Analysis Of Annular Raft Foundation using Finite Element Method

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Abstract. A finite element analysis of an annular raft and a circular raft is undertaken in this work. Different ratios of inner radius to outer radius are chosen to examine the effect of geometrical characteristics of annular rafts. The ratio of radius of ring beam to outer radius of raft was also varied. Finite element method is adopted to determine critical moments and deflections in both annular and circular rafts. Comparison of these critical moments and deflections is made for both annular raft and circular raft,for selection of suitable type of raft foundation. Finite element analysis of both the rafts is carried out using ANSYS software.The results show that values of critical moments and deflections in annular raft are less in comparison with those values in circular raft. Different ratios of inner radius to outer radius and radius of ring beam to radius of raft effect critical moments and deflections.

Keywords: Annular raft, Circular raft, Finite element method, Critical moments and deflections.

1 Introduction

Circular tower shaped structures find common application in a variety of modern fields like TV towers, microwave towers, chimneys, cooling towers and over head water tanks etc. The main loads to which these structures are subjected are gravity loads, wind forces and seismic forces. Vertical loads to be transferred in the first four types of towers listed above are relatively much smaller as compared to those in over head water towers. All these loads to which the towers are subjected are ultimately to be transmitted to the foundation and from foundation to the earth. Thus the selection of suitable type of foundation is as important as the shape of tower itself for economical and safe design of overall structure.

Economy and ease of construction determine the suitability of the foundation. The raft foundations are, therefore, most suitable for the towers transferring moderate loads to foundation and for towers of medium height. Thus, they find an extensive application in foundations for water towers. Bearing capacity of soil is an important parameter to decide the size of raft foundation. The raft may be either solid or annular. For relatively large horizontal forces the use of annular raft foundation will be more economical than solid raft because it offers more resistance to overturning. In the annular raft the location of ring beam through which the loads are transferred to the raft is another important factor which governs the economy of such rafts. Location of ring beam is generally fixed and depends upon the size of tower staging. Thus fixing the location of ring beam indirectly leads to proportioning of the

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raft in such a way that the resultant of soil pressure exerted on the raft does not become eccentric to the ring beam and the moments in the raft slab are minimized.

Present study primarily focused on the determination of critical moments and deflections in both annular raft and circular raft using finite element analysis approach, and comparison is made between these two types of rafts for selection of suitable type of foundation. The effect of geometrical characteristics of annular rafts on these critical moments and deflections, such as varying ratios of inner radius to outer radius and the ratio of ring beam radius to outer radius of raft, was also investigated.

2 Literature Review

Swathe A and Vishnu M Parkas [1] conducted a soil structure interaction research on a 200m reinforced concrete chimney with annular raft foundation under along-wind load. The influence of various height-to-base-diameter ratios (slenderness ratios) on the geometrical attributes of chimneys is investigated. The ratios of the annular raft's outer diameter to its thickness are also altered. Below the foundation, a variable soil profile is considered to better understand the influence of soil flexibility on the annular raft. Three separate soil strata were chosen for examination beneath the foundation. In this work, wind loads were computed using IS: 4998-1992. The ANSYS software is used in this project.

A.N.Kamble, Prof Dr.S.S.Patil [2], had studied the effects of footing size, ring radii ratio of ring foundation and load eccentricity by means of centrifuge modeling, the method of characteristics and the finite element technique. In this study ten different models of ring foundations were modeled and analyzed. The first of the model footings were circular, the others were ring footings. The experimental results indicate that the bearing capacity of the ring footings is depending directly on the ratio of the inside to outside radii, i.e. radius ratio.

Hider Hamada Gaye Al Quincy [3] investigated reinforced concrete ring beams using a nonlinear finite element method (NLFEA). The ultimate strength, mechanism of failure, crack pattern, and deformed shape of three reinforced concrete ring beams supported on four evenly spaced columns are assessed and projected using non linear finite element analysis software. All ring beams have the identical geometrical and material features, with the exception of cross sectional depth and reinforcement quality. The failure mechanisms of ring beams are dictated by their (depth/span) ratio, according to NLFEA statistics.

