FINITE ELEMENT ANALY[illegible]SING ANSYS SOFTWARE

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ABSTRACT

This research deals with the analysis of helical staircase based on finite element method using ANSYS software. Helical staircase is just a type from many type of staircase that has been designed and used nowadays. Helical stair has an open well at the center which is a continuous slab staircase without a central core. A helical is warped surface generated by a line wrapped around a central imaginary core. It will be like the curve of a screw. The slab is like inclined plane. It can be circular or elliptical (it has no central 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 helical staircase 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 three-dimensional using Finite Element Analysis Method (FEM) 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. To analyze the design of the helical stair, ANSYS software will be used. From the research study, two cases of study with five models have been design in order to compare and manage the results. The case 1 is where two model has been design with the reasons are to study the effect of different central angle to the helical staircase in terms of deflection and stress distribution. The obtained results for case 1 has proven that the least of central angle for degree of rotation will caused deflection and stress distribution results decrease also. While for the case 2, three models with different size of waist thickness has been create in order to complete the study of effect of waist thickness effect to helical staircase in terms of deflection and stress distribution. From the results obtained, it has been prove that, the greater size of waist thickness of helical staircase, the decrease the value in terms of deflection and stress distribution.

ABSTRAK

Kajian ini membincangkan analisis tangga heliks berdasarkan kaedah unsur terhingga menggunakan perisian ANSYS. Tangga Helicoid hanya satu jenis daripada banyak jenis tangga yang telah direka dan digunakan pada masa kini. Tangga heliks mempunyai juga terbuka di tengah-tengah yang merupakan tangga papak berterusan tanpa teras pusat. Helicoid adalah permukaan sesat yang dihasilkan oleh barisan dibalut di sekeliling teras khayalan pusat. Ia akan menjadi seperti lengkung skru. Papak adalah seperti satah condong. Ia boleh bulat atau elips (ia tidak mempunyai struktur pusat). Terdapat banyak kajian yang dilakukan untuk menganalisis shell konkrit menggunakan kaedah unsur terhingga. Dari kajian, semua langkah-langkah pengiraan yang termasuk formula untuk menganalisis tangga heliks boleh didapati. Menggunakan perisian ANSYS telah menyebabkan kemajuan besar dalam analisis dan reka bentuk apa-apa struktur. Walaupun dengan menentukan reka bentuk tiga dimensi menggunakan Analisis Unsur Terhingga Kaedah (FEM) dengan menggunakan persamaan matriks terdiri daripada matriks anjakan global dan juga tekanan matriks anjakan. Kerana semua kaedah ini adalah berdasarkan kepada analisis yang mudah, mereka tidak dapat menyediakan jurutera dengan semua maklumat reka bentuk yang dikehendaki dan hanya menyediakan jurutera dengan semua maklumat reka bentuk yang diingini dan hanya memberikan tanda-tanda yang sangat terhad. Untuk menganalisis reka bentuk tangga heliks, perisian ANSYS akan digunakan. Daripada kajian penyelidikan, dua kes kajian dengan lima model telah reka bentuk untuk membandingkan dan menguruskan keputusan. Kes 1 adalah di mana dua model telah reka bentuk dengan sebab-sebab adalah untuk mengkaji kesan sudut pusat yang berbeza untuk tangga heliks dari segi pesongan dan tekanan pengedaran. Keputusan yang diperolehi bagi kes 1 telah membuktikan bahawa kurangnya sudut pusat untuk tahap putaran akan menyebabkan pesongan dan tekanan hasil pengedaran mengurangkan juga. Manakala bagi kes 2, tiga model dengan saiz yang berbeza ketebalan pinggang telah mewujudkan untuk melengkapkan kajian kesan pinggang tebal kesan kepada tangga heliks dari segi pesongan dan tekanan pengedaran. Daripada keputusan yang diperolehi, ia telah membuktikan bahawa, saiz yang lebih besar tebal pinggang heliks tangga, penurunan nilai dari segi pesongan dan tekanan pengedaran.

