

# Behaviour of Cohesion Less Soil with Square Plate

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## ABSTRACT

*Many studies on the distribution of contact pressure have been made when a flexible or rigid footing is founded on soil. Many investigators have proposed bearing capacity theories assuming the footing to be rigid. But all theories have been based on the assumption that the footing will always be in contact with the soil.*

*In this paper numerical analysis is carried out to separate foundations with partial contact with soil from those with full contact. The factors determining the contact of footing with the soil are plan dimensions, thickness and elastic properties of the*

*material of the footing, modulus of sub grade reaction of the soil supporting it, the column to footing width ratio and eccentricity of loading.*

*The conventional method of finding bending moment says that the maximum bending moment is independent of the relative rigidity of the footing (i.e. thickness of the footing and the modulus of sub grade reaction of the soil supporting it). But ANSYS 12.0 results show that bending moment depends on relative rigidity of footing also. Experimental work have been conducted to verify the values of maximum bending moment given by ANSYS*

## 1. INTRODUCTION

A Considerable progress has been made in the design of superstructure whereas the design of foundations still needs much attention. Very little work has been done on such problems perhaps due to complexity of soil structure interaction. As a result, the foundations are designed very conservatively. In soil structure interaction problems, a very high factor

of safety (which is nothing but factor of ignorance) is used. Hence if considerable attention is imparted to the study of behaviour of structure in relation with soil, it will lead to reduction of factor of safety to be adopted in the estimation of bearing capacity and bending moment. In most cases, the conventional methods are conservative and in some cases, surprisingly unsafe.

### 1.1 INTRODUCTION TO ANSYS 12.0

The ANSYS 12.0 computer program is large scale purpose finite element program which may use to solve several classes of engineering analysis.

The analysis capabilities of ANSYS 12.0 include the ability to solve static and

Dynamic structural analysis, steady state and transient heat transfer problems, mode frequency and buckling Eigen value problems, static or time varying magnetic analysis and various types of field and coupled field applications.

The ANSYS 12.0 program does not require any special knowledge of system operation or computer programming in order to be used.

### 1.2 About ANSYS software:-

ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electromagnetic problems.

In ANSYS 12.0 library contains more than 100 elements. Elements having unique number and a prefix that defines its category.

**Static Analysis:** The applied loads and support conditions of the solid body do not change with time. Nonlinear material and geometrical properties such as plasticity, contact, creep, etc., are available.

**Modal Analysis:** This option concerns natural frequencies and modal shapes of a structure.

**Harmonic Analysis:** The response of a structure subjected to loads only exhibiting sinusoidal behaviour in time.

**Transient Dynamic:** The response of a structure subjected to loads with arbitrary behaviour in time.

**Eigenvalue Buckling:** This option concerns the buckling loads and buckling modes of a structure

And can be used for one dimensional, two dimensional, three dimensional problems also. In general, a finite element solution may be broken into the following three stages.

- Build the model
- Apply loads and obtaining the solution
- Review results

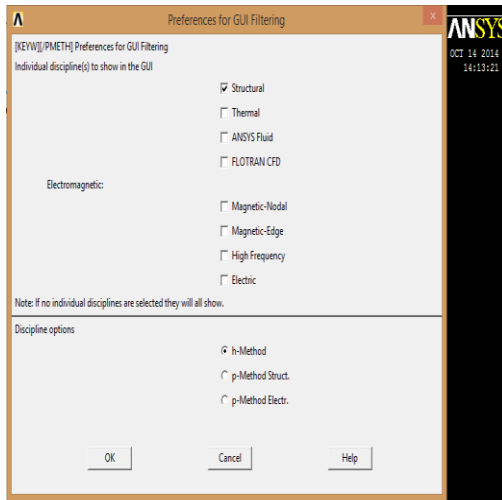
The first step in any analysis is specifying a job name and analysis title. Then to build the model PREPROCESSOR is used.

In this depending up on the model can select the element type, to that element real constants, and material properties can be defined, model can be prepared by using create option after that model can be created. Geometry can be prepared through key points, lines, areas, and volumes. After that mesh lines, areas, volumes as required SOLUTION phase is entered where the analysis type is specified.

- Assigning loads: here we specify the loads (point or pressure)
- Constraints: here we specify constraints (translational and rotational)
- Solving: finally solve the resulting set of equations.  
By using GENERAL POSTPROCESSOR the analysis results are reviewed
- Lists of nodal displacements
- Element forces and moments
- Deflection plots
- Stress contour diagrams

### 3.1 Step by step procedure for modelling

At first in preferences for structural engineering problems select structural



Step 1: pre-processor

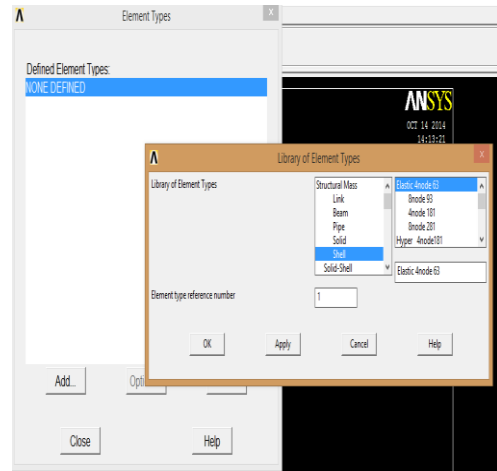
**Element type:** in this type of element is to be selected, i.e shell63