Abdulsamee Halahla [4] investigated the behavior of a reinforced concrete beam using Finite Element Analysis. The load-deflection response of reinforced concrete beams was investigated using finite element analysis.The finite element analysis findings are compared to the experimental results. Finite element software was utilized to model the reinforced concrete beam and conduct nonlinear static analysis.Stress and deflections from the finite element approach near the centerline of the beam were found to be in good agreement with actual data from a reinforced concrete beam and an analytical model produced using the energy method. The failure load predicted by finite element analysis is extremely close to the failure load obtained during experimental testing.

3 Methodology

Circular slab as Plate: Raft is supposed to be a plate loaded from the bottom and supported at the ring beam. The load may either be uniform or of varying intensity as the case may be. Theory of Elasticity of plates is used for the analysis. For the analysis by plate theory the solution of Fourth order differential equation is required. But in the analysis carried out by the plate theory it becomes very difficult to account for the varying thickness of plate and a close form solution is generally not available. Secondly the effect of width of ring beam in the design forces cannot be accounted for. At the same time the interaction with the complicated boundaries and the width of supports as provided by elastic ring beams cannot be considered in the analysis by plate theory. As such the numerical analysis becomes a necessity for obtaining realistic values of the design forces.The Finite Element Method is one of the most efficient computer methods for accounting for a variety of variables such as varying thickness, varying elastic characteristics of materials, and the effect of the breadth of interacting barriers such ring beam and soil structure interaction. The flexural characteristics of an isotropic circular plate are calculated using the Classical Plate Theory (CPT). The following are the numerous plate cases that are being explored for this study:-

a) Uniform pressure on a circular plate supported on a ring support.
b) Uniform pressure on an annular plate supported on a ring support.

The following are the standard values that are expected at the start of any study project:

Poisson's ratio of concrete (ν) = 0.2
Grade of concrete = M25
Young's modulus of concrete (E) = 25000 MPa
Verticalload (p)= 15000 KN
Thickness of raft (h)= 0.5 m
Outer radius of raft (r2) = 5 m

The inner radius to outer radius ratio of an annular raft can be 0.1, 0.2, 0.3, 0.4, or 0.5. For various ratios of the raft's inner to outer diameter, deflections and bending moments are estimated. Table 1 shows the geometrical features of various types of rafts.

GDE (Governing Differential Equation) of symmetrical circular plate bending:

$$\frac{d^3w}{dr^3}+\frac{1}{r}\frac{d^2w}{dr^2}-\frac{1}{r^2}\frac{dw}{dr}=\frac{Q}{D}$$

In other form it can be written as

$$\frac{d}{dr}\left[\frac{1}{r}\frac{d}{dr}\left(r\frac{dw}{dr}\right)\right]=\frac{Q}{D}$$

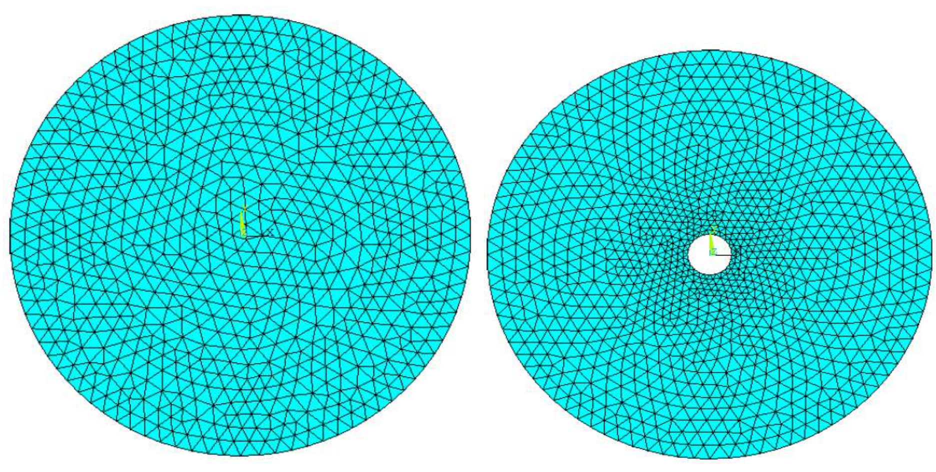
Table 1.Geometrical features of several raft types.