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a_1, a_2	Coefficients for redundant moment and force at mid-span
a_3	Coefficient for vertical moment at fixed end
B	Width of the stair section
E, G	Moduli of elasticity of concrete in tension and compression and in shear
H	Horizontal redundant force at mid-span
Df	Total depth of stair section
I_1, I_2	Second moments of area of effective section of stair about horizontal axis
K_2	Torsion Constant
M_o	Redundant moment acting in a tangential plane at mid span
M_{no}	Lateral moment
M_{ro}	Vertical moment
P_{no}	Thrust normal to tangent
R_i	Internal radius of stair
R_o	External radius of stair
R_1	Radius of center-line of load
R_2	Radius of center-line of steps
V_{no}	Shearing force across section of stairs
V_{ro}	Radial horizontal shearing force
T_o	Torsion moment
w	Total loads
β	Total area subtended by helix
σ	Stresses
Θ	Angle of subtended in plan measured from mid-point of stair
ϕ	Slope made by tangent to helix center line with respect to horizontal plane

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Recently, the need for structural rehabilitation of civil structures all over the world is well known and a great amount of research is going on this field. Every time new technology will develop which are changes in the contributing factors to structure such as increase in load requirement, corrosion deterioration to exposure to aggressive environments, changes in functionality, potential damaged caused by mechanical and environment effects, increase in material strength and durability and etc.

Many different methods are suitable for repair and strengthening, such as additional reinforcement cover by concrete, external steel plate bonding and etc. Nowadays, structural design and structural analysis are both of the criteria needed to create a structure that safely accomplish its function in order to produce structures in a stability condition. In civil engineering field, concrete is widely used in building construction.

For this research, staircase is a set of steps leading from one floor of a building to another and typically inside the building. Helical staircase is just a type from many type of staircase that has been designed and used nowadays. Helical or helical stair has an open well at the center which is a continuous slab staircase without a central core. A helical is warped surface generated by a line wrapped around a central imaginary core. It will be like the curve of a screw. The slab is like inclined plane. It can be circular or elliptical (it has no central

structure). The design of staircase requires proportioning components and determination of reinforcement and its detailing to satisfy both the serviceability and strength requirements.

In this research, Finite Element Methods (FEM) models were used to stimulate the behavior of concrete and reinforcement steel structure's ability using ANSYS 12.0 program. The ANSYS was founded in 1970, develops and globally markets engineering simulation software and technologies widely used by engineers and designers across a broad spectrum of industries like civil and mechanical engineering. This program capable of predicting deflection and stress in concrete concepts and also includes models constitutive laws for concrete material.

1.2 PROBLEM STATEMENT

Nowadays, there are many structure construct emphasize in term of few factor such as esthetic value, cost, time and shape of structure. Therefore, the helical staircase design is also was implicated in that factor. Because of that, many type of helical stairs is created rely on that factor. According of that, designers always have complex analysis of stairs depending on the typical shape of stairs while analysis. In this stage, an accurate analysis and design process need to be done correctly and careful to avoid the helical stairs failed by using ANSYS software analysis.

The most problem faced in designing of helical staircase is the loads that applied to mid span. Mid span of staircase are in parts of staircase structure are also called main structure which is important on order to support the load. Because of that, the mid span must be designed well to make sure it can support the load to make it safe for long period time. For completing the design analysis process, it depends on loads, length of span, poison's ratio, pressure on structure and others.

In construction field, analysis of structure is one of the important element be should considered before the process can be proceed to the next level which is designing process. It is important for engineers to know the deflection, stress and strain for the structure before they are designing it. In the markets recently have lots of commercial engineering software which can help designer with this problem such as STAAD PRO, AUTO CAD, STAIRCASE SOFTWARE, LUCAS and so on.

1.3 OBJECTIVES :

The objectives of this research are following:

i. To study the effect of various central angle for degree of rotation for helical staircase in terms of deflection and stress distribution.
ii. To study the response and behavior of helical staircase structure through a series of analysis under different waist thickness of the staircase.

