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FINITE ELEMENT ANALYSIS OF CELLULAR CIRCLE COFFERDAM FOR WET SOIL

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Abstract

This paper presented nonlinear finite element analysis to predict the load deflection behavior of circular cell cofferdam under lateral load by using **ANSYS (Analysis System)** (version 12.1) computer program. Eight-node solid element **(SOLID 45)** has been used to model filling soil, and the same element by using overlap and glue technique to model steel sheet pile of cofferdam. The bond between steel sheet pile and filling soil has been modeled by using nodes merge. The full Newton-Raphson method is used for the nonlinear solution algorithm**.** Single circular cell of width to height ratio b/H (1.00) has been analyzed and their results are compared with experimental data including the following factors: the effect of berm ratio (backfill of cell) (0.4 of the cell height), embedment depth ratios (0.2 and 0.4 of the cell height), Wet subbase soil was used as filling material. The results obtained using the finite element models represented by the load applied at one third of the cell cofferdam height deflection curves show good agreement (small differences) with the experimental data that based on experimental study done by **Al-Kassar, (2011)** for the case that considered in this study.The difference between the numerical ultimate loads and the corresponding experimental ultimate loads is in the range between (0-5.56)%**.** Only in the case of circular cell cofferdam on ground with width to height ratio b/H=1 the difference was 25%. For the numerical analysis at used berm ratio of (0.4 of the cell height) has increase the cell resistance (50%), while in experimental study the increase in cell resistance was (33%).

For numerical analysis of using embedment depth ratio of (0.2 of the cell height) the resistance of the cell has increased to (39.02%), compared with the ratio (0.4 of the cell height) the cell resistance increased to (53.13%). While in experimental study when the embedment depth ratio was (0.2 of the cell height) the resistance of the cell increased to (23.8%), compared with the ratio (0.4 of the cell height) the cell resistance increased to (40.72%).

Keywords: Finite Element ,Soil,Circular Cell Cofferdam

دراسة عددية لاستقرارية سدود الانضاب الخلوية باستخدام برنامج ANSYS

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الخلاصة

في هذه الدراسة تم استخدام التحليل اللاخطي بطريقة العناصر المحددة للتنبؤ بعلاقة الحمل باالازاحة بالنسبة لسدود الإنضاب الخلوية تحت تأثير الأحمال الجانبية وذلك باستخدام برنامج **ANSYS V.12.1**، وقد تم استخدام العناصر **(solid 45)** لتمثيل املائيات التربة والأساس كذلك تم استخدامها لتمثل الركائز الحديدية للسد بأستخدم تقنية التداخل واللصق، وتم استخدام تقنية الدمج بين العقد لتمثيل الترابط بين الركائز الحديدية والتربة. تم استخدام طريقة (**Full Newton-Raphson)** لحل معادلات التوازن اللاخطية.

تم تحليل نوع من انواع سدود الانضاب الخلوية وهي الدائرية بنسبة (القطر الى الارتفاع =1.0) وتم مقارنة هذه النتائج مع النتائج العملية. هذه الدراسة تضمنت تحليل تأثير العوامل التالية: الاملائيات خلف السد بنسبة (0.4) من ارتفاع الخلية , وتأثيرعمق الدفن تحت سطح الأرض بنسب مختلفة (0.2 ,0.4) من ارتفاع الخلية , حيث تم استخدام الحصى الخابط الرطب كمادة املائية.

النتائج التي تم الوصول اليها بأستخدام طريقة العناصر المحددة نتيجة لتسليط قوة في ثلث ارتفاع الخلية قد اظهرت أن التحليل باستخدام طريقة العناصر المحددة يعطي نتائج متقاربة مع النتائج العملية. الفرق بين القوة التي تم تسليطها بالتحليل العددي والقوه التي تم تسليطها مختبريا كان يتراوح من (0-5.56)% ماعدا الحالة الاولى بالنسبة لسد الانضاب الخلوي على سطح التربه بنسبة(العرض الى الارتفاع= 1.0) كان الفرق 25% السبب في ذلك هو ان الزيادة الكبيرة بين حمل مسلط واخر عمليا بينما الزيادة بالاحمال المسلطة في برنامج **ANSYS** يجب ان تكون قليلة. بالنسبة للخلية الدائرية ان استعمال نسبة الاملائيات الخلفية (0.4H) تزيد مقاومة الخلية بنسبة (50%) بالنسبة للتحليل العددي اما مختبريا فكانت الزيادة في مقاومة الخلية (33%) اما بالنسبة لزيادة عمق الدفن (0.2 ,0.4) من ارتفاع الخلية كانت الزيادة في مقاومة الخلية (53.13,39.02)% على التوالي اما مختبريا فكانت الزيادة (23.8, 40.72)% .

1. Introduction

Cellular cofferdams are a gravity retaining structures consisting of a series of interconnected soil material or rock filled cells to stabilize them, and resting on a soil or rock foundation, both acting as one unit. These cells and the connecting arcs constructed of interlocking steel sheet piling arranged in a variety of geometric shapes. The interconnection provides water-tightness and self-stability against the lateral pressure of water and earth **[Bowles, (1997)]**.

The purpose of the cofferdam is to retain a hydrostatic head of water as well as the dynamic forces due to currents and waves, ice forces, seismic loads and accidental loads or to provide a lateral support to the mass of soil behind it. However, the cofferdam is subjected to unbalanced lateral forces acting at different heights. These unbalanced forces will tend to produce a resultant moment which tends to overturn the cofferdam or to produce a resultant force which tends to slide the cofferdam on its base. The resisting forces and moments against the sliding and overturning vary in magnitude from soil to soil depending on the unit weight, the coefficient of friction of the soil, Young's Modulus of elasticity, poison's ratio, and cohesion **[Nemati, (2007)]**.

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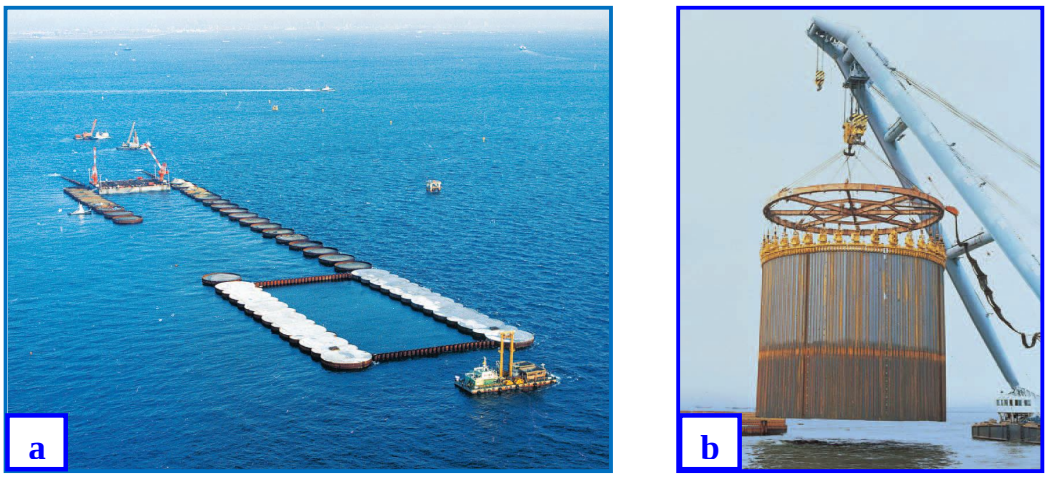

Fig.1: (a) Circular Cofferdam Filling with Soil, (b) Circular Cofferdam Sheet Pile[General Catalogue, 2009, (www.arcelormittal .com / sheet piling)].

2. Nonlinear Analysis

A structure can express mainly three types of nonlinearities **[Altan.et.al, (1983)]:**

a- Geometric nonlinearly
b- Material nonlinearly
c- Contact nonlinearly

Geometric nonlinearly analysis is a scribed to large deflection, large displacement and large strain. For material nonlinearity, the nonlinear effect lies only in the nonlinear stress-strain relation.