### 3. MODELLING

Shell 63 input summary

<b>Element name</b>	<b>Shell 63</b>
<b>NODES</b>	I, J, K, L
<b>Real Constants</b>	TK(I),TK(J), TK(K),TK(L), EFS, THETA, RMI, CTOP,CBOT
<b>Material Properties</b>	EX, EY, EZ, (PRXY, PRYZ, PRXZ or NUXY, NUYZ, NUXZ), ALPX, ALPY, ALPZ (or CTEX, CTEY, CTEZ or THSX, THSY, THSZ), DENS, GXY, DAMP
<b>Surface Loads</b>	<b>Pressures --</b> face 1 (I-J-K-L) (bottom, in +Z direction), face 2 (I-J-K-L) (top, in -Z direction), face 3 (J-I), face 4 (K-J), face 5 (L-K), face 6 (I-L)
<b>Body Loads</b>	<b>Temperatures --</b> T1, T2, T3, T4, T5, T6, T7, T8

option .For discipline option select h-method



Element type -> add/edit/delete-> add ->shell 63

**Real constants:** For shell 63 element from the problem considered

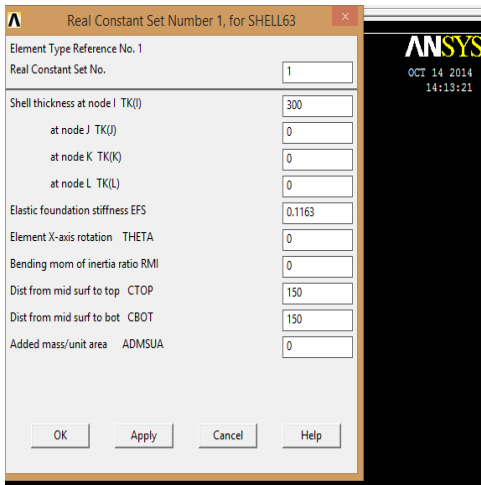
Thickness of the plate can be taken as 300 mm

Distance from top to mid surface is 150

Distance from bottom to mid surface is 150

Elastic stiffness value can be calculated from relation of CRR. By trial and error process CRR value can be fixed. For that value elastic stiffness (ks) can be fixed.

**Real constant-> add/edit/delete-> add ->shell 63-> values->ok**

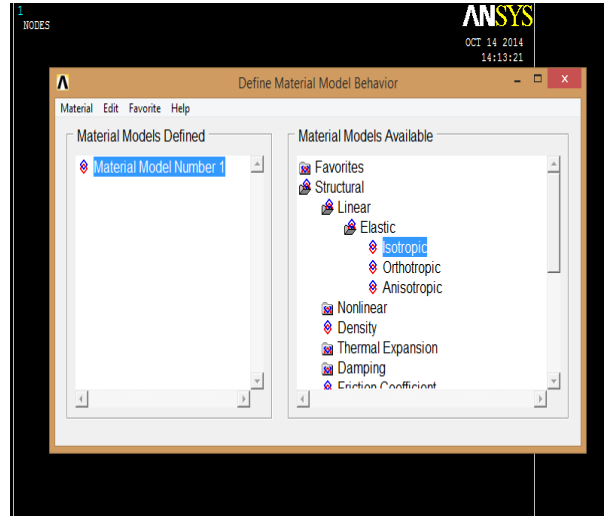


### 3.2 Material properties:

Depending up on the material used material properties can be defined.

In this model two different materials are used they are concrete and steel

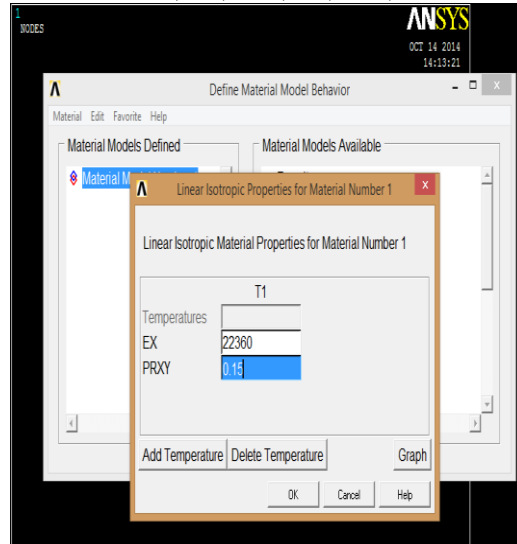
**Material properties-> material models-> material model 1-> structural->linear-> elastic-> isotropic-> values ->ok->close**



