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WELL FOUNDATION ANALYSIS COMPARISON BETWEEN NUMERICAL AND CONVENTIONAL APPROACH

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Abstract : This research paper presents a comprehensive numerical analysis of well foundations using midas gts nx(finite element method) under varying soil parameters, with comparisons to results irc:45-1972. The study focuses on evaluating critical aspects such as soil stress, displacement, and bending moment to assess the performance and reliability of well foundations in different geotechnical environments. Advanced numerical modeling techniques are utilized to simulate the soil-structure interaction, capturing the detailed behavior of well foundations across a range of soil types characterized by their cohesion, internal friction angle, and modulus of elasticity. Additionally, the findings are contrasted with the provisions of the IRC 45 code to evaluate their practical applicability and reliability.

The analysis reveals significant variations in the performance of well foundations based on soil parameters, highlighting the necessity for thorough site-specific geotechnical investigations. The study demonstrates that while MIDAS GTS NX offers highly precise predictions of soil stress, displacement, and bending moment, the IRC 45 code provides a practical and conservative design approach with sufficient safety margins. This research underscores the importance of integrating advanced numerical methods with established guidelines to optimize the design and safety of well foundations. The conclusions drawn from this study are expected to aid civil engineers in improving foundation design practices, ensuring structural integrity and longevity, and contributing valuable insights to the field of geotechnical engineering**.**

Keyword : Well foundation, Lateral response, Soil stress, Bending moment, Displacement

Introduction

Well foundations, also known as well or caisson foundations, are crucial structural elements used in a variety of civil engineering projects, such as bridges, offshore platforms, and high-rise buildings. These foundations are particularly favored in scenarios where the substructure needs to be deeply embedded in soil or rock to support heavy loads and ensure stability. The effectiveness and safety of well foundations largely

depend on the interaction between the foundation and the surrounding soil, making the analysis of soil parameters a critical aspect of their design. The behavior of well foundations under various loads is influenced by several factors, including soil type, density, cohesion, angle of internal friction, and the presence of groundwater. These soil parameters significantly affect the bearing capacity, settlement characteristics, and overall stability of the foundation. As a result, a thorough understanding of the soil-structure interaction is essential for designing well foundations that can withstand the demands of their intended applications.

Numerical analysis has emerged as a powerful tool in geotechnical engineering, enabling the detailed examination of complex soil-structure interactions that are difficult to assess through empirical methods alone. Advanced numerical methods, such as the Finite Element Method (FEM), Finite Difference Method (FDM), and Boundary Element Method (BEM), provide insights into the stress distribution, deformation patterns, and potential failure mechanisms of well foundations under various loading conditions. These methods allow engineers to model the nonlinear behavior of soils, account for anisotropy and heterogeneity, and evaluate the impact of different soil parameters on foundation performance.

This paper aims to investigate the numerical analysis of well foundations for different types of soil parameters. By employing state-of-the-art numerical techniques, we analyzed the response of well foundations embedded in various soil types, including sandy, clayey, and mixed soils. The study will focus on key soil parameters such as cohesion (c), angle of internal friction (ϕ), modulus of elasticity (E), and Poisson's ratio (ν), examining their influence on the bearing capacity, settlement, and overall stability of the foundation.

The research will contribute to a better understanding of how different soil conditions affect the performance of well foundations. The findings will provide valuable guidelines for the design and optimization of these foundations, ensuring safety, reliability, and cost-effectiveness in civil engineering projects. By integrating numerical analysis with practical considerations, this study aims to bridge the gap between theoretical research and real-world applications, ultimately enhancing the design practices for well foundations in diverse geotechnical environments.

Design Aspects Of Well Foundation

The design of the bottom plug, curb, steining thickness, and grip length are the primary well foundation design elements. It is best to sink a well foundation below the maximum scour depth so that the grip length is this embedded length, and there is sufficient lateral stability. Grip length is necessary for creating enough passive resistance to offset the overturning moment brought on by the horizontal force at the well top, in addition to the Rankine depth factor. An additional need is that the well be dug to a depth where it rests on strata with sufficient bearing capability for the force being transmitted.

It is important to construct the steining thickness so that it can withstand the forces that are created during installation and sinking. If at all possible, the thickness should be planned to provide the well with enough self weight, preventing the need for additional for sinking, use weight or kentledge. In addition to the forces at work, additional forces brought on by sand blows and the need for mild blasting when boulders prevent the well from sinking should also be taken into account.

Analysis & Procedure

1. IRC method (irc:- 45-1972)

   The analysis of well foundations using the IRC 45-1972 code involves adhering to standardized guidelines for the design and construction of foundations in India. This code provides comprehensive criteria for evaluating the bearing capacity, settlement, and stability of well foundations under different loading conditions. By following IRC 45-1972, engineers can ensure that the design accounts for crucial factors such as soil type, cohesion, angle of internal friction, and groundwater effects. The code also specifies detailed procedures for load testing and quality control, which are essential for ensuring the reliability and safety of well foundations in various civil engineering projects.

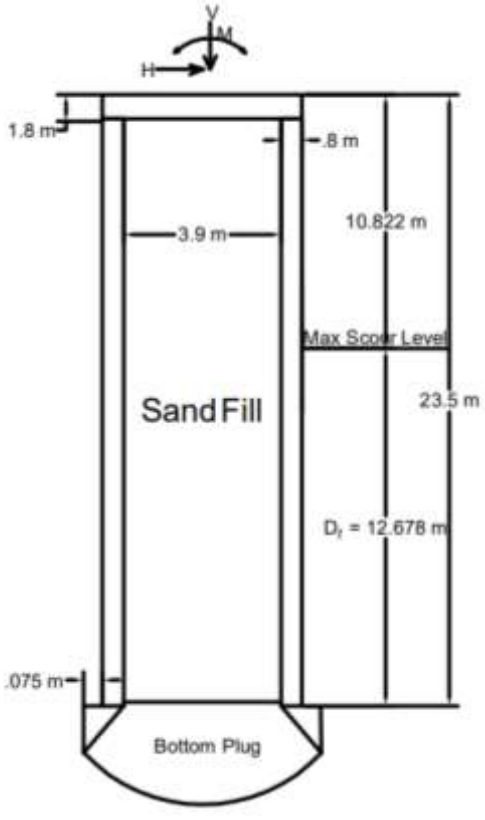
2. Finite element analysis

The analysis of well foundations using MIDAS GTS NX software, which employs the Finite Element Method (FEM), enables precise simulation of soil-structure interaction. This advanced software facilitates the evaluation of stress distribution, deformation patterns, and stability under various loading conditions. By modeling different soil parameters such as cohesion, angle of internal friction, and modulus of elasticity, engineers can gain insights into the foundation's performance. MIDAS GTS NX allows for the consideration of complex geotechnical factors, enhancing the design's accuracy and reliability. This study aims to optimize well foundation designs by leveraging the capabilities of MIDAS GTS NX in diverse soil conditions.