In this study the cause of nonlinearity are deformation of soil, yielding of steel, geometry, plastic deformation of soil and steel, and due to slipping between the components of soil, the soil and piles, and soil and piles with ground surface.

Contact problems range from frictionless contact in small displacements to contact with friction in general large strain conditions. Although the formulation of the contact conditions is the same in all these case, the solution of nonlinear problems in some analysis can be much more difficult than in other cases. The nonlinearity of the analysis problem is now decided not only by the geometric and material nonlinearities considered so far but also by the contact conditions.

Plasticity theory provides a mathematical relationship that characterized the elastic-plastic formulations response of materials; the options which characterized different types of material behavior are:

1-Bilinear kinematics hardening
2-Multilinear kinematics hardening
3-Bilinear isotropic hardening (BISO)
4-Multilinear isotropic hardening (MISO)

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5-Anisotropy
6-Drucker Prager
7- William Wrankle (concrete theory)

In this study the Drucker Prager (soil theory) is used in the ANSYS analysis.

3. Finite Element Model of Soil

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the node's x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

The element is defined by eight nodes and the orthotropic material properties. Orthotropic material directions correspond to the element coordinate directions, the element coordinate system orientation is as described in Coordinate Systems.

Element loads are described in Node and Element Loads. Pressures may be input as surface loads on the element faces as shown by the circled numbers on **Figure 2** Geometry. Positive pressures act into the element Temperatures and fluences may be input as element body loads at the nodes**.** The geometry and node locations for this element are shown in **Figure2**, **[ANSYS 12.1, (2010)].**

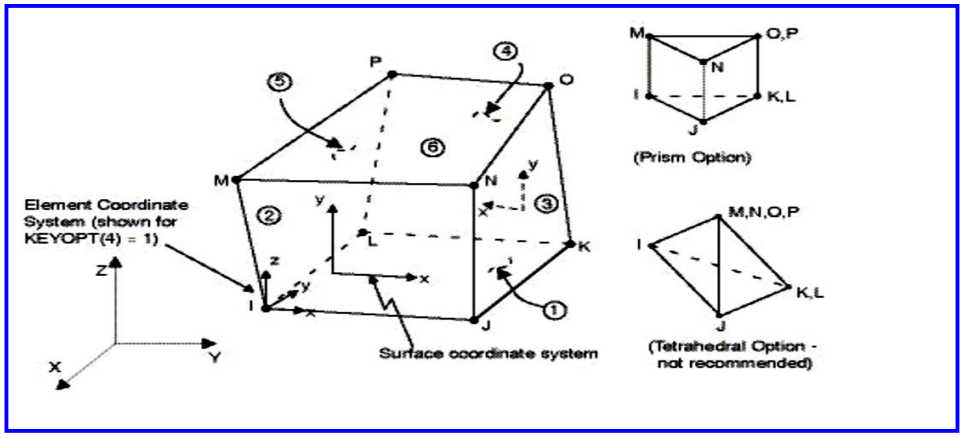

Fig.2 : SOLID45 Element [ANSYS12.1, (2010)].

4. Material properties

Parameters needed to define the material models can be found in **Table 2**. As shown in this Table, there are multiple parts of the material model for each element. Material Model Number 1 refers to the **SOLID45** element. The **SOLID45** element was being used for modeling the filling material of cofferdam, the nonlinearity was controlled using Drucker-Prager failure criterion (**DP**).

A data table is a series of constants that are interpreted when they are used. Data tables are always associated with a material number and are most often used to define nonlinear material data (stress-strain curves, creep constants, swelling constants, and magnetization curves). Other material properties are described in Linear Material Properties. For some

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element types, the data table is used for special element input data other than material properties. The form of the data table (referred to as the **TB** table) depends upon the data being defined. This option **(TB**, DP) is applicable to granular (frictional) material such as soils, rock. The input consists of only three constants:

- ***The cohesion value (must be > 0)***
- ***The angle of internal friction***
- ***The dilatancy angle*****,** the amount of dilatancy (the increase in material volume due to yielding) can be controlled with the **dilatancy angle**. If the dilatancy angle is equal to the friction angle, the flow rule is associative. If the dilatancy angle is zero (as taken in this study) (or less than the friction angle), there is no increase in material volume when yielding and the flow rule is nonassociated. Temperature-dependent curves are not allowed. The constants (C1-C3) entered on **TBDATA** shown in **Table 1**:

Table 1: Parameters of Drucker-Prager Theory.

Constant	Meaning
C1	Cohesion value (Force/Area)
C2	Angle (in degrees) of internal friction
C3	Dilatancy angle (in degrees)

Material model Number 2 refers to the SOLID45. The SOLID45 was being used for modeling the steel sheet pile by using the volume overlap (Vovlap) to have a steel sheel and volume glue (Vglue) technique to ensure the load transfer from steel sheet pile to the soil, the input of this element is shown in Table (2).

Table 2: Material properties

Material Model Number	Element Type	Material Properties		
		Subbase Soil		
1	SOLID45	E_{soil}	Young's modulus (N/m^2)	$150*10^6$
		υ_{soil}	Poisson's ratio	*0.35*
		ρ_{wet}	Density of wet soil (kg/m^3)	*1850*
		C	Cohesion (N/m^2)	*1000*
		ϕ	Angle of Friction(o)	*38*
2	SOLID45	*Steel*		
		E_s	Young's modulus (N/m^2)	$201000*10^6$
		υ_s	Poisson's ratio	*0.3*
		ρ_s	Density of steel (kg/m^3)	*7865*

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5. Steel

Steel is a much simpler material to represent. Its stress- strain behavior can be assumed to be identical in tension and in compression. A typical uniaxial stress-strain curve for a steel specimen loaded monotonically in tension is shown in Figure 3.

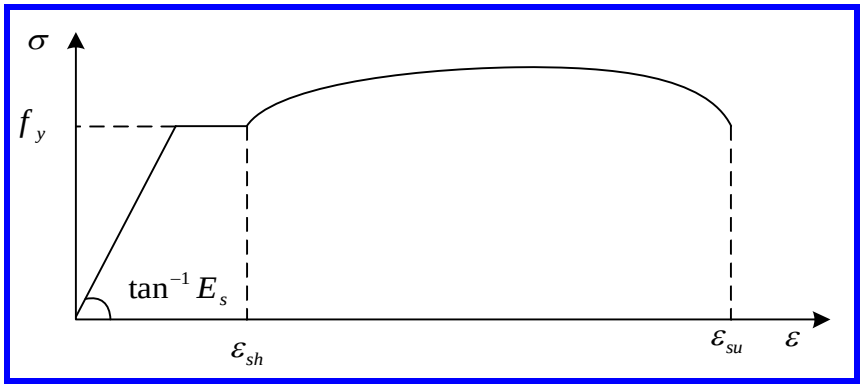

Fig.3: Typical Stress-Strain Curve for Steel [Chen, (2007)].

The stress-strain diagram may for simplicity consist of two branches: the first branch starts from the origin with a slope equal to E_s, up to f_y. A second branch is horizontal or, for practical use of computers, is assumed to have a very small slope such as $10^{-4}E_s$ and this last case is limited to the strain 0.01 according to **[EC4, Eurocode 4 :(1994)]**.

6. Applying Loads and Obtaining the Solutions

In this step, one will define the analysis type (i.e. static, transient…etc) and options (large deflection, large strain and large displacement), and then apply loads, specify load steps, and initiate the finite element solution. A non-linear analysis will differ from a linear solution in that it often requires load increments and always requires equilibrium iteration. In our problem a non-linear static analysis was applied, with convergence criteria and incremental load and specified load step, including special elements. The main goal of the finite element analysis is to examine how a structure or component responds to certain loading conditions. In this study The load is applied laterally at one third of the height of the dam in all cases it's worth to mention that it was used to divide the line of circular cell for nine elements that mean three elements gave (100mm) high and that represented one third of the cell height which facilitates the load applied.