Outer radius r_2 (m)	Inner radius r_1 (m)	r1/r2	Radius of ring beam r_a (m)	Area of raft A (m^2)	Load on raft R (kN)	Pressure applied on Raft P= R/A (kN/m^2)

5	0	0	3.500	78.540	15000	190.986
5	0.5	0.1	3.500	77.754	15000	192.916
5	1	0.2	3.575	75.398	15000	198.944
5	1.5	0.3	3.625	71.471	15000	209.875
5	2	0.4	3.750	65.973	15000	227.366
5	2.5	0.5	3.825	58.905	15000	254.647

4 ANSYS Solution

ANSYS APDL is used to study circular and annular rafts. ANSYS is a numerical technique-based software that uses finite element analysis. ANSYS APDL is used to represent the plate geometry. For circular plate analysis, a Shell 281, 8 noded element is employed It works well with thin to moderately thick shell constructions. The element has eight nodes, each with six degrees of freedom, as well as translations in the x, y, and z axes and rotations around the x, y, and z-axes. It is ideal for nonlinear linear, huge rotation, and/or large strain applications. Nonlinear analysis takes into account changes in shell thickness. This factor accounts for the follower (load stiffness) effects of distributed pressures .Logarithmic strain and actual stress measurements are used in the element formulations. Membrane strains are limited by the element kinematics (stretching).The curvature variations within a time interval, on the other hand, are believed to be minor. For the purposes of this study, deflections and bending moments are estimated for a variety of instances. Mesh is created using a mapped mesh with a triangle element. The analytical solutions are used to validate the ANSYS results (i.e. CPT results). Figure 1 shows the finite element models of the annular and circular rafts.



(a) (b)

Fig 1. FEM model of various types of raft a) circular raft b) annular raft

Table2. Comparison of analytical technique and ANSYS deflection and bending moments for annular raft subjected to UDL.

r1/r2	Radius of ring beam ra (m)	Uniform pressure P (kN/m^2)	Maximum deflection (mm)		Maximum Radial Moment MR (kN-m)		Maximum Tangential Moment MT (kN-m)	
			Analytical	ANSYS	Analytical	ANSYS	Analytical	ANSYS
0.1	3.500	192.916	2.2982	2.2993	171750	172000	79300	79800
0.2	3.575	198.944	2.0359	2.0369	170899	171000	75100	75600
0.3	3.625	209.875	1.7653	1.7654	154650	155000	73200	73800
0.4	3.750	227.366	1.2810	1.2819	129880	130000	50150	50700
0.5	3.825	254.647	1.1219	1.1220	111950	112000	50050	50900

Table3. Comparison of deflections and bending moments for annular raft and circular raft.

Types of Raft	Outer radius r2 (m)	Inner radius r1 (m)	Area of raft A (m^2)	Uniform pressure P (kN/m^2)	Radius of ring beam ra (m)	Maximum deflection (m)		Maximum Radial Moment MR (kN-m)		Maximum Tangential Moment MT (kN-m)	
						Analytical	ANSYS	Analytical	ANSYS	Analytical	ANSYS
Circular	5	0	78.540	190.986	3.5	2.2222	2.2487	182600	183000	129700	130000
Annular	5	0.5	77.754	192.916	3.5	2.2892	2.2993	171750	172000	79300	79800

5 Numerical Results

The ratio r1/r2 will depend on the moment of inertia and the bearing area required for footing such that the maximum stress developed does not exceed the safe allowable bearing pressure specified for the soil. For a particular b/a ratio, the value of ra/r2 at which the maximum moments are minimum were obtained from (Fig 2)

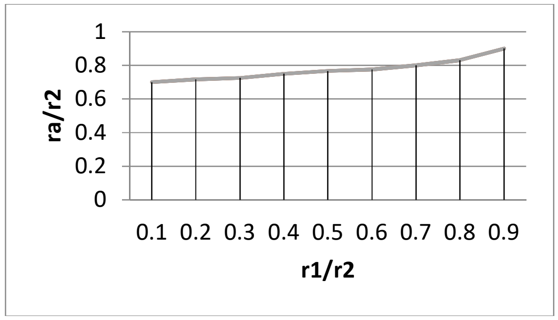


Fig 2. Position of Ring Beam for Minimum Value ofthe Maximum Moments

The analytical technique and ANSYS are compared to obtain flexural parameters such as deflections and bending moments for various examples of an annular raft, as shown in Table 2.Table 3 shows a comparison of deflection and bending moment values in both annular and circular rafts.