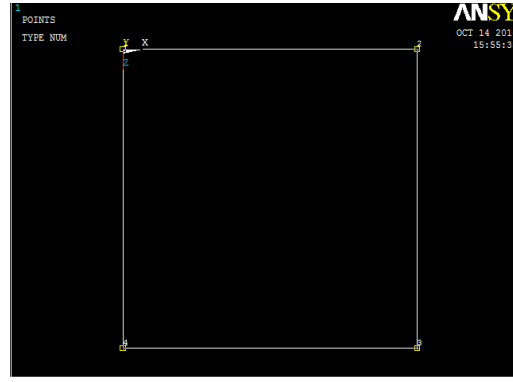
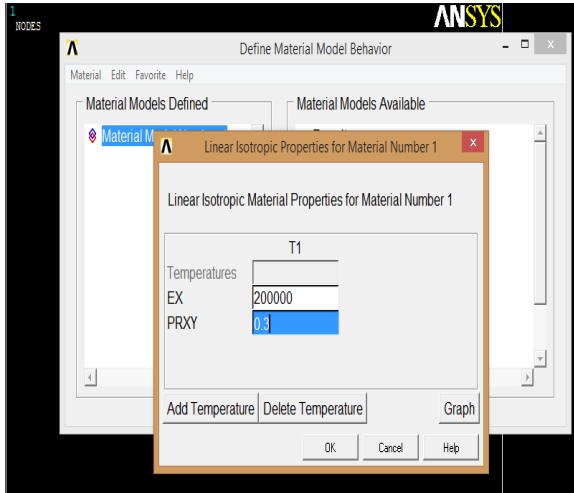
For concrete M<sub>20</sub> grade is taken and young modulus of can be calculated from the formula

$$E = 5000\sqrt{f_{ck}} = 22360$$

And Poisson's ratio value can be taken for different values like 0.15, 0.2, 0.25, 0.3, 0.35, and 0.4



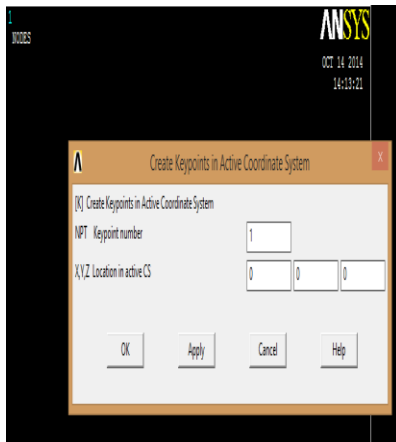
If the material used is iron plate young modulus is considered as E= 200000  
Poisson's ratio as 0.3



### 3.3 Modelling:

create option can be used design the model Modelling can be done by using creating key point option. For that key points can be selected like

- 1) (0,0,0)
- 2) (3000,0,0)
- 3) (3000,0,3000)
- 4) (0,0,3000)

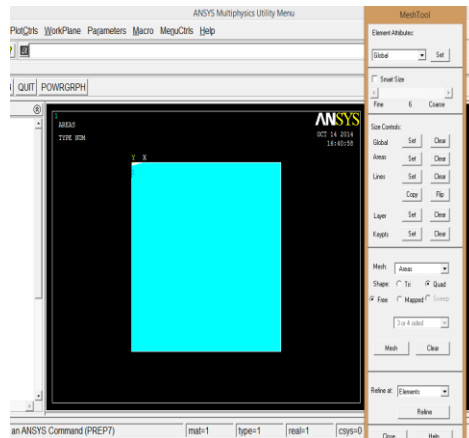


**Modelling-> create-> key points-> in active cs-> enter key points-> apply-> ok**

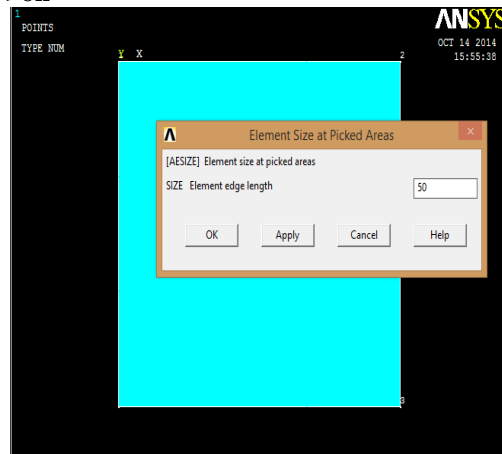
After creating key points we have to join the key points by using areas option.

**Create-> areas->arbitrary-> through key points->then select key points-> join points->ok**

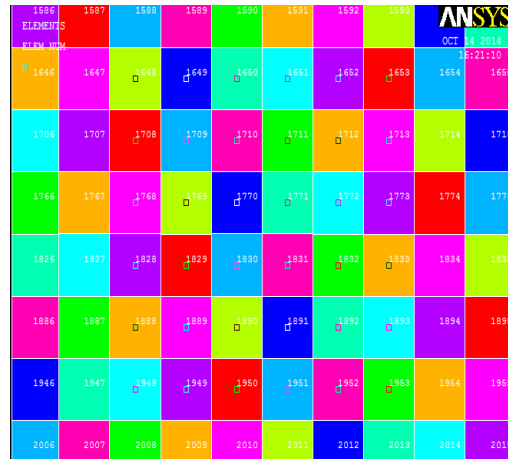
**It will appear like below figure**



For this model element edge length can be taken as 50  
**Meshing-> mesh tool-> areas-> set-> select the model-> ok-> element edge length -> enter value->ok**