7. Nonlinear solution

The finite element discrimination process yields a set of simultaneous equations **[ANSYS, (12.1)]**:

$[K]\{u\} = \{F^a\}$

Where:

[K] = coefficient matrix. Nm

{u} = vector of unknown DOF (degree of freedom) values.

$\{F^a\}$ = vector of applied loads.

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In nonlinear analysis, three basic solution techniques are usually used to solve the governing equations. These are the iterative, the incremental and the combined incremental-iterative approaches. These approaches are diagrammatically illustrated in Figure 4for nonlinear analysis of a single degree-of-freedom system.

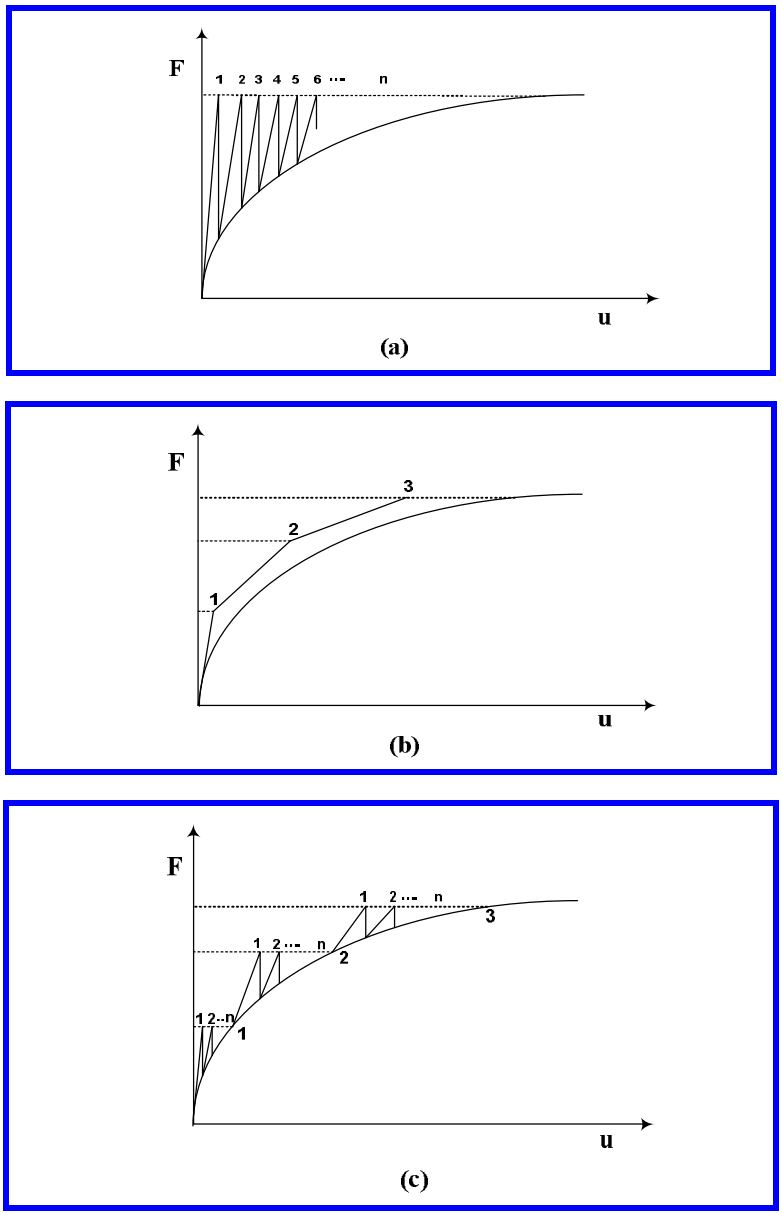

Fig.4: Basic techniques for the solution of nonlinear equations
(a) Iterative (b) Incremental (c) Incremental-Iterative [McGuire et.al, (2000)].

The purely iterative techniques imply the application of the total load in a single increment, as shown in **Figure 4-a**. The out of balance force is used as an additional load. The total displacement is taken as the sum of the accumulated displacements from each iteration. The iterative corrections continue until the out of balance forces become negligibly

small. This type of technique is not suitable for tracing the entire nonlinear equilibrium path because it fails to produce information about the intermediate stages of loading.

The purely incremental techniques are usually carried out by applying the external loads as a sequence of sufficiently small increments, as shown in **Figure 4-b.** Within each increment of loading, linear constitutive relationships are generally assumed. Because the purely incremental technique does not account for the redistribution of forces during the application of loading increments, the method suffers from a progressive and uncorrected tendency to drift from the true equilibrium path.

The combined incremental-iterative technique implies the subdivision of the total external load into smaller increments, as shown in **Figure 4-c.** Within each increment of loading, iterative cycles are performed in order to obtain a converging solution corresponding to the stage of loading under consideration. In practice, the progress of the iterative procedure is monitored with reference to a specified convergence criterion **[McGuire et.al, (2000)].**

ANSYS employs the "Newton-Raphson" approach to solve nonlinear problems. In this approach, the load is subdivided into a series of load increments. The load increments can be applied over several load steps. **Figure 5** illustrates the use of Newton-Raphson equilibrium iterations in a single DOF nonlinear analysis.

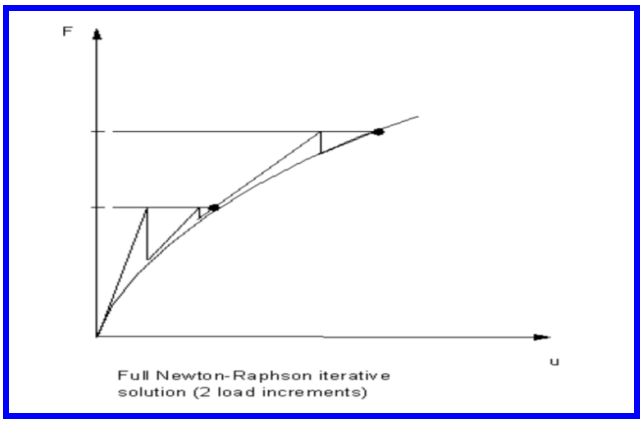

Fig.5: Newton-Raphson approaches [ANSYS 12.1]

Before each solution, the Newton-Raphson method evaluates the out of balance load vector, which is the difference between the restoring forces (the loads corresponding to the element stresses) and the applied loads. The program then performs a linear solution, using the out of balance loads, and checks for convergence. If a specified convergence criterion is not satisfied, the out of balance load vector is reevaluated, the stiffness matrix is updated, and a new solution is obtained. This iterative procedure continues until the problem converges.

From the previous discussion, a nonlinear analysis in the **ANSYS** computer program can be organized into three levels of operation:

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- The "top" level consists of the load steps that it defines explicitly over a "time" span. Loads are assumed to vary linearly within load steps (for static analyses), as shown in **Figure 6.**
- Within each load step, it can direct the program to perform several solutions (substeps or time steps) to apply the load gradually.
- At each substep, the program will perform a number of equilibrium iterations to obtain a converged solution.