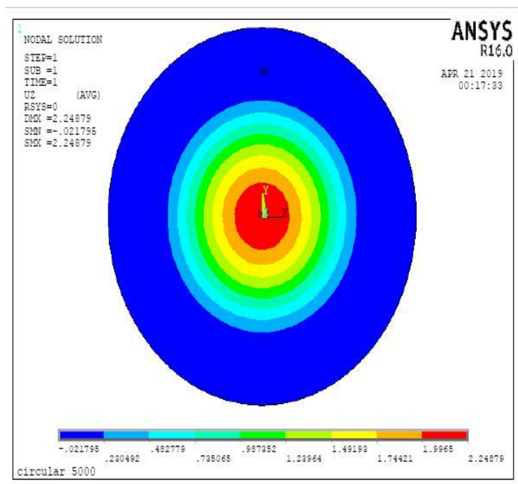


Figure 3. Deflection contour for circular raft

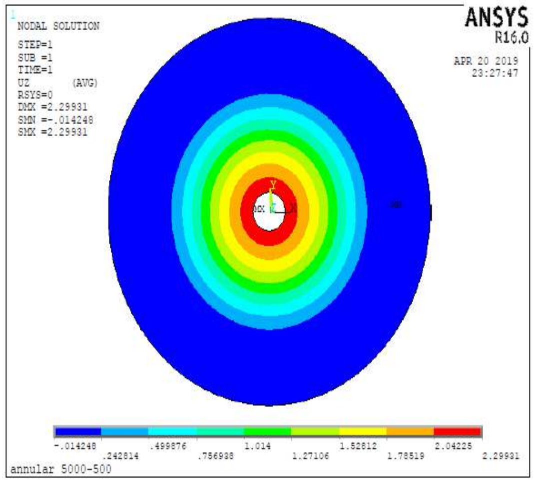


Figure 4. Deflection contour for annular raft

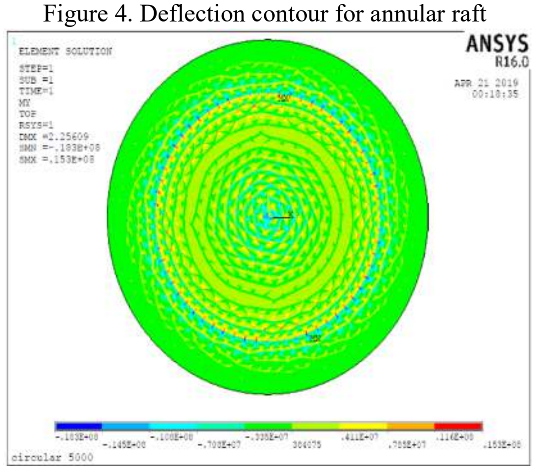


Fig 5. Radial moment contour for circular raft

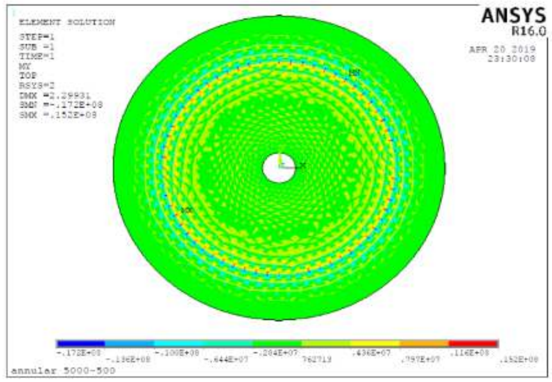


Fig 6. Radial moment contour for annular raft

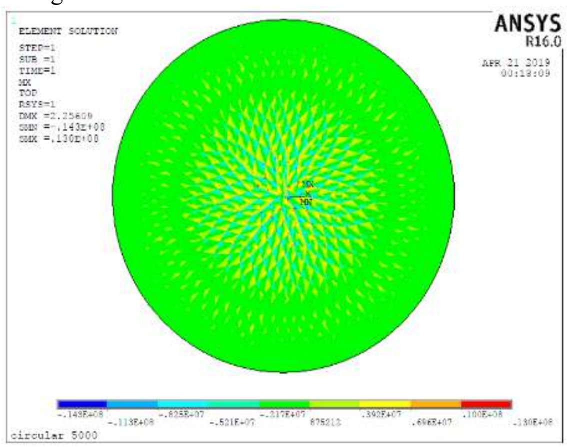


Fig 7. Tangential moment contour for circular raft

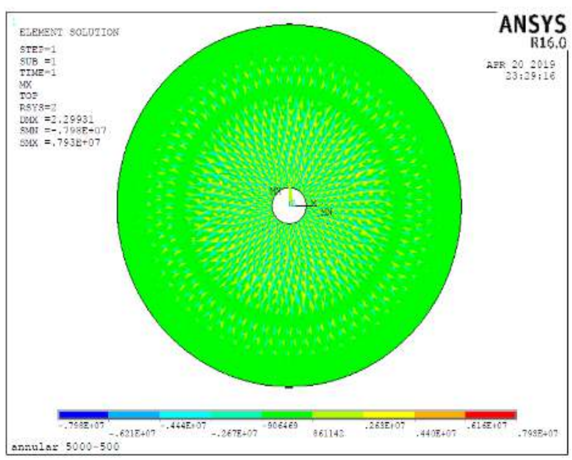


Fig 8. Tangential moment contour for annular raft

6 Discussions

For various ratios of inner radius to outer radius of annular raft, Table 2 compares deflection and bending moments computed using analytical technique and ANSYS. Table 2 shows that the results derived from analytical equations for deflections and bending moments correspond well with the findings obtained from ANSYS. The results from both procedures are substantially identical in 95 to 97 percent of cases. For circular and annular rafts exposed to uniform pressure, Table 3 compares deflection and bending moments determined from analytical and ANSYS simulations. Table 3 shows that the findings of the analytical technique and ANSYS for deflection and bending moments for annular and circular rafts match roughly 95 percent.

For various ratios of inner radius to outer radius of annular raft, Table 2 compares deflection and bending moments computed using analytical technique and ANSYS. The maximum deflection value, as well as the maximum bending moments, increases as the ratio of the inner radius to the outer radius of the annular raft grows; this is due to a reduction in raft area. The product of force and distance