad. Cengkerang konkrit mempunyai banyak jenis yang berbeza bentuk yang dilipat pinggan, kubah bulat dan shell terjemahan. Untuk menganalisis reka bentuk shell konkrit, perisian ANSYS akan digunakan. Perisian terdiri daripada tiga peringkat proses reka bentuk. Peringkat pertama adalah prapemprosesan yang langkah-langkah menentukan masalah yang termasuk menentukan bahan, elemen jenis, mercu shell, shell hartanah dan geometri dan juga bersirat model. Peringkat kedua adalah penyelesaian. Pada peringkat ini, ia akan memberikan beban, kekangan dan menyelesaikan terdiri daripada menyatakan beban seperti titik dan tekanan, kekangan translasi dan putaran dan akhirnya menyelesaikan set terhasil persamaan. Peringkat ketiga adalah pascapemprosesan mana ia lagi memproses dan melihat keputusan. Pada peringkat ini seseorang mungkin ingin melihat reka bentuk tetulang shell, menganalisis pesongan, tegasan dan terikan model. Bahan-bahan untuk shell konkrit adalah konkrit dan mengukuhkan keluli.

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LIST OF SYMBOLS

N_i	Shape function matrix of the degenerated shell element
h	shell thickness
ζ	z axis coordinate of shell element
ξ	y axis coordinate of shell element
η	x axis coordinate of shell element
$\{\sigma\}$	is the stresses matrix in direction of x, y, and z for three-dimensional model
ε	Strain
$[D]$	Constitutive matrix for the model
ν	Poisson's ratio
E	Young's Modulus
$\{\varepsilon\}$	Strain of the concrete shell in direction of x, y and z
$[B]$	Strain displacement matrix
$\{\delta\}$	Displacement vector

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete shell has a meaning that consider as a very thin shell concrete structure. According to studies, the concrete shell structure contained a particularly thin shell of concrete sometimes with no interior columns or any exterior buttresses. A buttress is an architectural structure that built against or stick from a wall which serves to support or also could reinforce the wall. General and common sizes of concrete shells are between ellipsoids or cylindrical sections or combination of both of the shapes. Other than that, the concrete shell can also be in the form of plates or domes.

Most building that commonly uses concrete shell as the structure of their buildings is including storage facilities, commercial buildings and also residential homes. Customary, curved shaped that often used for concrete shells are strong structure. This is because it's allowing wide areas to be spanned without the use of internal supports, giving an open obstructed interior. Modern thin concrete shells, which began to appear in the 20s, are made from a very thin steel reinforced concrete, and in many matters, lack of any ribs or additional reinforcing structures, depending entirely on the shell structure itself. Furthermore, the used of concrete as the building material decreases the costs of material and also construction where concrete is generally cheaper and easy to shape it into any compound curve. The construction of concrete shells began in since 1920s. The shells are made from thin steel reinforced concrete.

The oldest known concrete shell is called the Pantheon that was established in Rome. It is still standing where the diameter of the dome is 43 meter with a circle hole at its centre. There are several types and forms of shell structure that built around the world. The types are folded plate, barrel vaults, and short shells, changes of domes, folded plate domes, intersection shells, warped surfaces, combination and shell arches. There are really unique and has its own aesthetic value when it constructed on any building. But not all building was constructed with thin shell structure.

From previous study, thin shell concrete structures are pure compression structures formed from inverse catenary shapes. Catenary shapes can be defined as for those taken by string or fabric when allowed to hang freely under their own weight. As the string can no longer support compression, the free hanging form is in tension. The reverse of this form is a compression of a structure. Compression is an ideal for concrete as concrete has high compressive strength and very low tensile strength. These shapes of concrete shells maximize the effectiveness of the concrete itself, allowing it to form thin light spans (Jessica Mandrick, 2000)

Finite element formulations are presented for improved analysis of reinforced concrete shell structure critical in shear. The accuracy formulation is examined by investigating three different series of test, subjected to transverse shear and flexure which hollow rectangular over and under reinforced beams subjected to torsion and flexure and a scale model of an offshore structure subjected to hydrostatic pressure.