A numerical model of soil-well foundation system

A circular well foundation is considered in the present study in fig. 1. Total width of well foundation B is 5.5 m diameter of the dredge hole is 3.9 m and Total length of well foundation is 23.5 m. The dredge hole is filled with the sand with elasticity modulus 76750 Kpa. Top plug having thickness 0.8 m & Bottom plug are made of M20 grade concrete. In the present study, maximum scour level is considered 10.822 m and embedment depth is 12.678 m. Well cap thickness is considered 1.8 m. Steining thickness is consisered 0.8 m and also Thickness of well curb is more than 75 mm and I will considered 75 mm thickness. IRC 78-2000 recommends that a well foundation shall be taken down to a depth which will provide a minimum grip of 1/3 of the max. depth of scour below design scour level. Loading condition applied in the well foundation top of the well cap including vertical Load (KN), Horizontal Load (KN), and Moment(KN m).

In present study well foundation considered to be embedded in Sandy soil and also surrounded consistency matter in the soil-well structure. The sandy soil model considered to be loose sand, medium sand, dense sand.



Numerical modelling

Soil-well foundation system considered in the present study is 3D model. Numerical modelling is done using MIDAS GTS NX software (Finite Element Method). However, the deformation response and below the base of well foundation solid stress, Displacement at the top of well cap, vertical settlement, Horizontal displacement and scour displacement, bending moment and rotation of the well foundation. The soil-well foundation method is regarded as a plain strain issue by IRC standards as well. Though it must be specified as a semi-infinite domain for numerical simulation, the surrounding soil media is actually a finite domain without sacrificing the precision of the findings. This is accomplished by carrying out a sensitivity analysis, which yields the ideal size for both the element and the domain. Appropriate material models to represent the surrounding soils and well foundation, as well as a model depicting the contact between the well foundation and the surrounding soil, are necessary for sensitivity analysis. These fall into three categories: interface modeling, material modeling, and geometric modeling, in that order. The geometric modeling, material modeling, and interface modeling that this study examined are described in the following sections.

Material modelling of the well foundation

Material	M35	M20	SAND (dredge hole)
Young's modulus E (GPa)	29.58	22.36	0.07675
Poisson ratio μ	0.15	0.15	0.35
Density γ (KN/m3)	24	24	18.24
Cohesion (KPa)	-	-	0
Ø (°)	-	-	37

Table 1. Material property of the well foundation

Loading Data Of The Well Foundation (Reference - som & das book)

Dead Load (kN)	12400
Live Load (kN)	1390
Lateral Load (kN)	1755
Total Load (kN)	13790
Applied Moment (kN m)	27768

Table 2. Loading data of the well foundation

In this study considered the well foundation in concrete structure material property assign isotropic elastic model and soil material property assign mohr-coulmb model.

Result & Discussion

Problem 1 – Well Foundation In Loose Sand

Material	γsat (KN/m3)	cohesion (KPa)	Ø (°)	δ (°)	Young's modulus E (KPa)	SPT (N)
Sand	16.8	0	27	18	39420	6