**Mesh-> select areas->mesh->ok-> close**

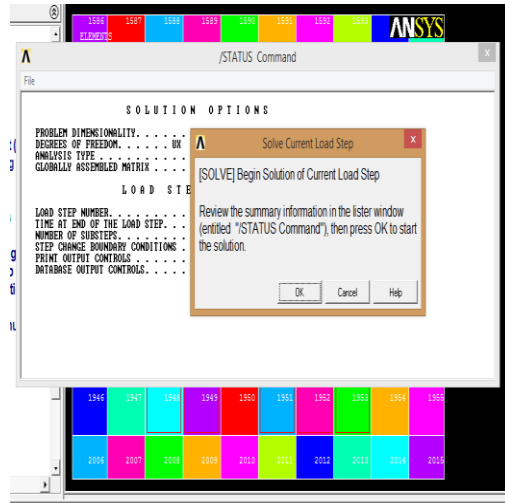
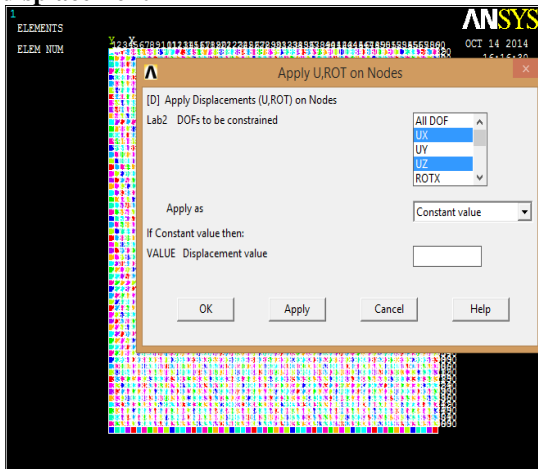


**Solution:**  
Solution can be used for solve option

**Loads:**

In loads by depending up on end conditions ends can be fixed.

**Loads-> define loads->apply-> structural-> displacement**



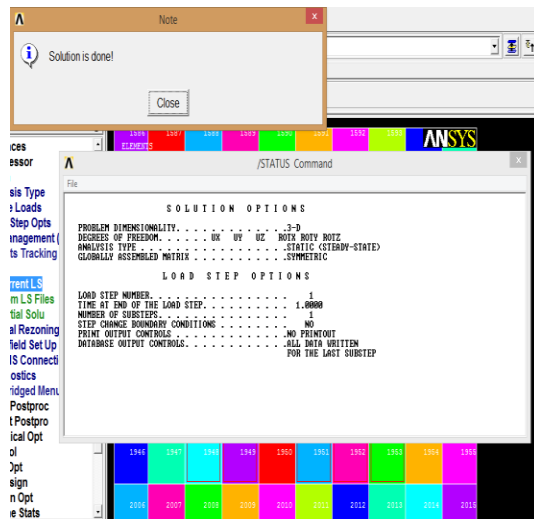
**Solution->solve->current Ls->ok**

If solution have no errors it will appear like this

After that pressure can be applied to the element.

For this model for different E/B ratios 0.1, 0.2, 0.3, 0.4 and different c/B ratios are taken 0.1, 0.2, 0.3 and 0.4

**Loads-> define loads-> apply -> structural-> pressure-> select element-> ok -> pressure value->ok**



**GENERAL POST PROSESSOR:**

From the general post processor we can get the solution results

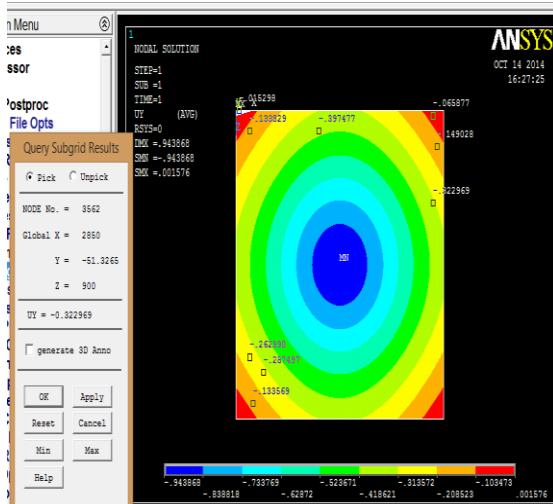
**GENERAL POST PROCESSOR**

->PLOT RESULT->COUNTOUR PLOT->NODAL SOLUTION-> DOF SOLUTION->Y- COMPONENT OF DISPLACEMENT

THE VALUES CAN BE VIEWED FROM QUERRY RESULTS THE VALUE CAN BE VIEWED

GENERAL POST PROSESSOR->QUERRY RESULTS ->DOF SOLUTION->UY->OK

AFTER THAT VAUES CAN BE APPEAR LIKE BELOW.



PROCESS WILL BE CONTINUED UNTIL WE GET UP LIFT VALUE

**4. DEVELOPMENT OF EQUATION OF CRITICAL RELATIVE RIGIDITY(CRR)**

**4.1 Introduction**

In this chapter, Multiple Linear Regression Analysis is carried out to develop the equation for Critical Relative Rigidity (CRR). And also based on the equation developed, a single graph is presented for CRR by taking all the factors in to consideration (i.e., both the soil and footing properties).