ANSYS software is a general purpose finite element modeling package for numerically solving a wide variety of problem including static/dynamic structural analysis which is both linear and non-linear according to University of Alberta ANSYS Tutorial. Other than that, workbook and tutorial E are provided specially for the tutorial of ANSYS CivilFEM with all related to Civil Engineering topics.

For the analysis, ANSYS software could produce finite element analysis results, in which are element OK or not OK, forces and moments, stress and strain, code checking for

Eurocode 2 and Eurocode 3, buckling, deflection, deformation and lots of other results in terms of engineering that we can get using ANSYS software. With the result, many things can be adjusted to improve our design on structure and improve it without wasting any time by determine the problems using hand calculations. But sometimes, there are students that did their research on concrete shells by comparing the result of finite element method calculation with the result from ANSYS analysis.

1.2 PROBLEM STATEMENT

The design of concrete shell can manually determined using Finite Element Analysis Method with the use of matrix equations consist of global displacement matrix and also strain displacement matrix. Because all of these methods are based on simplified analysis, they cannot provide the engineer with all the desired design information and only provide very limited indications.

Concrete shells consist of many different types of shapes. The shapes are such as folded plate, spherical domes, and translation shells. These different types of concrete shells might also have the different result when analysis of finite element is applied to these types of concrete shells.

The introduction of ANSYS CivilFEM software has resulted in considerable advances in the analysis and design of any structures. Therefore, it is of great encouragement to study and understand the use of software in solving the practical problem.

1.3 OBJECTIVE

- a) To analyze the effect of shell thickness of spherical shell to deflection, stress and strain.
- b) To make observation of deflections of spherical shells with different thicknesses using ANSYS software.

1.4 SCOPE OF STUDY

To be able to achieve all the objectives of this project, scope of works has been identified in this research. The very first scope of works is to learning and getting use to using ANSYS software to solve finite element problems. Then, practice the workbooks and tutorials for ANSYS software that have been provided. The study to show how load will affect the structure generally and more specific, how load affect to the deflection, stress and strain of the structure.

To complete this project, the main thing to search is the title of the project. Before selecting the perfect title, doing some research on previous thesis made by graduated students' journals is privilege. In this project, I chose to do research on analysis of concrete shell using ANSYS software. Therefore, I need to study on what is concrete shell, how many type does concrete shell have, what are the uses of concrete shells in Civil Engineering and also how to run concrete shell using ANSYS software.

To complete this report, I need to find as many journals that related to concrete shell as I can find. There are so many researches that have been done about concrete about lots of difference aspects. From this, I could also get the formulas that can be used to calculate by finite element method manually. To achieve my understanding on the topic, I need to really understand about concrete shells. Therefore, I might be able to improve the future construction on concrete shell.

To get the result from ANSYS software, the study on the workbooks and tutorial E provided. By studying these tutorials, I may know how to get results for my topic and also how to design the concrete shell using ANSYS software. Every different structure has different steps to used using the software. Understanding the steps is also privilege for this project to be done perfectly. The workbook helps to design the modeling that going to be use for final year project. For this project, the BS 8110 (British Standard 8110) will be used for the design of the structure. The material of concrete and reinforce steel are according to the BS 8110.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO CONCRETE SHELL

Shells are one of the most important members of structures. Other name for concrete shell is thin shell concrete structure due to the very thin shell of concrete composed. It is generally in the form of flat plates and domes but sometime in the form of ellipsoids or cylindrical sections and sometime in the combination of both. The first concrete shell construction take placed in the 2nd century.

Many shells structures have other different shapes than spherical or cylindrical. There are even cone shape, pyramid shape, parabolic, folded and others. Materials for shells are either constructed of concrete or reinforced concrete. The reinforced concrete combined another advantage where tensions were resisted by steel bars. This material was described by Eduardo Torroja, as “technically the most nearly perfect material” (Torroja, 1962).

Spherical shells are the most constructed shell. Spherical shell also called as monolithic dome is the most selected by designer to build probably because of its unique structure and very elegant to build. In other countries, lots of building that built with domes. The buildings are included studio apartment, school, church, and even houses. Construction of domes is quick and easy according to the contractor that builds domes. Other than that, spherical shells consider a super structure where it is very strong and could also survive from hurricane.