. Table 3. Soil Parameter Problem 1

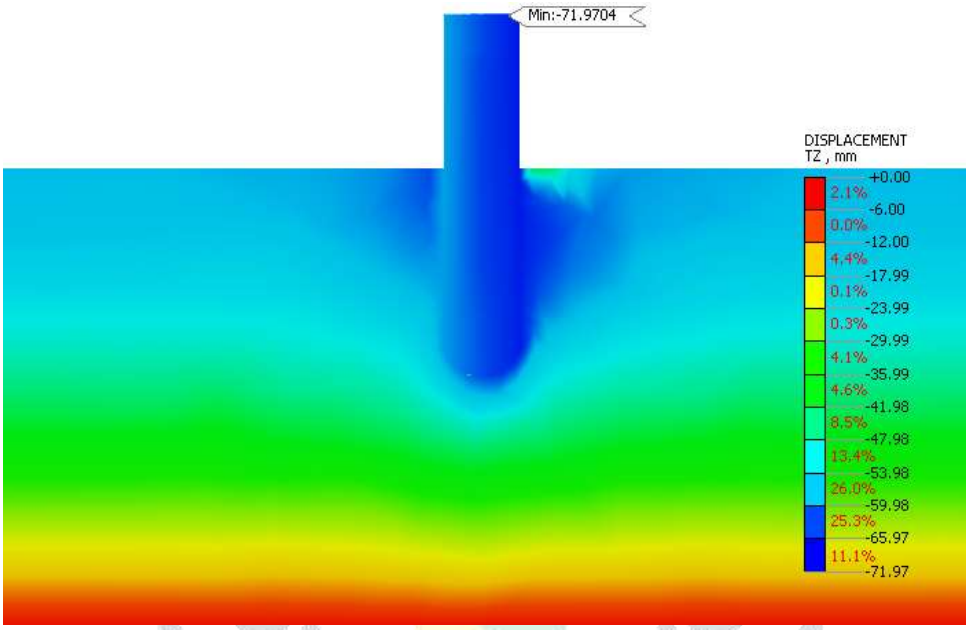


Figure 2. Vertical Settlement in mm

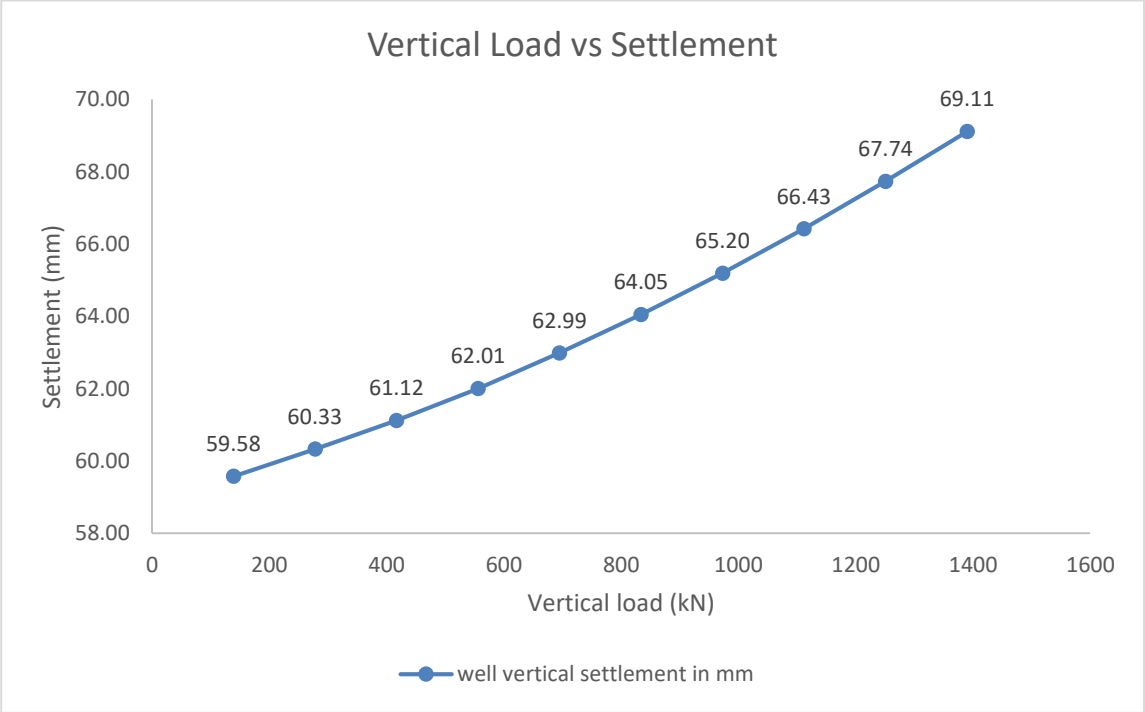


Figure 3. Vertical Load vs Settlement in well foundation

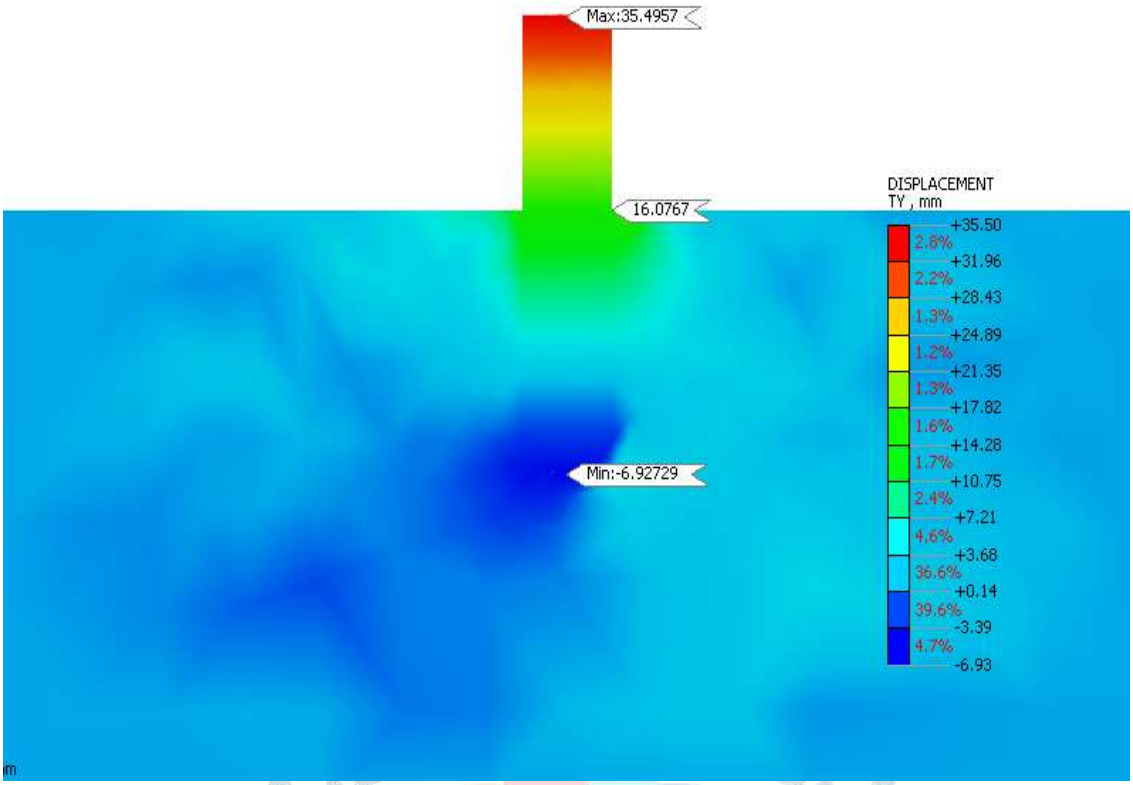


Figure 4. Top of well cap & Scour Displacement in mm

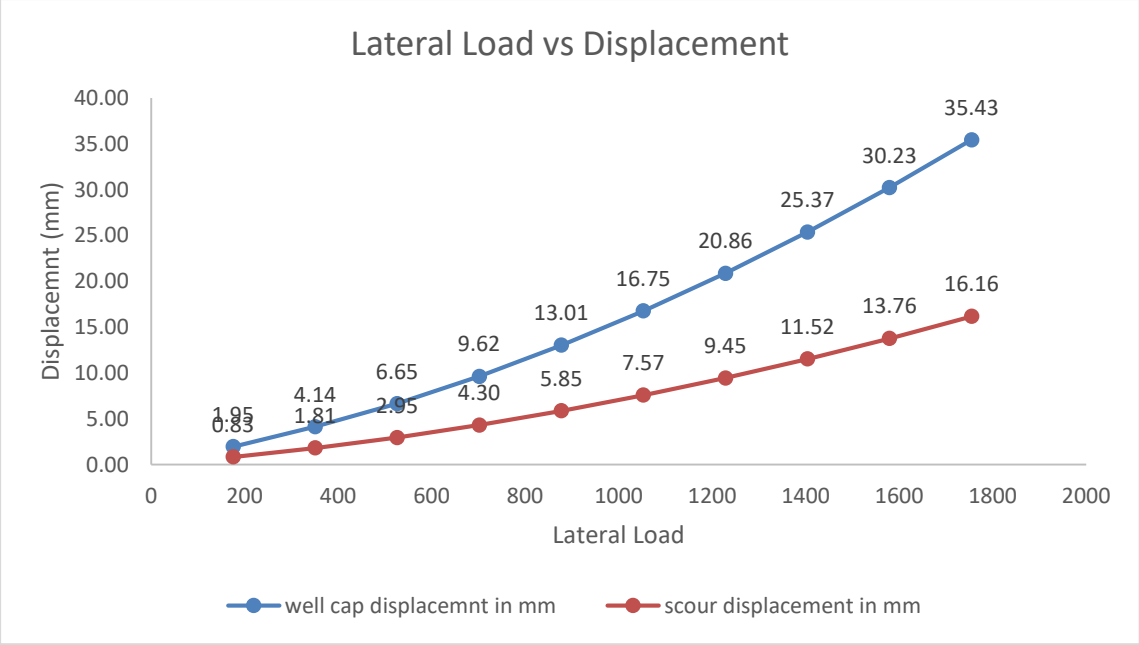


Figure 5. Lateral Load vs Displacement of well cap and scour level

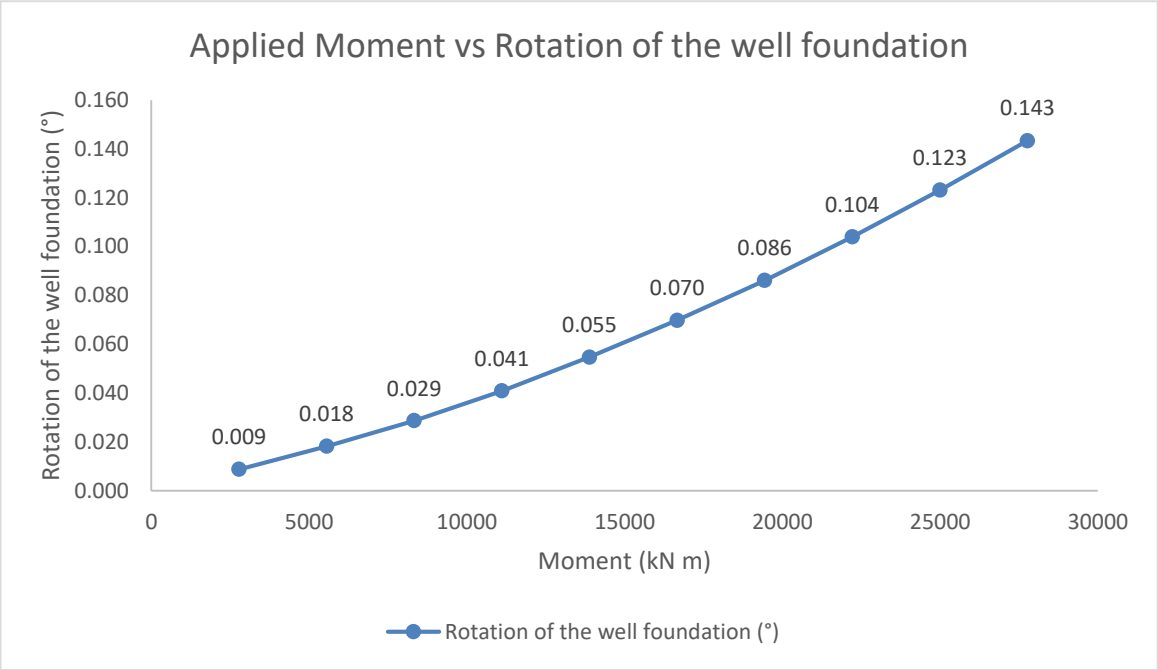


Figure 6. Moment vs Rotation of the well foundation

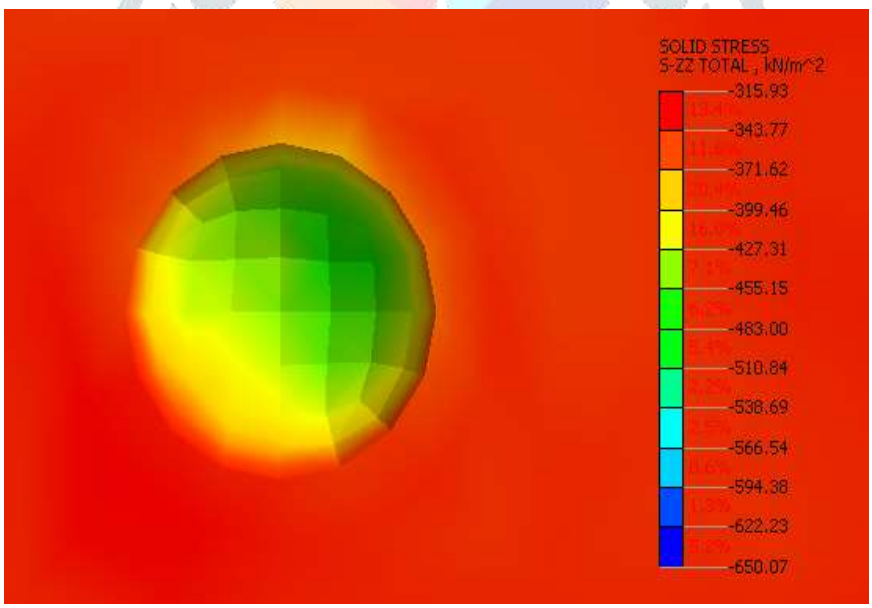


Figure 6. Moment vs Rotation of the well foundation

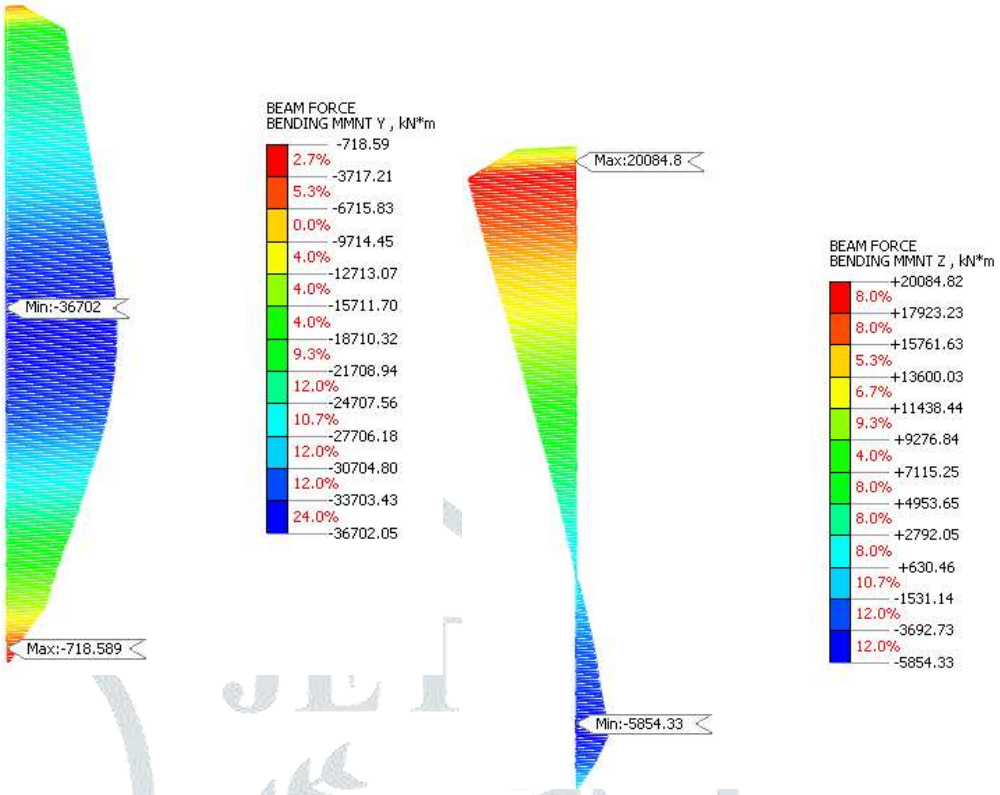


Figure 8. Bending Moment Y-Direction and Z-Direction in kN m

Fig.2 shows the vertical settlement of the well foundation embedded in homogeneous sandy soil. As per given Table 2 in loading condition will be applied and I got max. settlement 71.97 mm. Fig.4 shows lateral Y-direction in top of well cap displacement 35.50 mm, scour displacement 16.16 mm. Generated moment applied in the well foundaion got the rotation 0.143°. Fig.7 shows loading condition applied then after of well foundation solid stresses will be generated max. 483.00 kN/m^2 and min. 371.62 kN/m^2. Fig. 8 shows got the bending moment in Y-direction max. 36701.5 kN m & min. 718.59 kN m and Z- direction max. 20084.82 kN m & min. 5854.34 kN m. As well as shown the Fig. 3 plot the load vs settlement curve in iteration number and got the settlement in given load. Fig.5 shows the plot the lateral load vs displacement curve of well cap displacement, scour displacement. Fig. 7 shows the plot the curve of moment vs rotation in the well foundation I got rotation.

Problem 2 – Well Foundation In Medium Sand

Material	γsat (KN/m3)	cohesion (KPa)	Ø (°)	δ (°)	Young's modulus E (KPa)	SPT (N)
Sand	18.85	0	33	22	65906	20