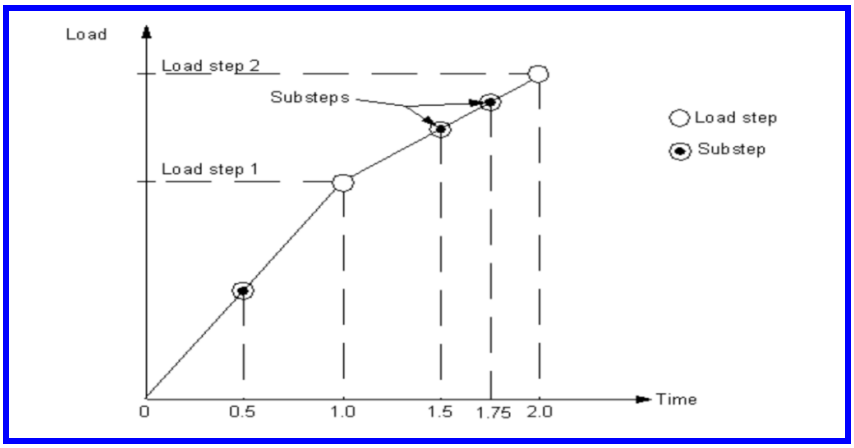

Fig.6: Load Step, Substeps and Time [ANSYS 12.1]

8. ANSYS Modeling

The soil was modeled as a volume by solid45 element for:

1. **Circular Cell Cofferdam on the Ground Surface: Figure 7** shows the details of dam geometry. The circular cofferdam details are the depth (300mm), and diameter (300mm). Dimensions of the foundation base are (X=1250mm, Y=1058mm, and Z=300mm)**,** the circular cofferdam is placed at (x=30cm, y=52.9cm, and z=30cm) on the foundation**.**

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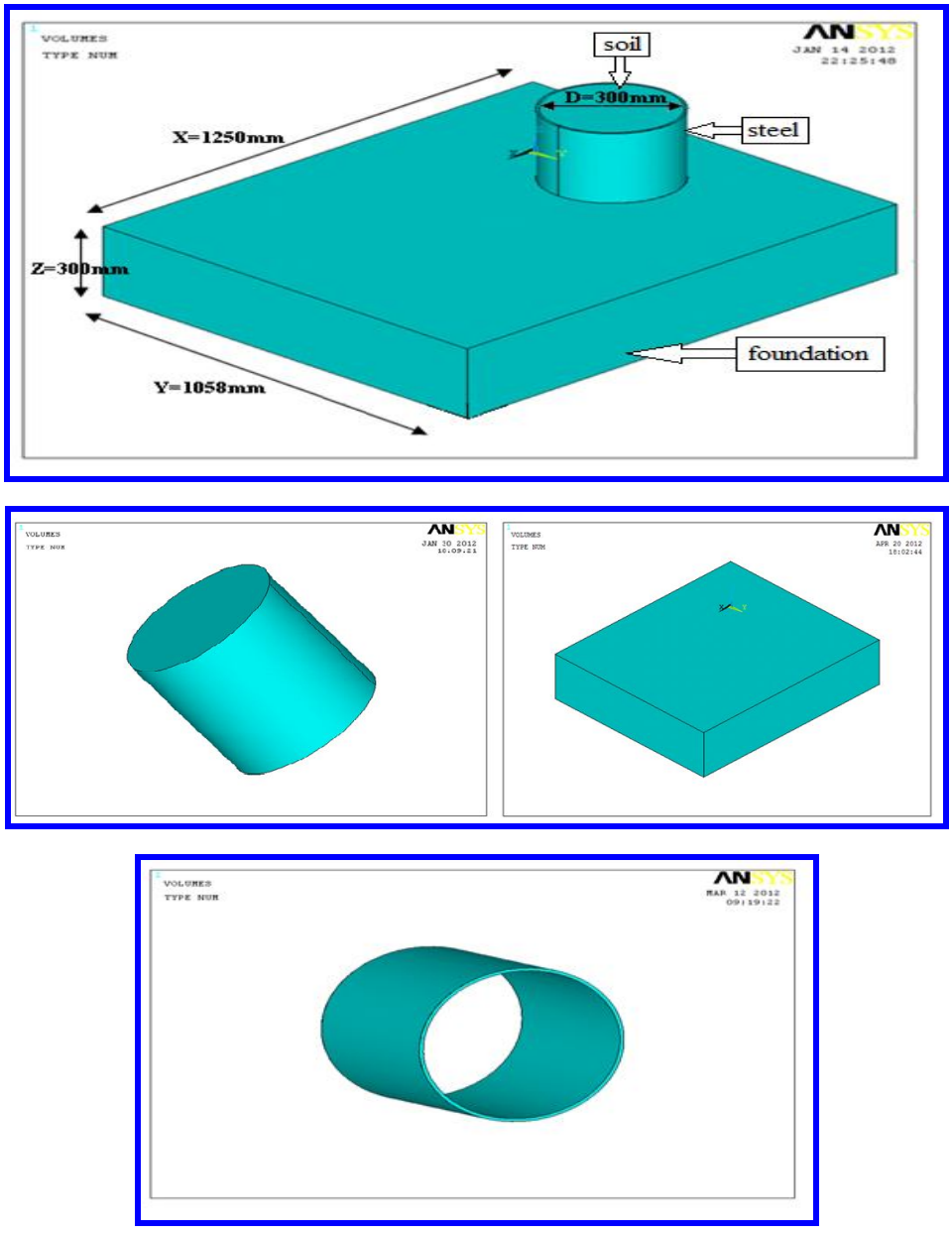

Fig.7: Geometry of Circular Cofferdam with b/h Ratio=1

2. Circular Cell Cofferdam on ground with berm (back fill) ratio (0.4) from height of cell.

To understand the effect of berm (back fill) on stability of cofferdams, single cellular cofferdam cell with (b/H = 1.0) has been modeled. Trapezoidal berm is placed in the back side of cell for the ratio (0.4) from the height of cell, the slope of berm was (1V:3H) as shown in **Figure 8. Figure 9** shows the details of dam geometry.

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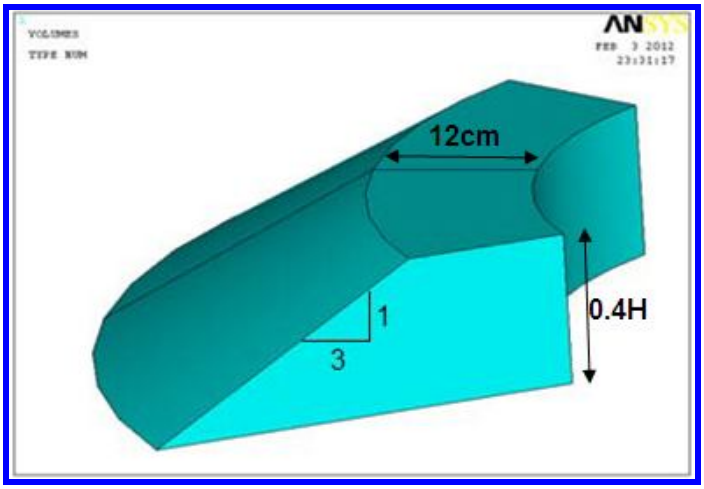

Fig.8: Geometry of Berm (Back Fill).

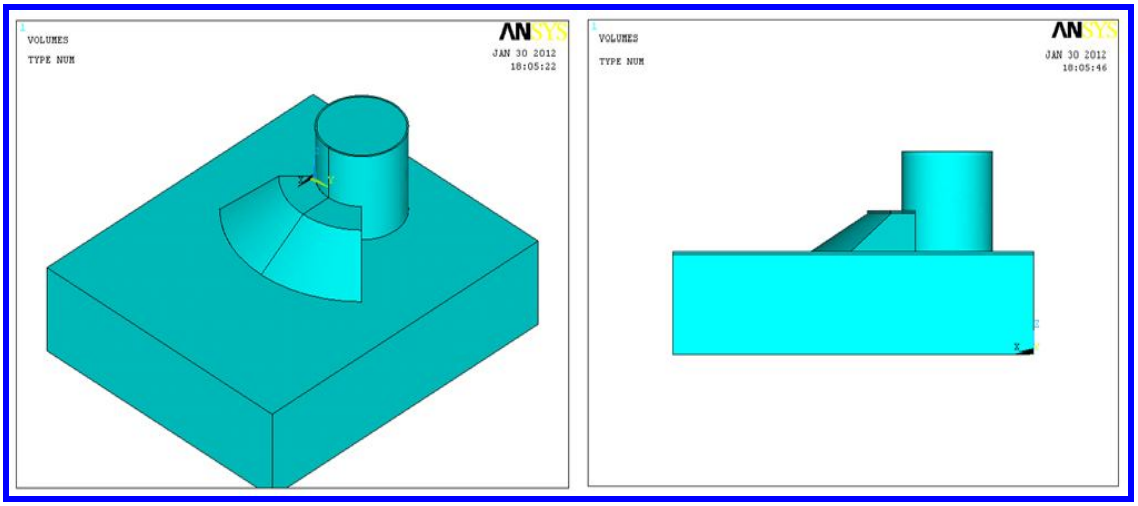

Fig.9: Geometry of circular cofferdam b/H ratio=1 with berm (0.4H)

3. Different embedment depths (0.2, 0.4) from height of cell for (b/H= 1.0).

To understand the effect of the embedment depth, single circular cell with (b/H=1.0) has been modeled the lower end of the cell was placed (0.2, 0.4) depth (D) to height (H) ratios below the ground surface as shown in **Figure 10-a** by plotting lines to show the embedment depth while **Figure 10-b** shows the solid geometry of dam.