Figure 2.1: Styrofoam dome houses at Aso Farm Land (Photo by: Erika Snyder)

2.2 BASIC CONSIDERATION

First consideration for concrete shell is thickness. For concrete shell, the overall thickness should not be less than 50 mm for singly curved shells. Commonly, the thickness of the shells is around 80mm to 120mm based on general consideration (Hammad Al-Azzawi, 2011).

The second consideration is span and chord width. For the span of reinforced should not be greater than 30 m to limit the size and reinforcement with in practicable limits in the edge beams. The width of the edge member is limited to 2 to 3 times the thickness of the shell (Hammad Al-Azzawi, 2011).

The third consideration of shell is depth of shells. For large span shells, the depth (1/6) to (1/12) span large figures are applicable to small spans for shells without edge members, depth for span/10 shells with chord with much larger than the span depth (1/10) chord width (Hammad Al-Azzawi, 2011).

The fifth consideration of shell is the reinforcement in shell where the diameter of reinforcements should not exceed 10 mm for 50 mm thickness shells and 12 mm for 65 mm thickness shell and 16 mm for shells having thickness greater than 65 mm in the junction zones where the shell is thickened, large diameter bars are allowed. The spacing of the bars should not be more than 5 times the thickness of the shell. Minimum clear cover must be 12 mm or the nominal size of the reinforcing bar. Generally a minimum reinforcement of 0.15 percent of the gross cross section in the principal direction is recommended for thin shell structures (Hammad Al-Azzawi, 2011).

The sixth consideration for concrete shell is its semi central angle. The semi central angle should be in the range of 30 to 45 degrees. If the angle is less than 45 degree, the effect of wind load may be ignored. For larger angles with steep slopes, back forms may be necessary for casting (Hammad Al-Azzawi, 2011).

Therefore, concrete has its own limitation of thickness, span and cord width, depth of shell, reinforcement on shell and semi central angle. If these limitation of sizes of the concrete shell is over the limit, then the concrete shell might undergo a failure and cannot be constructed and do not last for a very long time compares to other concrete shell. One of concrete shells that have been constructed a long time ago still stands until this day.

2.3 STRUCTURAL DESIGN AND ANALYSIS OF THIN SHELL STRUCTURES

Structural design of the thin shell concrete structure is going to be computed using geometrical shape equations. The design will be 'anticlastic' meaning that its main curvatures run in opposite directions, like the hyperbolic saddle. The shell will be subject to analysis of stress and deflection using ANSYS+CivilFEM 12.0 finite element software. ANSYS+CivilFEM 12.0 software will reveal many critical areas and may also lead to modifications in the design if the strength of the concrete shell is surpassed at any point. The structure will most likely be modeled using plates. When the concrete shell is analyzed for stresses and deflections where the axial stresses represent the tension and compression,

and the stresses in diagonal members represent the shears within the thickness of the shell (Jessica Mandrick, 2000).

2.4 CONCRETE SHELL STRUCTURE REVISITED.

The concrete shell structures appears to be the limiting factor with respect to awareness of concrete shell structure in an economically in an interesting ways during the construction process. Therefore, to stay in touch with digital modeling in technology that has been used in engineering and design. Considering the way shell surfaces are developed either experimentally, digitally or analytically, it really is make sense to be the most effective way of construction. By using principles derived from 'nature' also to the real time gridshell construction where it save time, labour and also the materials used, Vacuumatics formworks produce a reasonably prompting and approaching 'low tech' for constructing with efficiency getting the shaped concrete shells with the inspiration for the previous philosophy (Frank Huijben, Frans Van Herwijnen, Rob Nijse (2011).