Table 4. Soil Parameter Problem 2

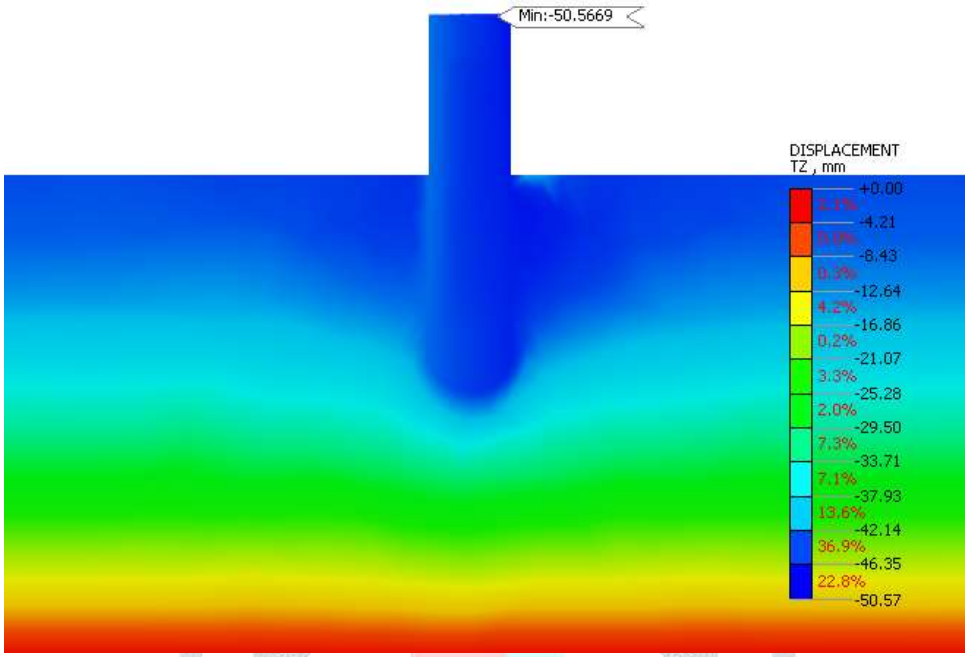


Figure 9. Vertical Settlement in mm

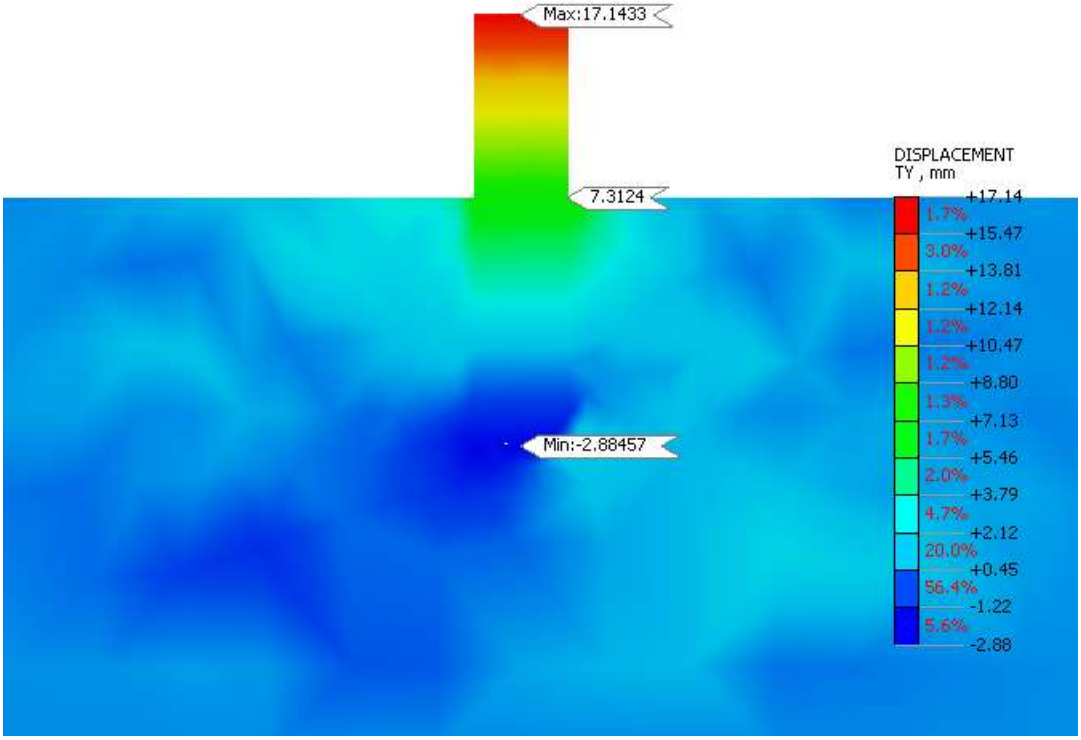


Figure 10. Top of well cap and scour level dispalcement in mm

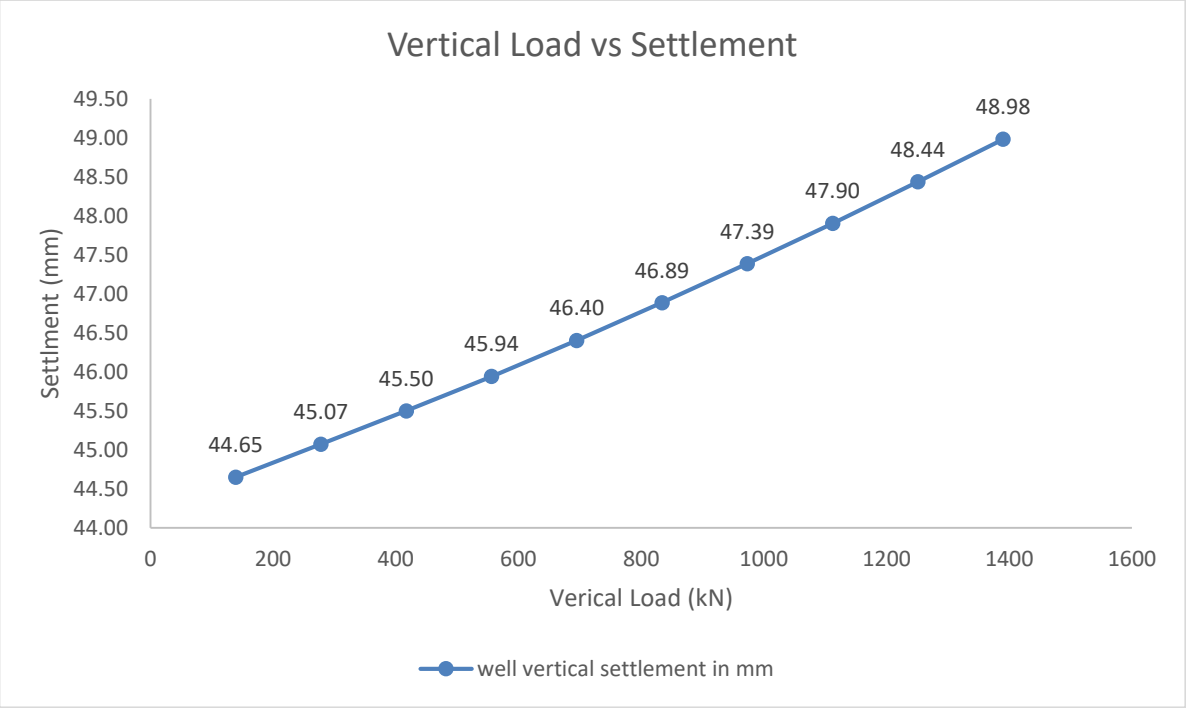


Figure 11. Vertical Load vs Settlement in the well foundation

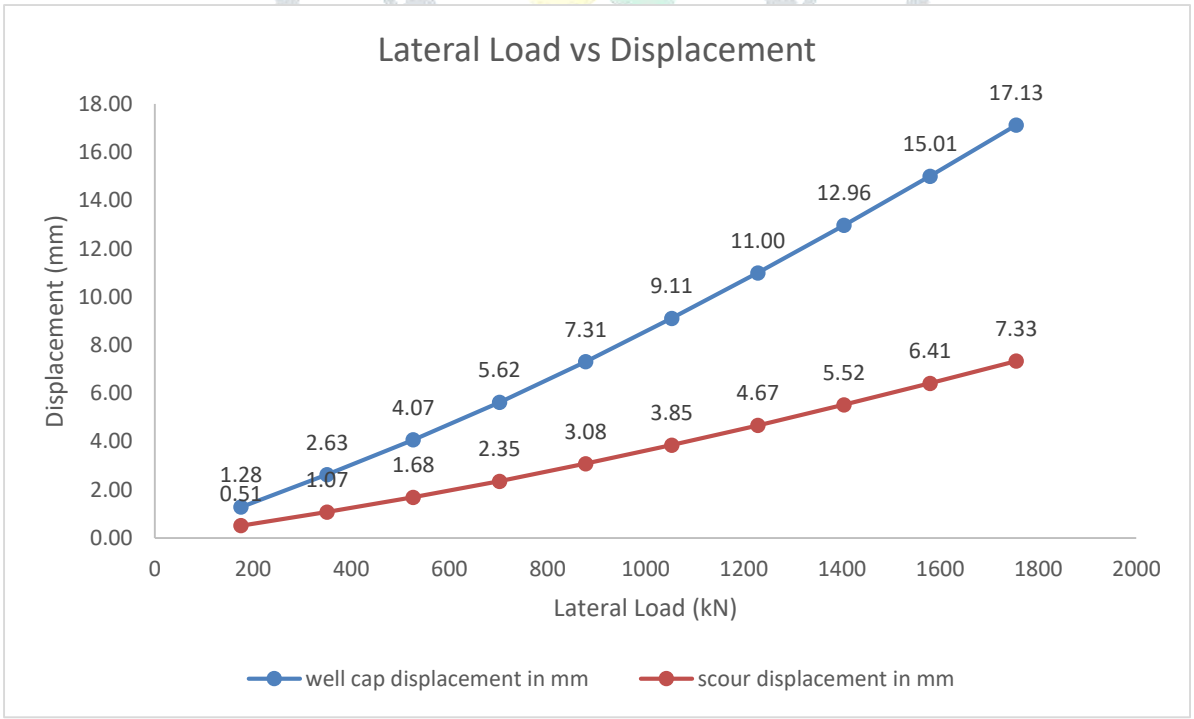


Figure 12. Lateral Load vs Displacement of well cap and scour level

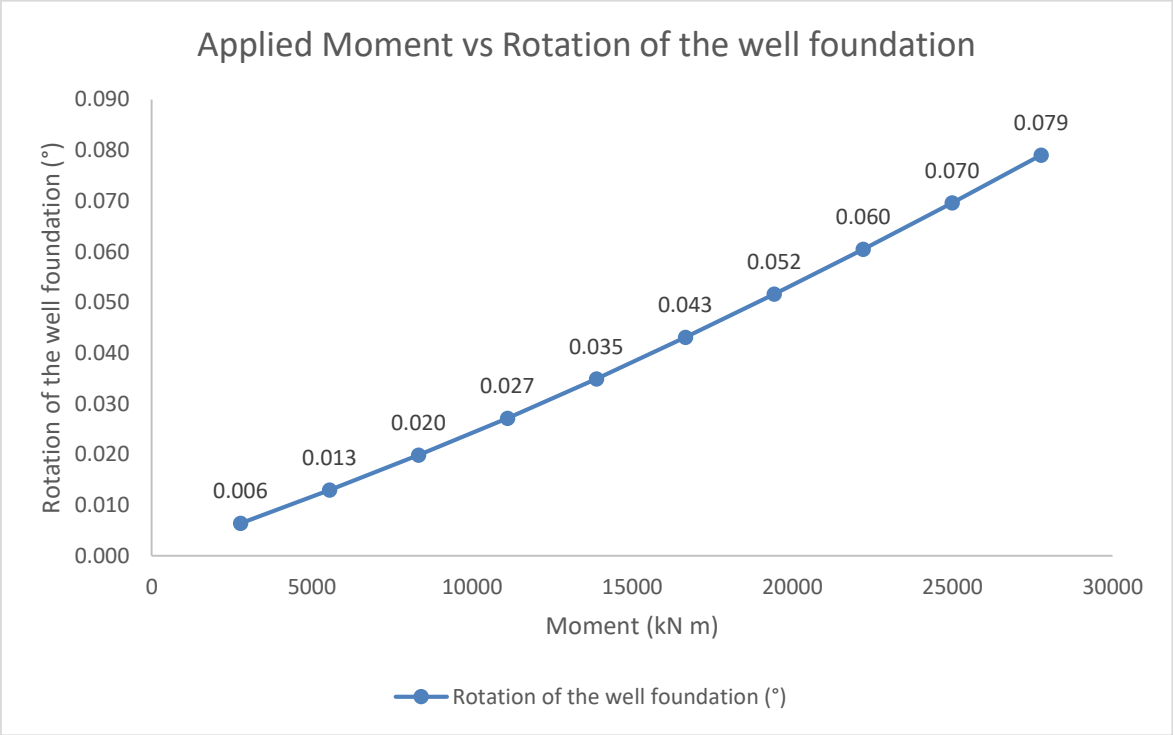


Figure 13. Moment vs Rotation of the well foundation

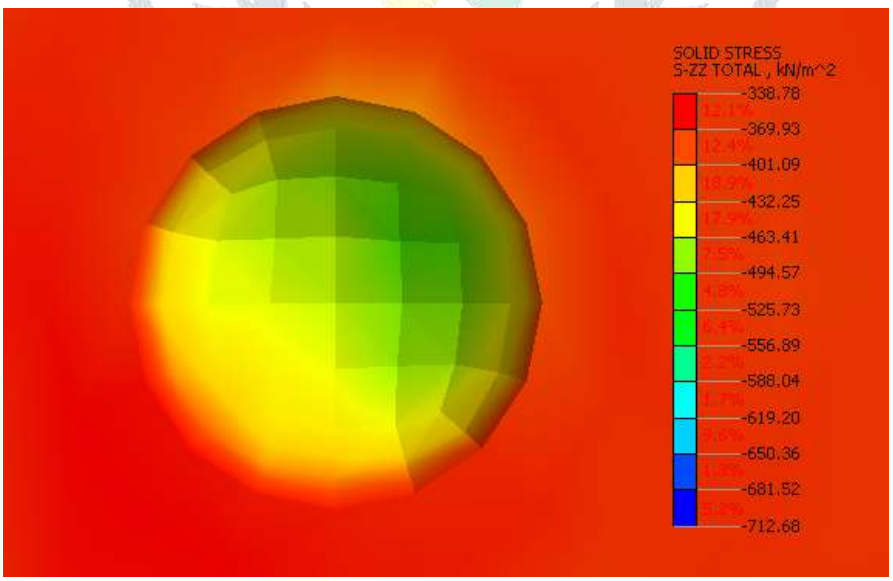


Figure 14. Solid Stress generate below the well foundation