1.4 SCOPE OF STUDY

This investigating is mainly focusing on generating a 3-Dimension model using the ANSYS software. These focused on the analyzing of helical staircase by using British Standard and use the data to generate the results by proving the parameters in ANSYS. In order to achieve the objectives of the researches, there are few researches scope is necessary to be followed. Study the type of british code of helical staircase and characteristic of the structure.

This research will carry on by using various size,load and parameter of helical staircase. The results of this, will be comparing for getting the best result due to complete the research study. Explore the ANSYS program by learning how to use the programming by using tutorial from internet. Practicing of tutorials can helps to solve problem when running the real models.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In recent years, number of studies have been made in designing the helical staircase and development in this type is still continued until now. Many researchers try to present the easier and simple way for example comes out with software such as AUTOCAD, ANSYS, Visual Basic and so on for determination of the section sizes which meet the principals and limitations as stated in BS 5950-1:2000.

Apart from that, several methods were introduced to fulfill the criteria which are Loading and Boundary condition,Strain Energy Method and Stress Resultant. The effectiveness of these methods is relevant to attempt final design for results in deflection and axial bending of helical staircase in order to make sure the ability of stair to stand alone wihout any failure.

This method does not stand alone where means that a supporting computer program should be established to help the researchers reducing the difficulty when designing the helical stair structure. The new software among students in Malaysis that can be used in ANSYS 12.0. the establishment of this computer program actually can help us to modify the structure's design.

2.2 HELICAL STAIRCASE

Staircase is an inclined structural system for movement from one level to another. The steps of a staircase may be on waist slab or slabless tread riser or isolated step. A staircase behaves like an ordinary slab which is it may be span either in the direction of the step or in the direction of going. A staircase spanning in the direction steps may have fixed on one end (cantilever), simply supported and etc.

The stairway spanning in the longitudinal direction will conctructed with steps on waist slab or with slabless tread risers. The structural behaviour are similar with the slab. In case of stread risers staircase, the design load may be considered acting at the junction of tread and riser. Moment in the riser is constant throughout its depth and moment in the tread varies linearly. In case of restrained ends, the analysis for moment can be made by the force method considering the end moments as rebundants.

Geometrically, a helicoidal surface is a three dimensional structure in space consisting of a warped surface which is generated by moving a straight line touching a helix so that the moving line is always perpendicular to the axis of the helix.

2.2.1 STRESS RESULTANTS

Six stress resultants are available at any section of a spacestructure. Helicoidal slab, being a space structure, also has sixstress resultants at any cross section, which are (a) verticalmoment (Mv), (b) lateral moment (Mh), (c) torsion (T), (d)thrust (N), (e) lateral shear force (V), and (f) radial horizontalshear force (F).The positive directions of these stress resultants have beenillustrated in Figure 2.2.

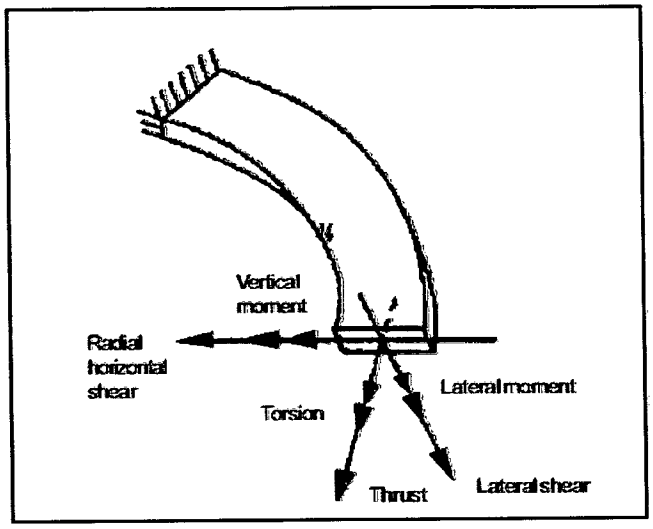

Figure 2.2:Stress resultant in helical staircase

2.2.2 LOADING AND BOUNDARY CONDITION

The helicoidal stair slab has its self weight. This dead load (selfweight) is assumed to be uniformly distributed. In addition,the slab is subjected to live load. The live load could beuniformly distributed over the surface, point loads, line loadsor symmetrical loads about the central axis of the slab.However, in this work the live load is considered uniformlydistributed over the entire surface on the horizontal projectionof the stair.