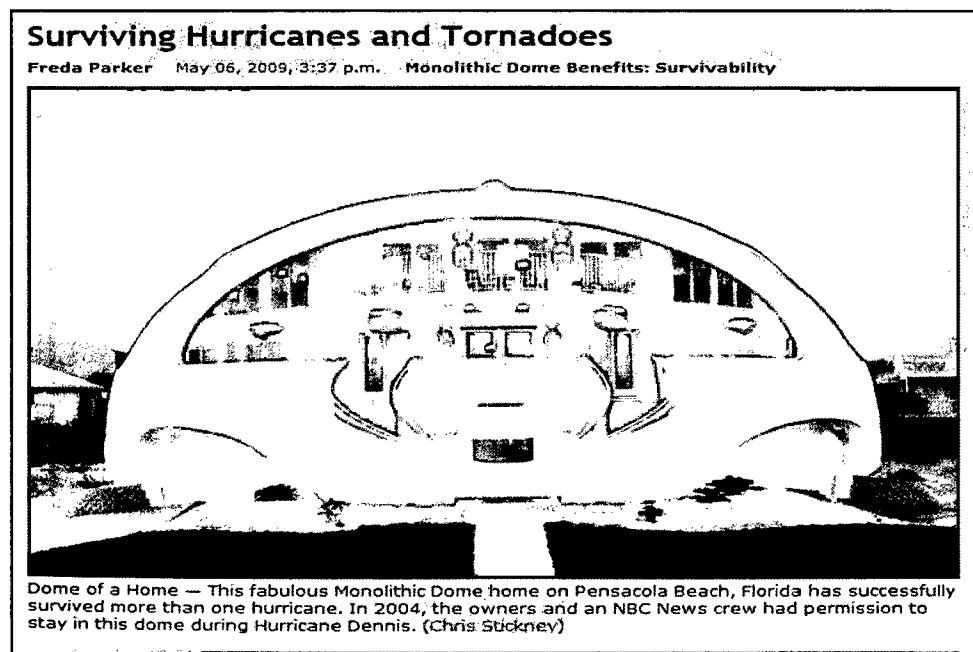


Figure 2.2: Monolithic dome home that survived from hurricane

2.5 SHELL DEGENERATING

According to the previous study by M.L Bucalem and K.J Bathe, it is stated that degenerating the shell approach is very interesting way to use the thin shell theory. Shell behavior will be described in this approach by imposing thoughtfully on the three dimensional continuum mechanics conditions. The shell element formulations presented by Ahmad have some key features that make a very suitable for shell finite element construction. Where the formulation is suitable for any shell geometry, enough for thin and thick situations and only uses engineering nodal point degrees of freedom such as displacement. Even though the displacement based formulation of all the elements are very prominent in features, which it is very demanding to be used in engineering practices, it will suffered from serious shortcoming of membrane and shear locking.

2.6 DEVELOPMENT OF SHELL FINITE ELEMENT

By the study from M.L Bucalem and K.J Bathe, they say that the development of shell finite element should be guided by some requirements which are the element the shell should be reliable, should be computationally effective, it should be general where the element should be applicable to non-linear analysis of geometric and non-linear solutions, thick and thin plate or shell situations and in any shell geometry and lastly the formulation should be clear and simple to cause the elements suitable for engineering analysis.

2.7 FINITE ELEMENT DEFLECTION IN SHELLS

In the previous study by Asokendu Samantha and Madhujit Mukhopadhyay on large deflection static analysis of shallow and deep stiffened shells, stated that static analysis of composite and isotropic stiffened shells has been completed by Liao and Redy where they use continuum based stiffened composite shell element. The study made to analysis the deflection in shell is based on the load on the shells. From the result provided, as the load increases, the deflection that only taken at the center of the shell also increases. Therefore, in this project, it is required to try to analysis shell displacement with different thicknesses.

2.8 KIRCHHOFF HYPOTHESIS

The Kirchhoff hypothesis assumed that deformations of shell in such way that particles starting on a normal to the references surface will find themselves after the shell is deformed on the same normal where their range from the references to the surfaces are unchanged. This hypothesis made by Kirchhoff is a primacy of all the observations that in many other situations where a very little shearing of extension happened through the thickness over major portions of the shells during deformation.

Therefore, it is assume that the shell is of uniform thickness and identify the references surface with the middle surface of the shell, although any surface parallel to the middle surface would give an equivalent theory.