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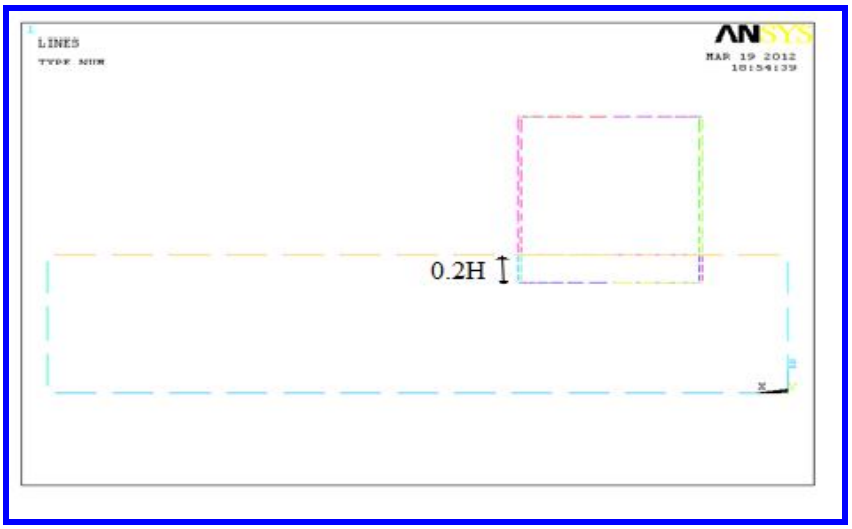

Fig.10-a: Dam Geometry for Embedment Depth of 0.2H with b/H=1.0

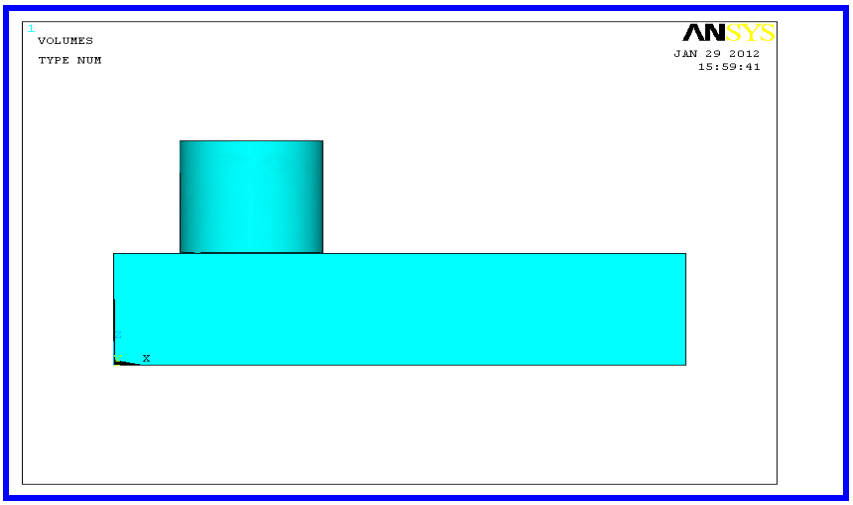

Fig.10-b: Solid Geometry of Cofferdam for Embedment depth of 0.2H with b/H=1.0

9. Meshing of Cofferdam

A problem was pointed out during meshing process of the model. The first finite element mesh used was (map and hexahedral) but because of the geometry of cofferdam wasn't able to mesh it (invalid topology for mapped brick meshing) so this mesh changed to be (free and tetrahedron) as shown in **Figure 11 and 12.**

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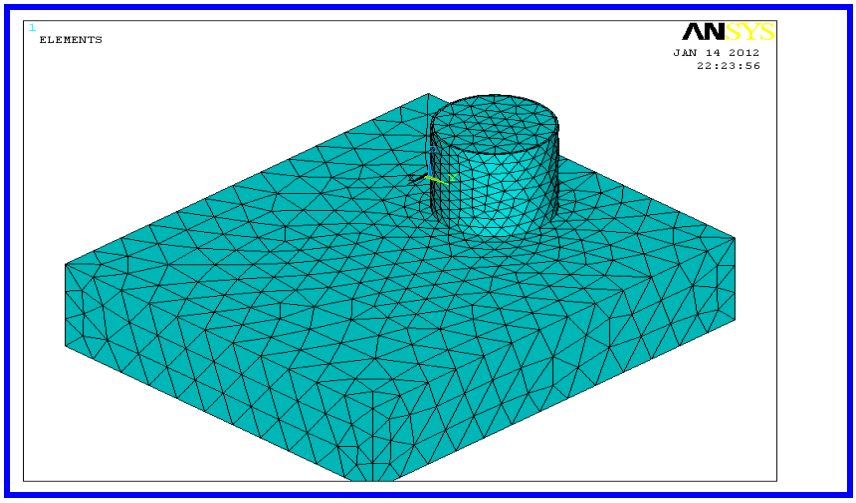

Fig.11: Finite Element Mesh used for Circular Cell Cofferdam b/H=1.0.

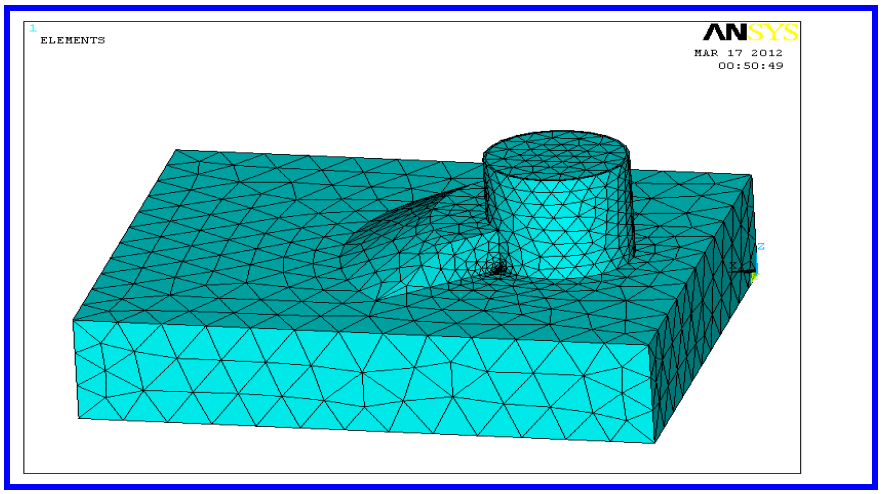

Figure (12): Finite Element Mesh used for Circular Cell Cofferdam b/H=1.0 with 0.4H Berm.

10. Boundary Conditions and Applied Loads

The **SOLID45** element which is used to model the soil has three degrees of freedom UX, UY and UZ per node. All of these degrees of freedom at the base of the soil foundation were restrained to simulate the real boundary conditions the dimension of foundation was taken according to the experimental work as shown in **Figure 13.**

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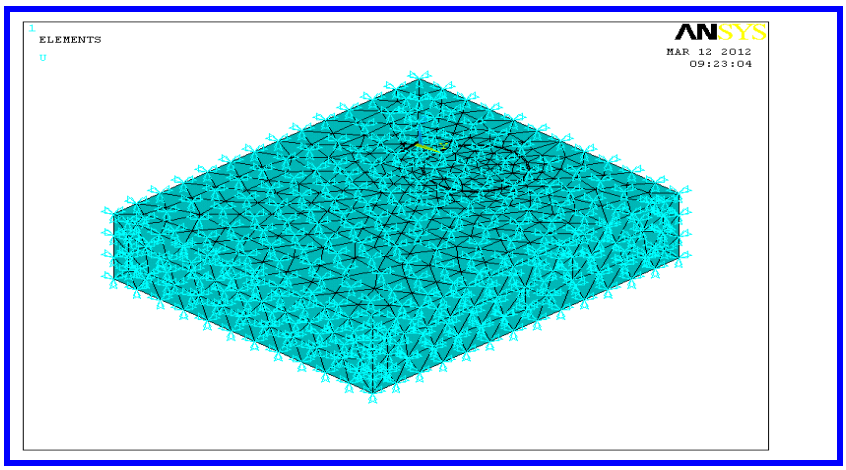

Fig.13: Boundary Conditions used for Soil Foundation.