**4.2 A Brief Summary of Work done by Robindavis.P (20)**

Robindavis. P(20) had done some work to separate foundations having partial contact with the soil from those with full contact. The relative rigidity of footing at which the footing starts losing contact (CRR) is found by him for different combinations of factors like

eccentricity to footing width ratio, Poisson’s ratio of the material of the footing and column to footing width ratio. Also he developed charts for Critical Relative Rigidity.

ANSYS 12.0, a finite element method package was used for analyzing a square footing resting on soils of different modulus of subgrade reaction subjected to loading with different eccentricities through columns of different column to footing width ratios.

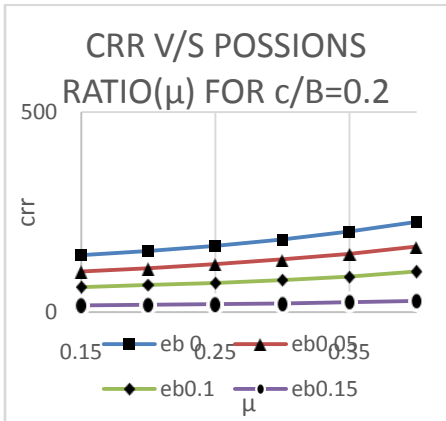
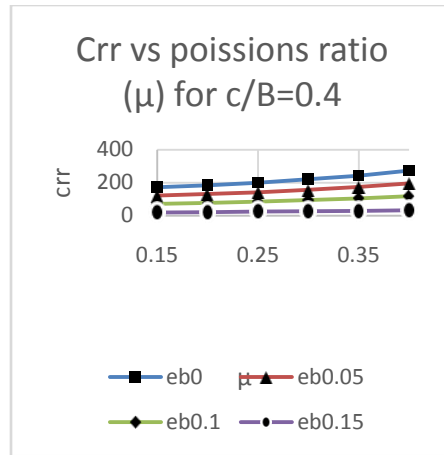
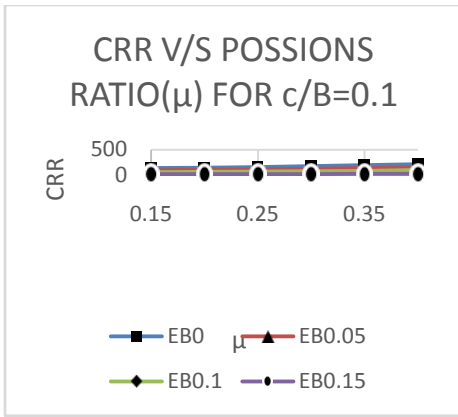
A footing of plan dimensions 3m\*3m and thickness 0.3m was modelled using shell 63 element (fig 3.2). For a particular Poisson’s ratio of the material of footing, eccentricity and a small value of modulus of subgrade reaction uniformly distributed load was applied through the columns having a particular column to footing width ratio and the deflection pattern was found in the solution. Since the modulus of subgrade reaction selected for the first trial is very small, the value of R is small and hence the footing is rigid with respect to the soil and is in full contact with the soil.

In the subsequent trials the value of  $K_S$  was increased (i.e., the footing is made less rigid) keeping all other parameters the same and the deflection pattern was analysed. In one of the trials, one of the nodes experiences upward deflection indicating that the footing loses contact with the soil. The relative rigidity corresponding to this modulus of subgrade reaction was calculated and was taken as Critical Relative Rigidity (CRR).

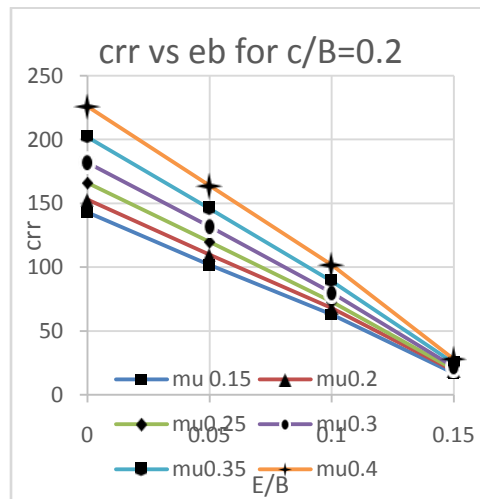
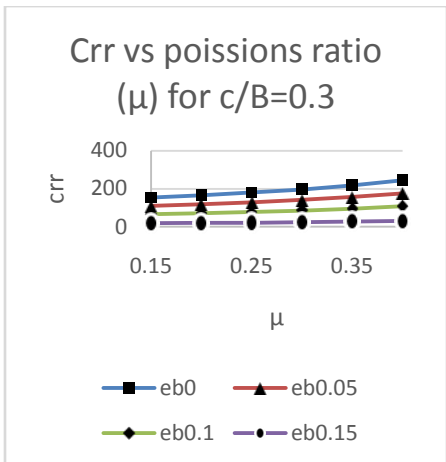
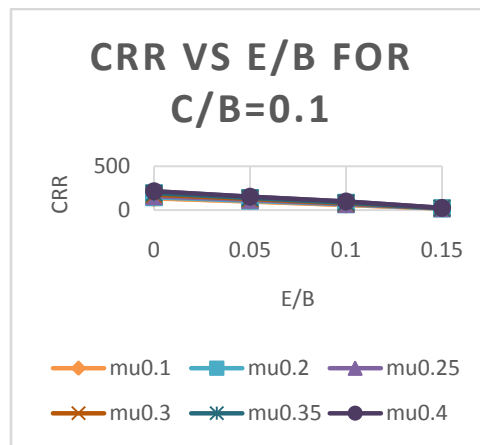
The physical meaning of CRR is that any footing having a relative rigidity less than the CRR is in full contact with the soil and the one having the relative rigidity more than CRR suffers loss of contact.