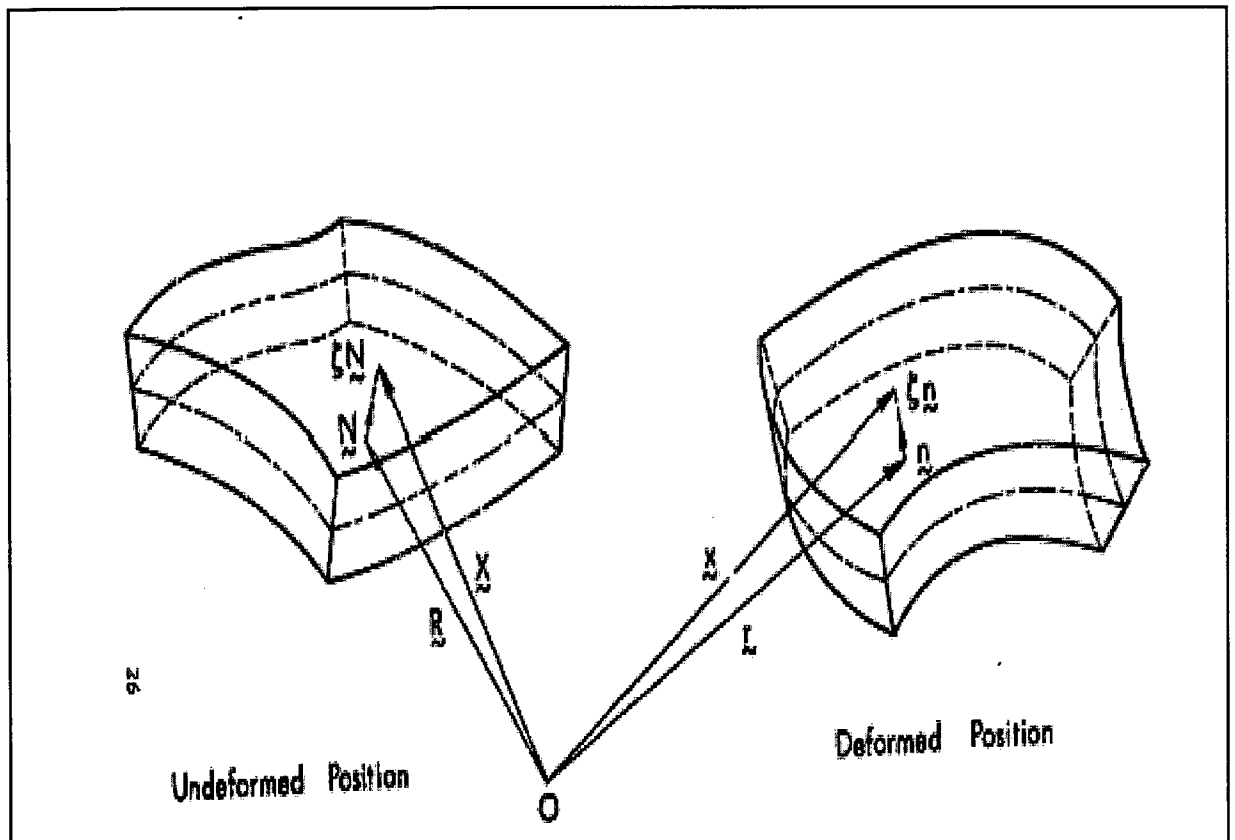


Figure 2.3: The deformations of the shell under Kirchhoff hypothesis

2.9 DEFINITION OF STRAINS

Strain is any quantity measuring the amount of stretching that occurs in the local neighborhood of a particle during deformation according to Joseph I. Santiago. In any case in engineering, a force or load causes a deformation of the length of the structure. In engineering, usually will be change the forces in stress while the deformation in strain where strain could also be defined as the deformation per unit of the original length. Strain is a value without units since it is a ratio of length to length. Most of the engineering materials does not stretching too much before it break down and become damaged. Therefore, strain values are very small. Engineers would use the abbreviation of μ to denote the value of strain.

2.10 DEFINITIONS OF STRESS

When forces are applied to an elastic body, deformation will occur on the body. The way in which the body deforms depends on the type of force applied to it. Compression force makes the body shorter while tensile force makes the body longer. Stress can be defined as force per unit area upon which it acts. In this project the force applied to the surface of the shell will be assumed as constant.