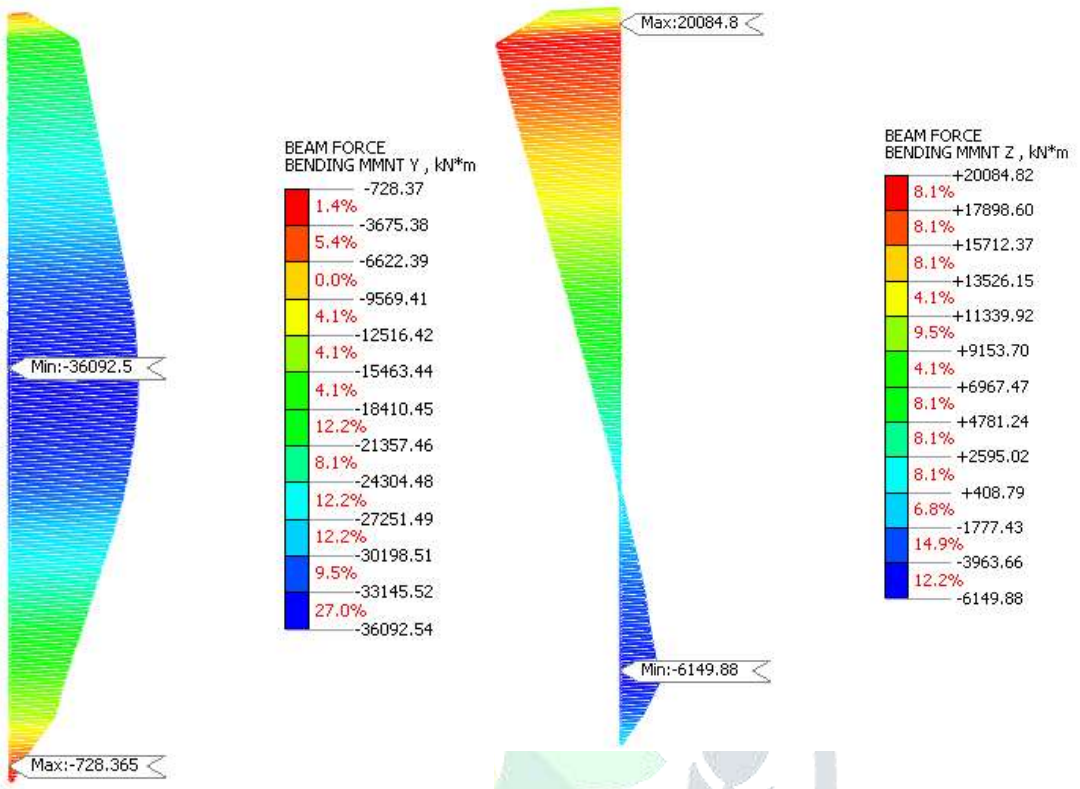


Figure 15. Bending Moment Y-Direction and Z-Diection in kN m

Fig.9 shows the vertical settlement of the well foundation embedded in homogeneous sandy soil. As per given Table 2 in loading condition will be applied and I got max. settlement 50.57 mm. Fig.10 shows lateral Y-direction in top of well cap displacement 17.14 mm, scour displacement 7.31 mm. Generated moment applied in the well foundaion got the rotation 0.079°. Fig.14 shows loading condition applied then after of well foundation solid stresses will be generated max. 494.57 kN/m^2 and min. 432.25 kN/m^2. Fig. 15 shows got the bending moment in Y-direction max. 36092.54 kN m & min. 728.36 kN m and Z- direction max. 20084.82 kN m & min. 6149.88 kN m. As well as shown the Fig.11 plot the load vs settlement curve in iteration number and got the settlement in given load. Fig.12 shows the plot the lateral load vs displacement curve of well cap displacement, scour displacement. Fig.13 shows the plot the curve of moment vs rotation in the well foundation I got rotation.

Problem 3 – Well Foundation In Dense Sand

Material	γsat (KN/m3)	cohesion (KPa)	Ø (°)	δ (°)	Young's modulus E (KPa)	SPT (N)
Sand	19.18	0	38	22.5	79900	38