11. Results of Analysis

In this study, the load plotted against lateral displacement for circular and cell cofferdam with (b/H= 1.0) with different cases and the results of circular cell were compared with experimental test to check the validity of ANSYS model.

By comparing the result of Finite element analysis with that of experimental study in all cases of circular cell, the comparison gives a difference between experimental and theoretical results by about (0%-5.56%) and only in the case of circular cell cofferdam on ground with b/H=1 the difference was 25%.

11.1. Results of Analysis for Circular Cell (Cofferdam Placing on Ground Surface).

Figure 14 shows the experimental and numerical load- displacement behavior of circular cell cofferdam on ground surface

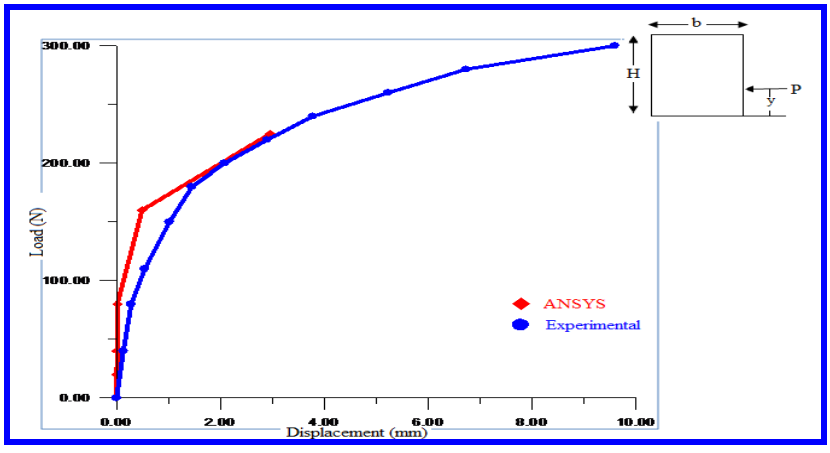

Fig.14: Experimental and Numerical Load- Displacement Behavior of Circular Cell Filling Subase with b/H=1

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11.2. Results of analysis for circular cell (Cofferdam on ground with berm (back fill) ratio (0.4) from height of cell).

Figure 15 shows the experimental and numerical load- displacement behavior of circular cell cofferdam with berm (back fill) ratio (0.4) from height of cell.

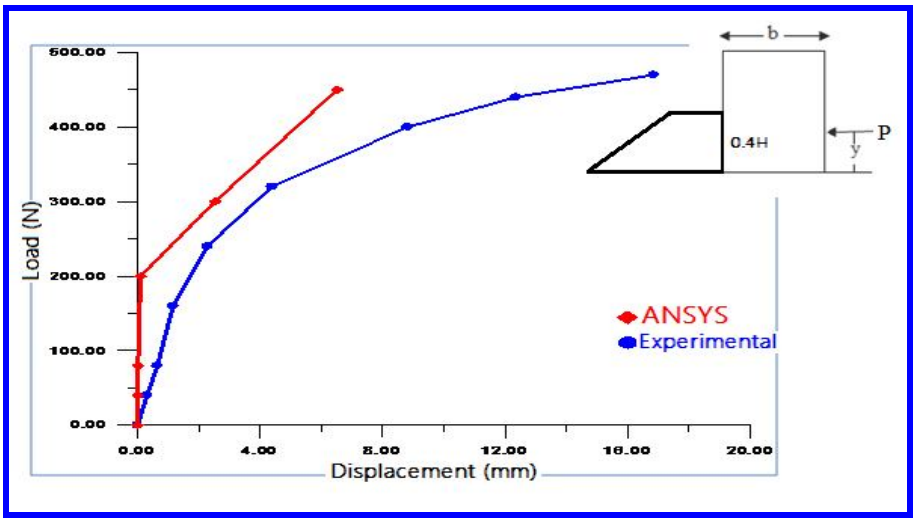

Figure (15): Experimental and Numerical Load- displacement Behavior of Circular Cell Cofferdam b/H=1 with 0.4H berm.

11.3. Results of analysis for circular cell (Different embedment depths (0.2, 0.4) from height of cell).

Figures 16 and 17 show the experimental and numerical load- displacement behavior of circular cell cofferdam with different embedment depths (0.2, 0.4) from height of cell.

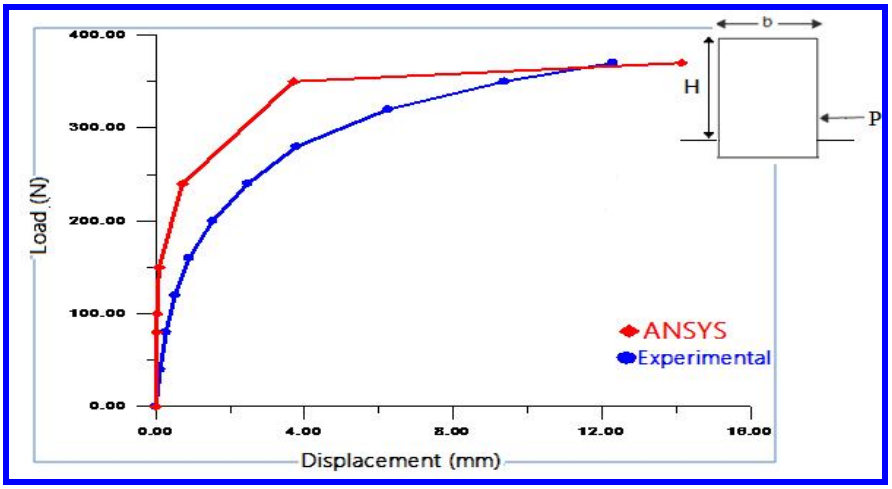

Fig.16: Experimental and Numerical Load- Displacement Behavior of Circular Cell Cofferdam b/H=1 with 0.2H Embedment Depth.

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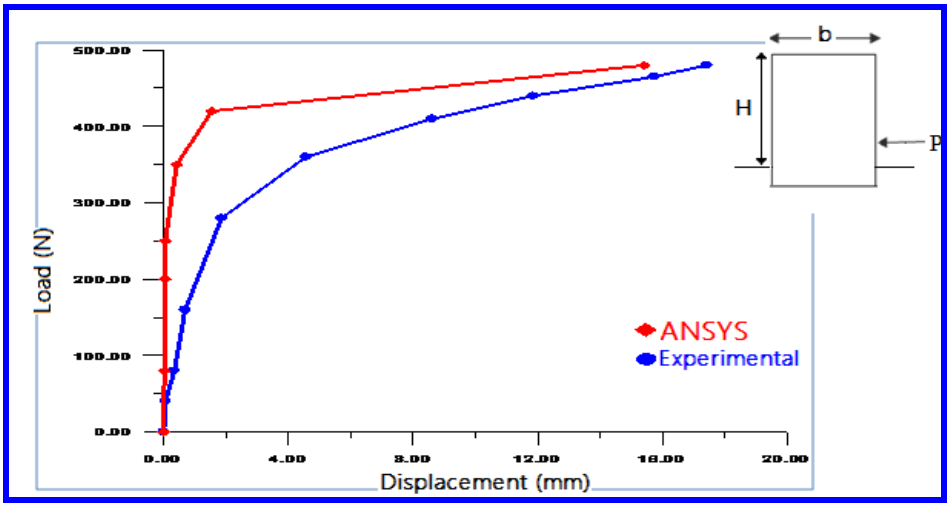

Fig.17: Experimental and Numerical Load- Displacement Behavior of Circular Cell Cofferdam b/H=1 with 0.4H Embedment Depth.