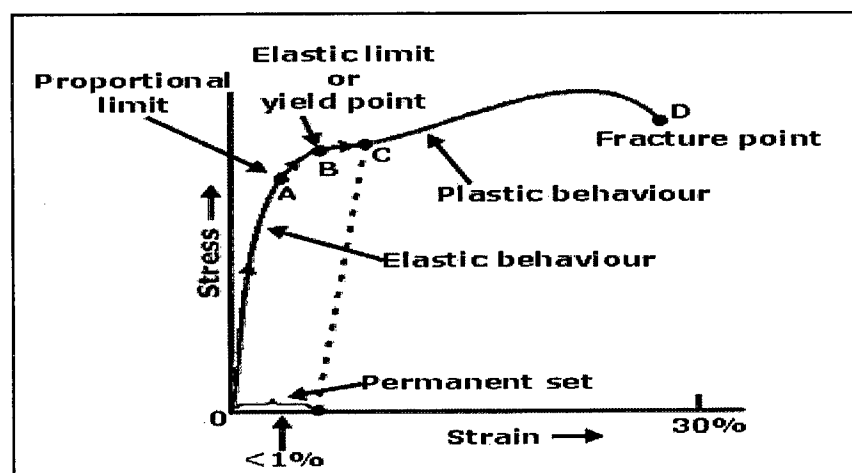


Figure 2.4: Stress and Strain relationships

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss the method used to analyze and model the structure. Finite element method (FEM) was used to get the solution for the forces and moments of the reinforced shell and also the shell reinforcement results. ANSYS program will be used to analyze the forces and moments of the reinforced shell and also the shell reinforcement results. In ANSYS, the analysis may be broken into three stages which are preprocessing, solution, and post processing. In preprocessing stage, model will build to define key points, element type and material, and mesh lines as required. While for the solution stage, the loads and constraints will specify and finally solve the resulting set of equations. In post processing stage, the viewing results will produced such as performing the shell reinforcement design, analyze shell reinforcement results and analyze reinforced shell forces and moments or any other results viewing that needed to see for the purpose of the research and also to achieve the objectives. The result viewing is the most important part of the analysis because it will show the result that needed which make the modeling can be run smoothly which can be proceed to the result. To make it run smoothly, doing the steps correctly is crucial. With the correct step, analysis is correct and can produce the solution.

3.2 DESIGN PROCESS

In the design process for this project, software ANSYS+CivilFEM 12.0 were used. The finite element analysis using ANSYS+CivilFEM software is divided into three stages.

The stages include of preprocessing, solution and post-processing. In the preprocessing stage, the modeling will be defining it material of the model. The material used for the model in this project is concrete grade C30 according to BS 8110 and the reinforce steel of the concrete shell where will be taken as 460N/mm^2 . Then in the same stage, the shell properties and geometry will be added. Mesh the model to insert the surface of the model is also in the preprocessing stage.

Next stage is solution. In solution, providing the load for the structure, limitation and also solving the modeling to get its result. For this, the models will be stated its loads either point load or pressure load on the surface of the shell. Limitation is where the translation and rotational will be provided. Finally, the complete model with complete features will be solving to get the result by the use of set of equations from the software.

Lastly is the post-processing process. Post processing process is a forward processing and producing the results. Any results that related to the modeling made and desired result to be analyzed. For this project, results that will be produce is going to be the deformed shape of the spherical shell, the deformation values from the axis of x, y and z, the stresses values and the elastic strain of the modeling.

3.3 PREPROCESSING

Before doing anything with ANSYS software, it is encouraged to insert the first. To make the title, the button is in the file menu and change title to appear the change title dialog box where desired title of the project can be typed.

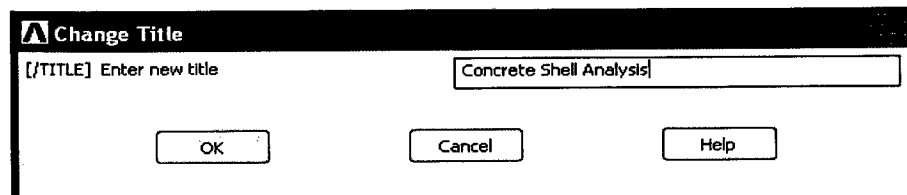


Figure 3.1: Change title dialog box

After that, after putting the title for the project, the software needs to be set the codes and units to be used during the analysis process. For this project, the codes used is only the reinforced concrete code that include the concrete grade and steel reinforcement strength which will be change to British Standard 8110(BS8110). For the unit, the system unit will be selected as user unit where force unit will be change from Newton to Kilo Newton.