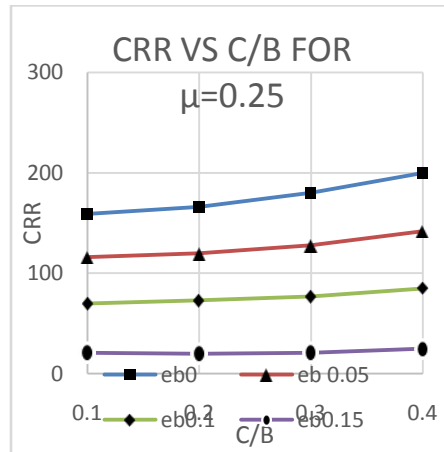
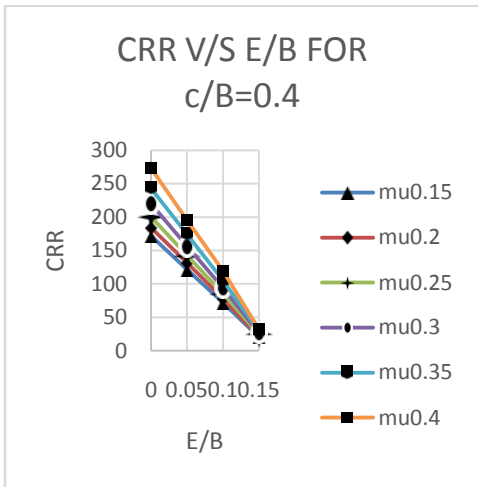
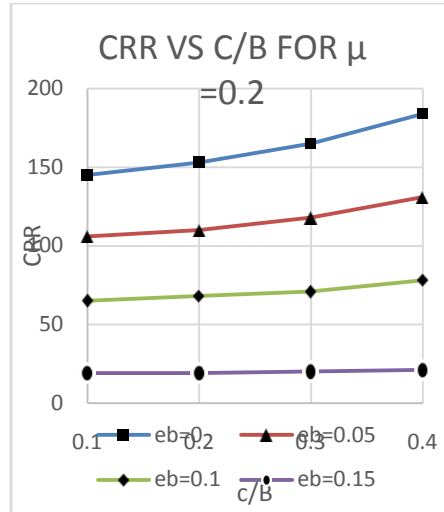
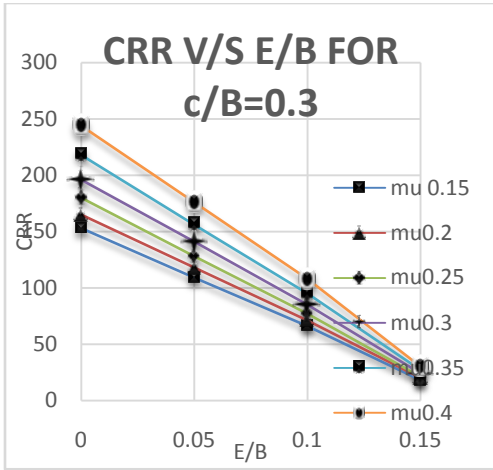
Now, changing one of the parameters (for e.g. column to footing width ratio) and keeping all other parameters constant, the CRR was found as described above. This was done, by changing all other parameters and CRR values of different combinations were found. Graphs were drawn for all the cases discussed above.

The graphs showing the variation of CRR with respect to ,eccentricity to footing width ratio( $e/B$ ), for various Poisson’s ratio of the material of the footing( $\mu$ ) and for the practical cases of the column to footing width ratios ( $c/B$ ) of 0.1,0.2,0.3 and 0.4 are presented in figure 5.1 to figure 5.14 respectively.