Variation in stresses along the circular cell cofferdam at load applied at one third from base of the cell is shown in figures (18 to 21), the max stress was at the area of applied load at one third of cell height.

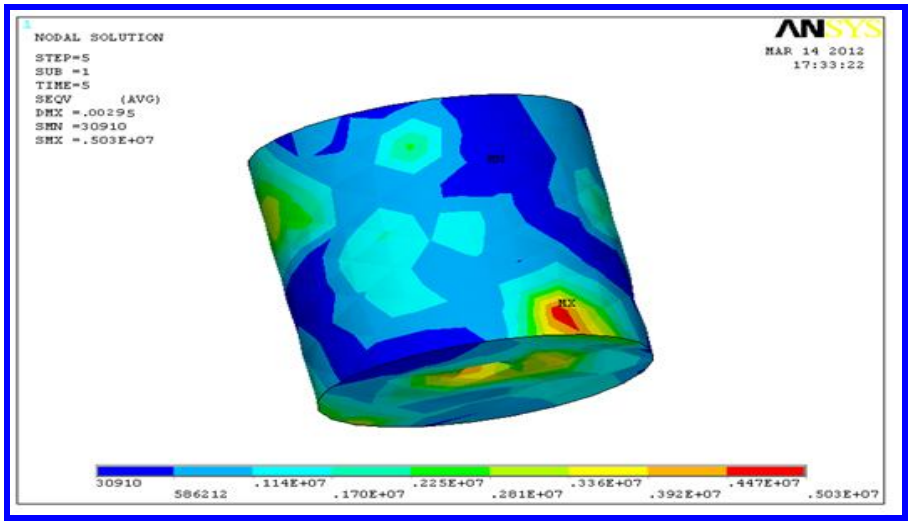

Fig.18: Variation in Stresses Along Circular Cell Cofferdam for b/H=1.

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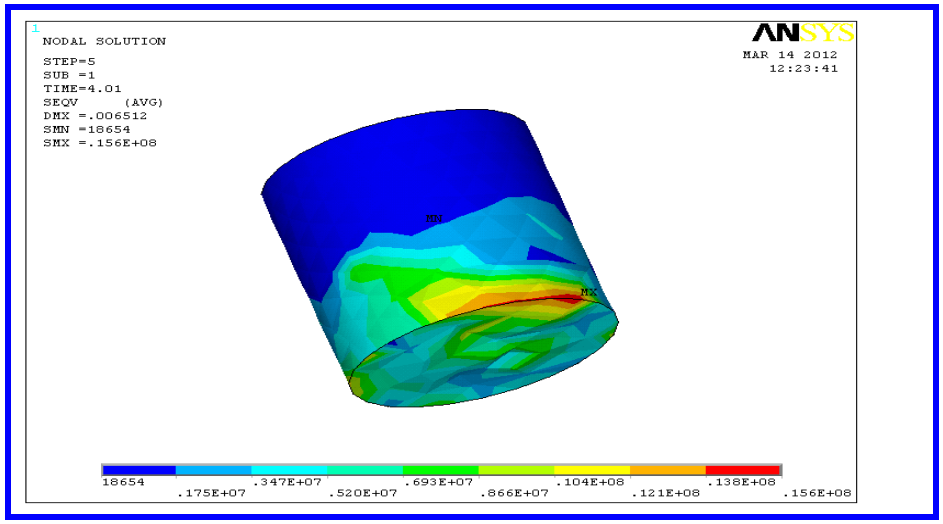

Fig.19: Variation in Stresses along Circular Cell Cofferdam for b/H=1.0 and 0.4H Berm.

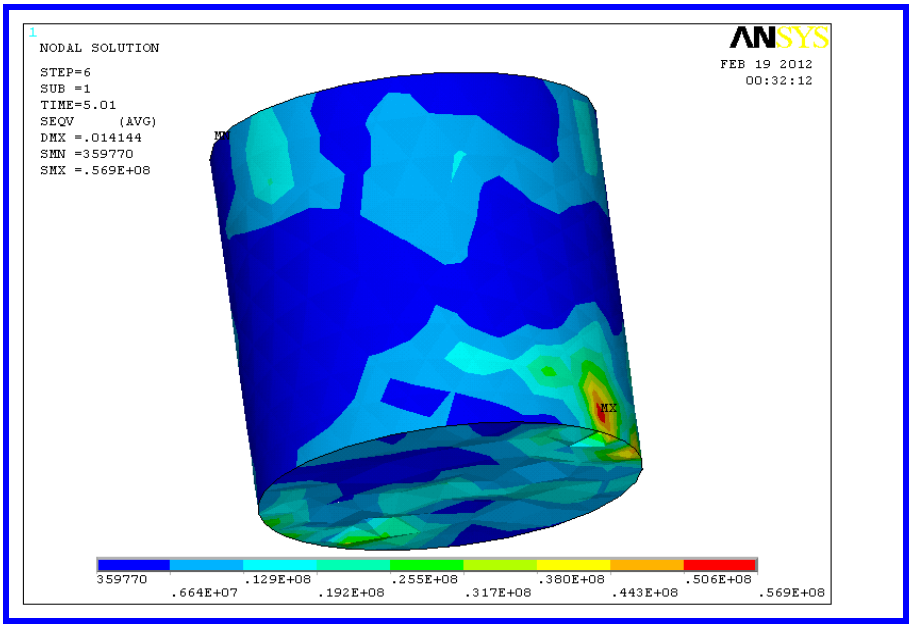

Fig.20: Variation in Stresses along Circular Cell Cofferdam for b/H=1.0 with 0.2H Embedment Depth.

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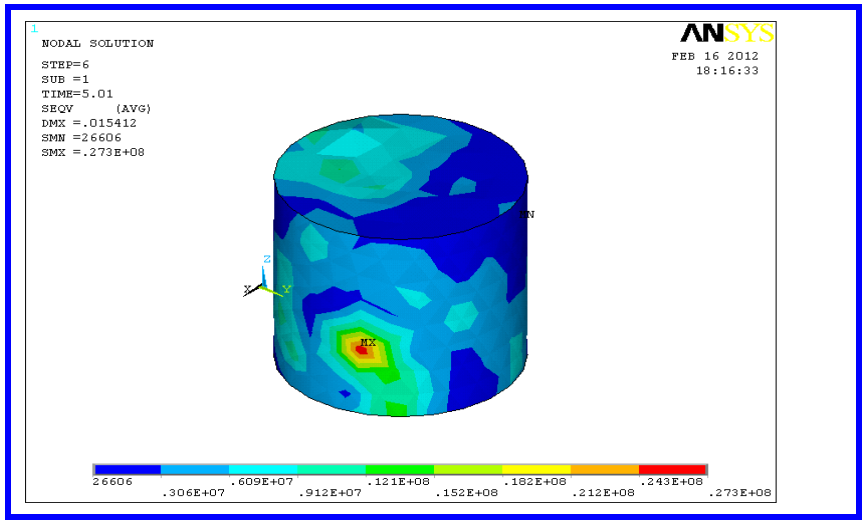

Fig.21: Variation in Stresses along Circular Cell Cofferdam for b/H=1.0 with 0.4H Embedment Depth.