The ends of the slab may be fixed, partially fixed or hinged.The slab fixed at both ends is six degree indeterminate; thereare six equilibrium equations and twelve unknown reactions.Helical slab with one end fixed and one end hinged isindeterminate to third degree. The stair slab here is considered fixed at its ends in all directions.

2.2.3 STRAIN ENERGY METHOD

The strain energy method has previously been successfullyemployed by Morgan and Holmes to analyse helicodial stairslabs. Because of symmetry in loading and geometry, in ahelicodial stair slab with a landing at the middle, the

slope atthe mid-span is zero and so is the horizontal deflection. This iswhy, according to the Castigliano.s second theorem, thepartial derivatives of the strain energy function with respect tothe vertical moment (M) and radial horizontal force (H) isequal to zero. That is,

$$\frac{\partial U}{\partial M} = 0$$

and

$$\frac{\partial U}{\partial H} = 0$$

Solution of these equations yield the values of M and H, which can be expressed in the form of:

$$M = k_1 wR_2^2$$

and

$$H = k_2 wR_2^2$$

2.2.4 LOADS ON STRUCTURE

There are many types of loading that can affect the behaviour of the structures. When designing a building, those loading should be taken into consideration because of miscalculate, absolute failure will occur in the structure. The example of load comes from static forces which consist of live load, dead load and forces due to settlement or thermal effect. These types of load are typically being considered when designing each structures.

Live loads are forces that act vertically downward onto the structure but it is not fixed in character. The value can change anytime and movable according due to the situation and condition. Occupancy and environmental can be described as live loads that include furniture, stored materials, human and etc.

On the other hand, dead loads are non-movable and fixed in behaviour such as those self weight of the structure, slab, bricks, finishes, mechanical equipment and etc.

2.3 HISTORY

In the first approach, Bergman (1956) produced the simplest solution by reducing the helicoid to its horizontal projection and resolving the problem into a fixed ended curved beam. It leads to over estimation of different forces. In the second approach, Holmes (1957), Scordelis (1960) and Morgan (1960) reduced the helicoid to its elastic line having the same stiffness as that of original structure. This simplification neglects the slab action of helicoid and assumes the bending and torsional stiffness of the warped girder as that of a straight beam.

Apart from all these theoretical efforts of finding logical analysis and design procedure for helicoidal stair cases, model tests were also carried out for this structure with a view to substantiating the analytical findings. The first known efforts of testing reinforced concrete helicoidal stairs to failure were made at Asian Institute of Technology (AIT, formerly SEA TO Graduate School of Engineering, Bangkok) by Trirojna (1962), Cusens and Trirojna (1964). Two half-scale models having 80-degree central angle were tested under uniform load.

The models were scaled down from a prototype, which was designed for the dining hall project of Chulalongkom University, Thailand. In this study, helical girder approach proposed by Morgan (1960) was used for analysis and design of the model. The first one of these two models was constructed as per the analysis, while in the second model the reinforcement required for resisting computed lateral moment was reduced by 50%. The study estimated that a design based on helical girder solution is sufficient from the safety point of view with a probable load factor of around 5. This load factor, however, seems to be too high from economic design point of view.

2.4 FINITE ELEMENT ANALYSIS

Finite element is a numerical technique used to obtain approximate solutions of boundary value problems in engineering. Boundary value problem is a mathematical problem in which one or more dependant variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain (David V.Hutton, 2004). They are used when hand calculations cannot provide accurate results.

In the finite element analysis of real structures, the actual structure is broken down into many small pieces of various types, shapes and sizes which then assembled together using the basic rules of structural mechanics, equilibrium of forces and continuity of displacements. They solve the field with discrete model. The field variables may include temperature, vibration, displacement and others.

Finite element has become a vital tool for students and engineers to solve various types of problems and unknown.