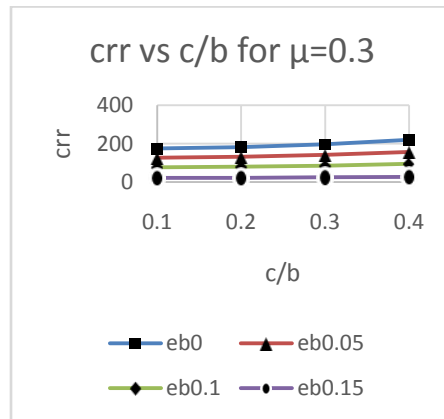
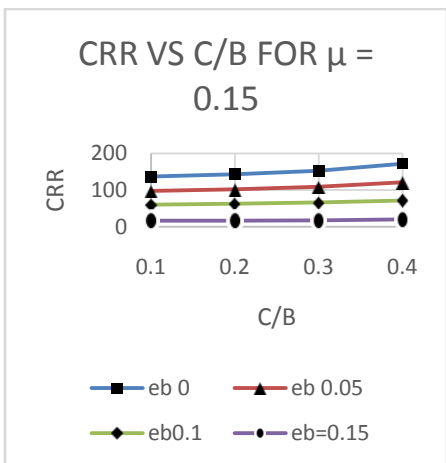


CRR VS E/B FOR DIFFENT C/B

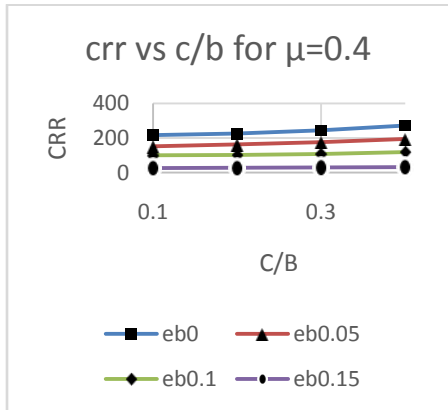
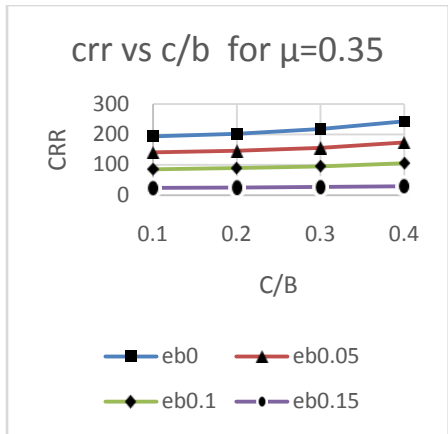




CRR VS C/B FOR MU







**4.3.1 Graph (Variation of CRR with respect of e/B, c/B and  $\mu$ )**

As it is inconvenient to use the graphs given by analytical results, a single graph is been developed for CRR values in terms of the parameters influencing it ( $\mu$ , c/B, and e/B).

The graph is presented in fig 5.15. The graph is used to find the CRR value for a given  $\mu$ , e/B, c/B. For example, if CRR is required for  $\mu = 0.2$ , c/B = 0.1 and e/B = 0.0 a horizontal line is to be drawn from 0.2 on the piston’s ratio axis so that it meets the curve corresponding to c/B = 0.1 (indicated in dotted line). From there a vertical line is to be drawn so that it meets the straight line corresponding to e/B = 0.0. From this meeting point, a horizontal line is to be drawn so that it meets the critical relative rigidity axis. The value of CRR is 157.

**4.3.2 Use of Determination of CRR:**

The determination of the CRR values for different conditions would go in a long way in helping the designer of footings in changing either the plan dimensions or the thickness of the footing in such a way that the actual relative rigidity is less than the CRR.

For example,

If a concentrically loaded concrete footing ( $\mu = 0.15$ ,  $E = 25 \times 10^6 \text{ KN/m}^2$ ) of plan dimensions 3 m x 3 m and thickness 0.5 m supporting a column of width 0.3 m (column to footing width ratio = 0.1) is resting on a very hard stratum of modulus of subgrade reaction  $8 \times 10^5 \text{ KN/m}^2$ , the actual Relative Rigidity works out to be

$$R = \frac{3\Pi(3)^4 \times 8 \times 10^5}{25 \times 10^6 \times 0.5^3} = 195$$

But the CRR for a concentrically loaded concrete footing ( $\mu = 0.15$ ) subjected to a loading with a column to footing width ratio of 0.1 is 145 (fig 5.1)

The actual relative rigidity is more than the CRR and as such this footing would only be in partial contact with the soil. Now the thickness can be increased in such a way that the actual relative rigidity is equal to CRR as below.

$$R = \frac{3\Pi(3)^4 \times 8 \times 10^5}{25 \times 10^6 \times D^3} = 145$$

$$D = 0.55 \text{ m}$$

If the thickness were increased to 0.55m, the footing would have full contact.

Alternatively the plan dimensions can be decreased as below

$$R = \frac{3\Pi(L)^4 \times 8 \times 10^5}{25 \times 10^6 \times 0.5^3} = 145$$

$$L = 2.78 \text{ m}$$

The plan dimensions can be reduced to 2.78 m provided the bearing capacity requirement is also satisfied for the reduced size.

**5. DISSCUSION OF RESULT**

**5.1 Introduction**

The following graphs have been drawn indicating the variation of Critical Relative Rigidity (CRR) with respect to

- 1) Poisson’s Ratio for various eccentricities and column width to footing width ratios.
- 2) Eccentricity to width of footing ratio for various Poisson’s ratio values and column width to footing width ratios.
- 3) Column width to footing width ratio for various eccentricities and Poisson’s ratio values.