is defined as moment.Due to reduction of area, there will be reduction in distance, hence bending moment gets reduced. It can be observed that with reduction in area of annular raft, load to be applied on raft gets increased. This increase in load is related to bearing capacity of soil. Hence selection of suitable type of annular raft depends upon the bending moments developed in raft and bearing capacity of soil.

For circular and annular rafts exposed to uniform pressure, Table3 compares deflection and bending moments determined from analytical and ANSYS simulations. Results indicate that maximum value of bending moments in annular raft is less in comparison with bending moments in circular raft. This is due to reduction in area of raft and increase in stiffness of raft.

7 Conclusions

The parametric analysis of bending moments and defections of circular and annular rafts using analytical methods like as CPT and ANSYS yielded the following results:

1. With increase in ratio of inner radius to outer radius in annular raft, maximum deflection value and maximum bending moment values get reduced.
2. In annular raft, up to ratio of 0.4, maximum deflection occurs at the inner edge of raft. Beyond 0.5 ratios, maximum deflection occurs at the outer edge of raft.
3. In an annular raft, the maximum radial moment occurs at the ring beam location, while the maximum tangential moment occurs at the raft's inner border.
4. Radial moments and tangential moments in annular raft are less in comparison with radial and bending moments in circular raft.
5. Annular raft is more economical to design in comparison with annular raft.

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