Distribution of shear stress in the (xy plane) along the circular cell cofferdam at load applied at one third from base of the cell is shown in **Figures 22 to 25.**

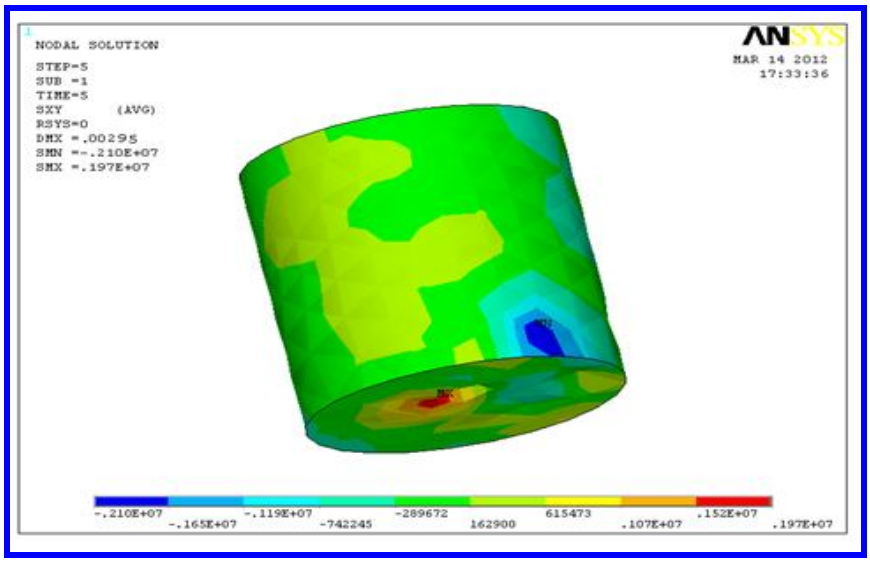

Fig.22: Distribution of Shear Stress in the (XY plane) along the Circular Cell Cofferdam for b/H=1.0.

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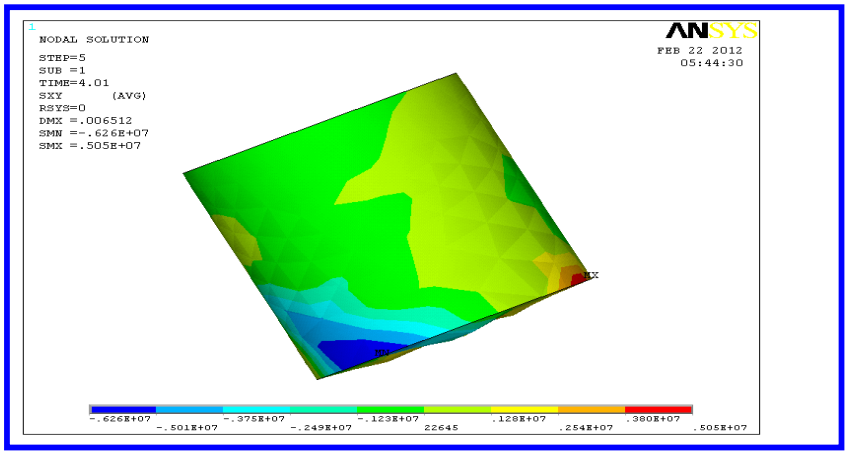

Fig.23: Distribution of Shear Stress in the (XY plane) along the Circular Cell Cofferdam for b/H=1.0 and 0.4H Berm.

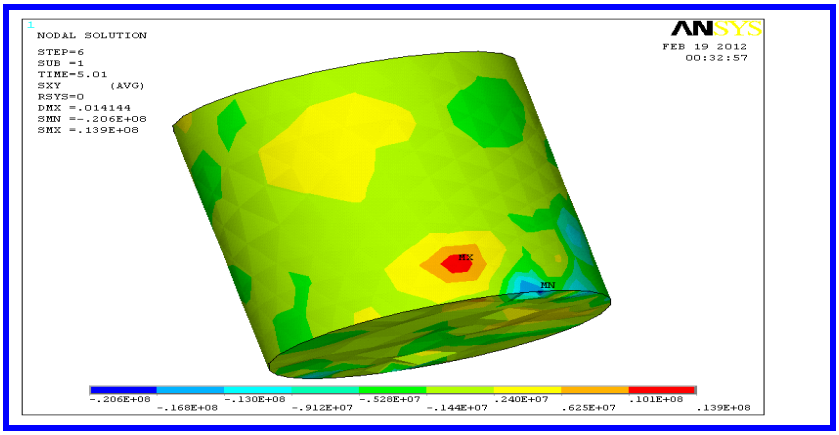

Fig 24: Distribution of Shear Stress in the (XY plane) along the Circular Cell Cofferdam for b/H=1.0with 0.2H Embedment Depth.

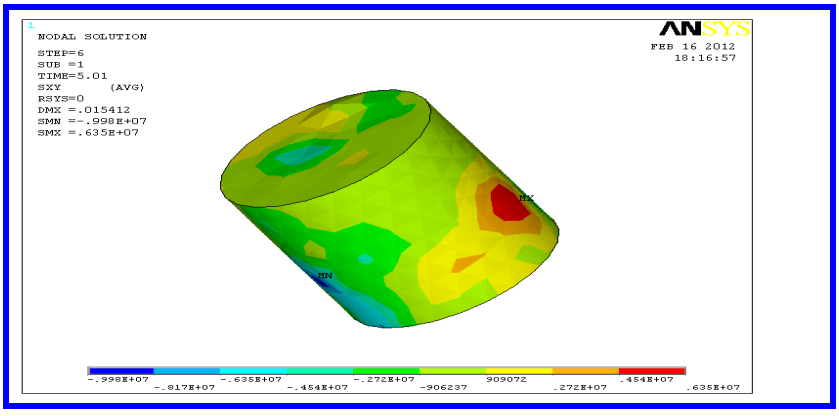

Fig.25: Distribution of Shear Stress in the (XY plane) along the Circular Cell Cofferdam for b/H=1.0with 0.4H Embedment Depth.

12. Conclusions

1. In general, the results obtained using the finite element models represented by the load applied at one third of the cell cofferdam height deflection curves show good agreement with the experimental data for the cases that considered in this study. The difference between the numerical ultimate loads and the corresponding experimental ultimate loads is in the range between (0-5.56)%**.** And only in the case of circular cell cofferdam on ground with b/H=1 the difference was (25%),because of the data that taken from the experimental work, where the increase between applying loads was large compared to increase in applying loads in **ANSYS** which should be small.
2. The present finite element modeling presenting the steel part by using **(solid45)** element and considering bond between steel and soil seems efficient and gives very good results by comparing with the experimental results and this gives an advance over may researches which neglected the contact between steel sheet pile and filling soil**.**
3. For the numerical analysis at used berm ratio of (0.4 of the cell height) has increase the cell resistance (50%), while in experimental study the increase in cell resistance was (33%). For the same reason mention in the result number one.
4. For numerical analysis of using embedment depth ratio of (0.2 of the cell height) the resistance of the cell has increased to (39.02%), compared with the ratio (0.4 of the cell height) the cell resistance increased to (53.13%). While in experimental study when the embedment depth ratio was (0.2 of the cell height) the resistance of the cell increased to (23.8%), compared with the ratio (0.4 of the cell height) the cell resistance increased to (40.72%).

13. References

[1] Al-kassar, H.M (2011), '' Experimental Study of Stability of the Cellular Retaining structures in Wetted Soils", M.Sc thesis, college of Engineering, University of Kufa.

[2] Altan.T.O.S.l and Gegel,H.L(1983), "Metal Forming American Society for Metals", Metals Park, Ohio,1.

[3] ANSYS 12.1 *(*2010), "ANSYS 12.1 Finite Element Analysis System Help," SAS IP, Inc.

[3] Bowels, J. E. (1977), "Foundation analysis and design ".McGraw-Hill, New York, U.S.A.

[4] Chen, W.F., "a plasticity in reinforced concrete" first Edition, J. Ross publishing, Inc., copyright 2007.

[5] C4, European Committee for Standardisation (CEN), Eurocode 4, "Design of Composite Steel and Concrete Structures", Part 1.1: General Rules and Rules for Buildings, DD ENV 1994-1-1.

[6]General Catalogue [2009], "Foundation Solution for Projects, Steel Sheet Piling" www.arcelormittal .com / sheet piling.

[7] McGuire, W., Gallagher, R. H., Ziemian, R. D., "Matrix Structural Analysis", Second Edition, John Wiley & Sons, Inc., Copyright 2000.

[8] Nemati, K.M. [2007],"Temporary Structure Cofferdam" Department of Construction Management, University of Washington.