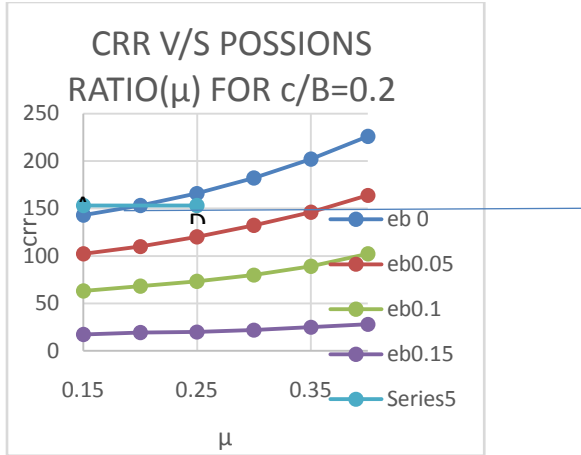
The following graph and the tables (experimental results) have been presented.

The graph drawn for .the variations of M/P(Maximum bending moment per unit width per applied load) with respect to RR for column to footing width ratio 0.2, eccentricity to

footing width ratio 0.0 and Poisson's ratio 0.3. In this chart conventional bending moment also has been indicated.

An example from each of these sets of graphs is taken and is explained as below,

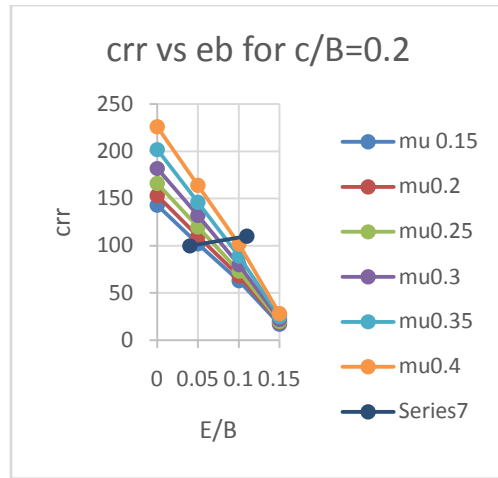
**5.2 The variation of Critical Relative Rigidity with Poisson's Ratio**



The ordinate represents CRR and the abscissa represents Poisson's ratio. As the Poisson's ratio increases CRR also goes on increasing. Considering a point A as shown in the figure and another point D which is marked on the same horizontal line through A. The point a represents the relative rigidity of a footing of Poisson's ratio 0.15.

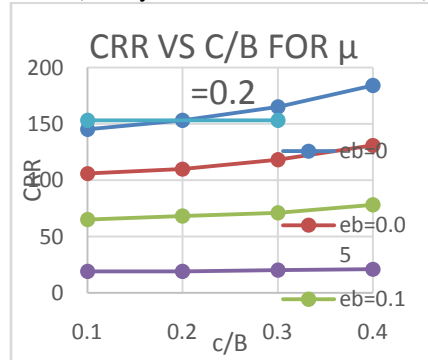
The point d corresponds to same relative rigidity as that of A but different Poisson's ratio say 0.3. The two footings are subjected to the same load concentrically. The point A is above the CRR for the footing with Poisson's ratio 0.15. This shows the concrete footing loses contact with the soil. The point D is below the CRR value for the footing with the Poisson's ratio 0.3 for the same loading conditions, indicating the steel footing is not losing contact when all other parameter are same.

**5.3 The variation of Critical Relative Rigidity with Eccentricity**



The graph (5.2) shows that as the eccentricity increases, the CRR value decreases. Comparing two points A & D having the same CRR, Poisson's ratio and C/B, but with different e/B ratio. The point A represents a footing loaded with an eccentricity 0.05 times breadth & D represents loading with an eccentricity of 0.1B.

Though both the footings are having the same CRR, Poisson's ratio, c/b, the footing which is subjected a loading at an eccentricity of 0.05B has full contact with the soil whereas the other footing with an eccentricity of 0.1 B is losing contact, even though in both the cases, the eccentricity is less than one sixth of width (satisfy the middle one third rule).



**5.4 The variation of CRR with column width to footing width Ratio**

The CRR Vs e/B variation is shown in the graph (5.3). The graph shows that a given e/B as the c/B increases, the CRR value also increases. Comparing two points A & D having the same RR, Poisson's ratio, e/B but with different c/B ratio. Point A represents footing with a c/B of 0.1 & D represents footing with c/B=0.3. Though both the footing are having the same RR, Poisson's ratio, e/B the footing which is having a c/B ratio 0.3 is in full contact with the soil whereas the other footing having c/B ratio of 0.1 is losing contact. The maximum bending moment variation with RR is shown in the graph 8.6 for c/B=0.2, e/B=0.0, and mu=0.3.

## 6. CONCLUSIONS

1. The graph drawn for the variations of M/P (Maximum bending moment per unit width per applied load) with respect to RR for column to footing width ratio 0.2, eccentricity to footing width ratio 0.0 and Poisson's ratio 0.3
2. ANSYS 12.0 results show that bending moment depends on relative rigidity of footing also
3. An equation for CRR critical relative rigidity was derived from the multiple linear regression analysis
4. Graphs have been drawn indicating the variation of Critical Relative Rigidity (CRR) with respect to Poisson's ratio, eccentricity and Column width to footing width ratio for various eccentricities and Poisson's ratio values.

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