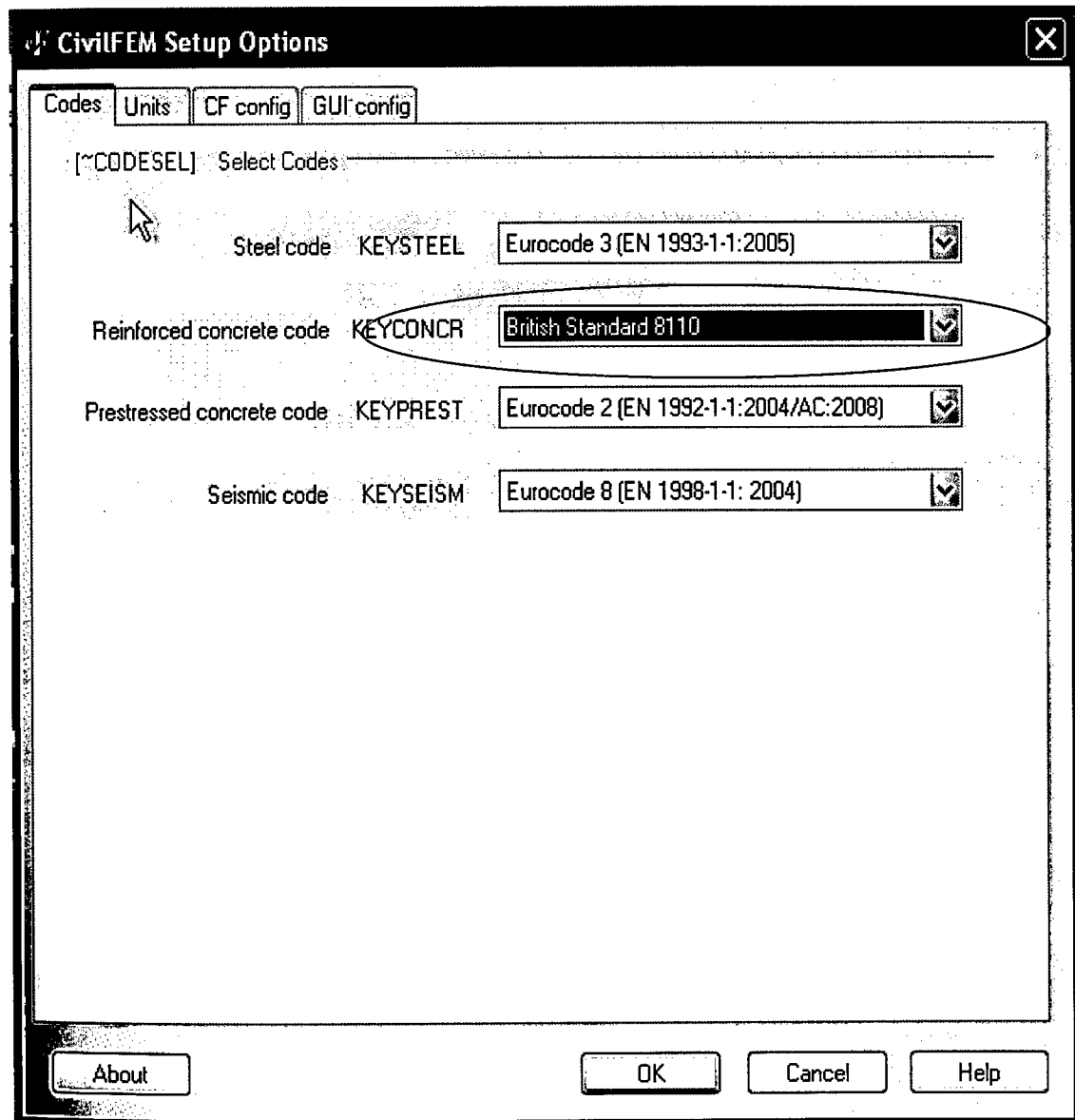


Figure 3.2: CivilFEM setup codes option dialog box.