2.4.1 BASIC STEPS IN FEM

The finite element method (FEM) can be defined as a general numerical technique for approximating the behaviour of continua by assembly of small parts (elements). In finite element modelling, discretize the continuous structures that have infinite numbers of degree of freedoms into smaller pieces called elements for analysis is an important process. After that, stiffness is determined and assembled into the system of equilibrium equation to solve nodal displacements. Different properties and geometries will be required to cater for various types of structures and their behaviours. The procedures involved in finite element analysis consist preprocessing phase, solution phase and post processing phase (T.R. Chandrupatla &A.D. Belegundu, 1997).

2.4.1.1 PRE - PROCESSING PROCESS

Geometric domain of the problem is defined. The solution domain is created and discretized into finite elements by subdividing the problem into nodes and elements depending on engineering judgement. It is either small enough to give accurate result or large enough to let the computational process easier. It is assumed that a shape function depends on the physical behaviour of an element and approximation of the simulation of the actual behaviour of the problem.

Equations then develop by defining the material properties, geometric properties, element connectivity as well as the boundary condition (physical constraints) and the loading. The global stiffness matrix will be constructed after assembly of the elements that represent the entire problem.

2.4.1.2 SOLUTION PHASE

A set of linear or non-linear algebraic equations will be solved simultaneously. The solution will give the nodal results for example displacement values at different nodes. Reduction of data storage requirements and computation time will be achieved by this solution technique. Gauss elimination is commonly used for static and linear problems. Additional computation and variables derivation such as reaction forces, elements stresses and strain can be done by applying the computed values before.

2.4.1.3 POST - PROCESSING PHASE

The last phase is the analysis and evaluation of the solution result. Example of operations thatcan be accomplished using post processing software:

a) Equilibrium checking
b) Computation of element stresses
c) Deformed structural shape plotting

d) Animation of dynamic model behaviour

e) Production colour coded stress contour.

f) Calculation for factor of safety

2.5 INTRODUCTION TO ANSYS

The use of finite element analysis as design tool has grown rapidly in the recent years. ANSYS was released at 1971 for the first time. It contains over 100,000 lines of code and a lot of analysis can be performed through ANSYS.

FEA program for over 20 years and now it has a completely new look and with multiple windows incorporating a graphical user interface (GUI) and other menus. ANSYS enables engineer to perform the following task (Saeed Moaveni, 2003):

a) Construct computer models or transfer CAD models of structures products, components or systems.

b) Study physical responses such as stress levels, temperature distributions or electromagnetic fields.29

c) Apply operating loads or other design performance conditions.

d) Optimize a design early during the development process for the purpose of production costs reduction.

e) Do prototype testing in undesirable or impossible environments.

2.5.1 OVERVIEW THE ANSYS PROGRAM

The ANSYS program is divided into two levels which are the Begin level and the Processor level. Role of the Begin level acts as a gateway into and out of the ANSYS program and access certain global program controls. Database clearance and file assignment changing can be done from the Begin level. Meanwhile, most of the analysis will be done at the Processor Level which is available to accomplish a specific task in ANSYS.

There are three typical steps for analysis in ANSYS, which involves three most frequently used processors (Saeed Moaveni, 2003):

2.5.1.1 Pre-processing

This step is done using the Processor, which contains the commands needed to build a model which is define element types and options, define material properties, define element real constants, create model geometry, define meshing controls and mesh the object created.

2.5.1.2 Solution

Boundary conditions and loads are applied in this step by using SOLUTION processor. Then it initiates finite element solutions.

2.5.1.3 Post-processing

Post-processing is where the process for distrubuting the result of stucture. Post-processor has the commands that allow result display and tabular listing:

a) Read results data from the results file
b) Read element results data
c) Plot results
d) List results

2.5.2. Using of Ansys in analyzing in helical staircase

Apart from these aspects, the experimental work reported that the lateral cross section of the stair slab showed a curved cross section profile under uniformly distributed loading which was described as the evidence of 'slab action' in this structure.All these findings of the model study indicate the necessity of introducing ANSYS approach for studying the behaviour of the