Table 5. Soil Parameter Problem 3

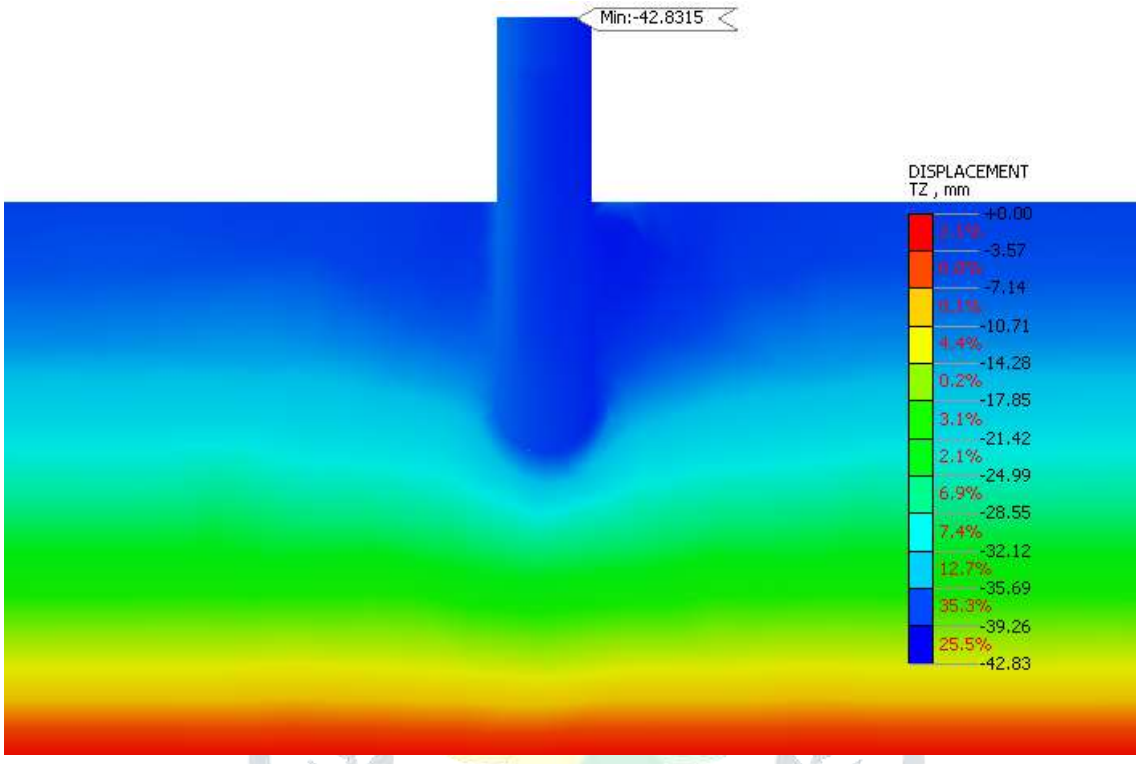


Figure 16. Vertical settlement in mm

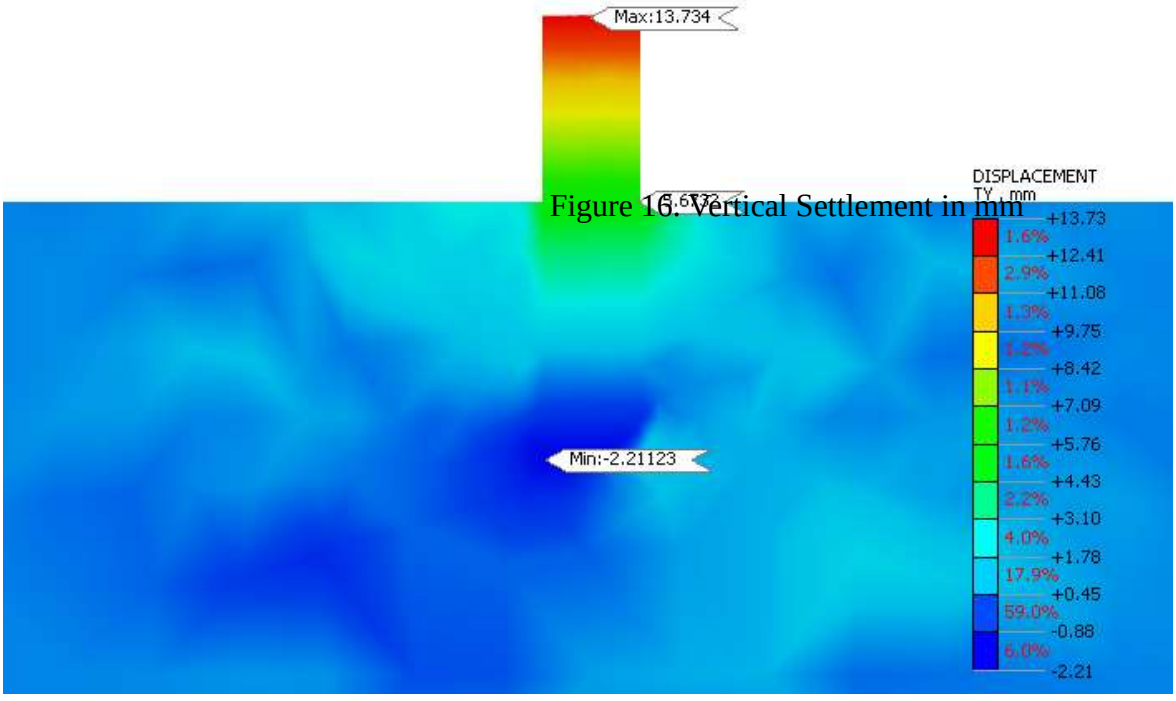


Figure 16. Vertical Settlement in mm

Figure 17. Top of well cap and scour level dispalcement in mm

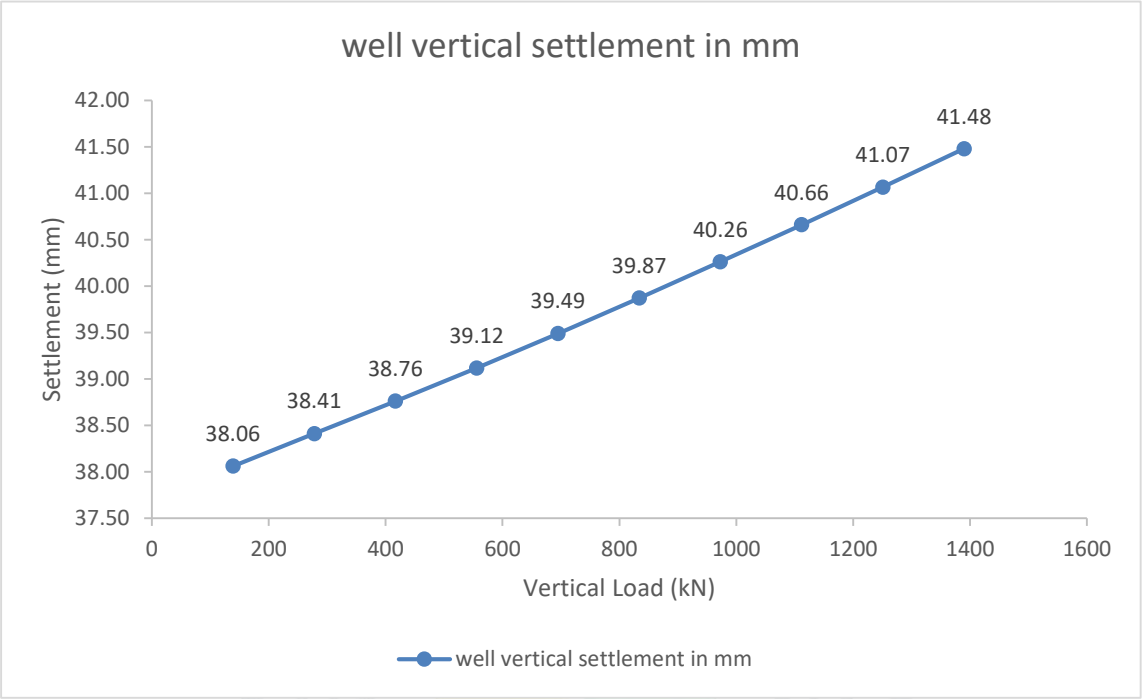


Figure 18. Vertical Load vs Settlement in well foundation

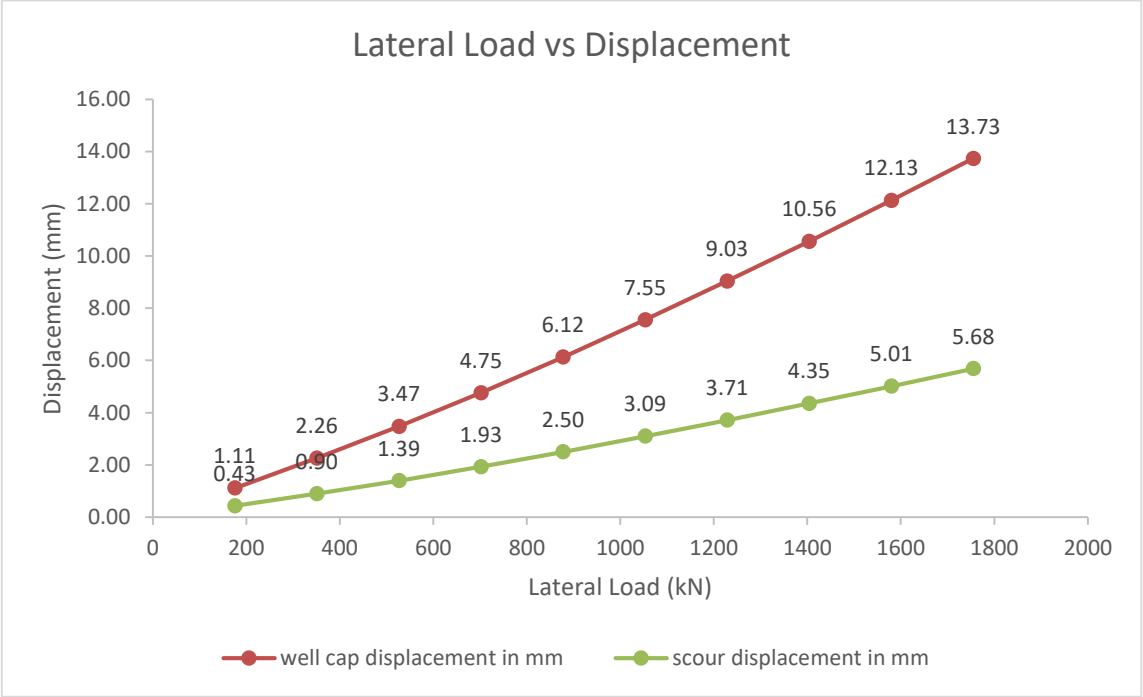


Figure 19. Lateral Load vs Displacement of well cap and scour level

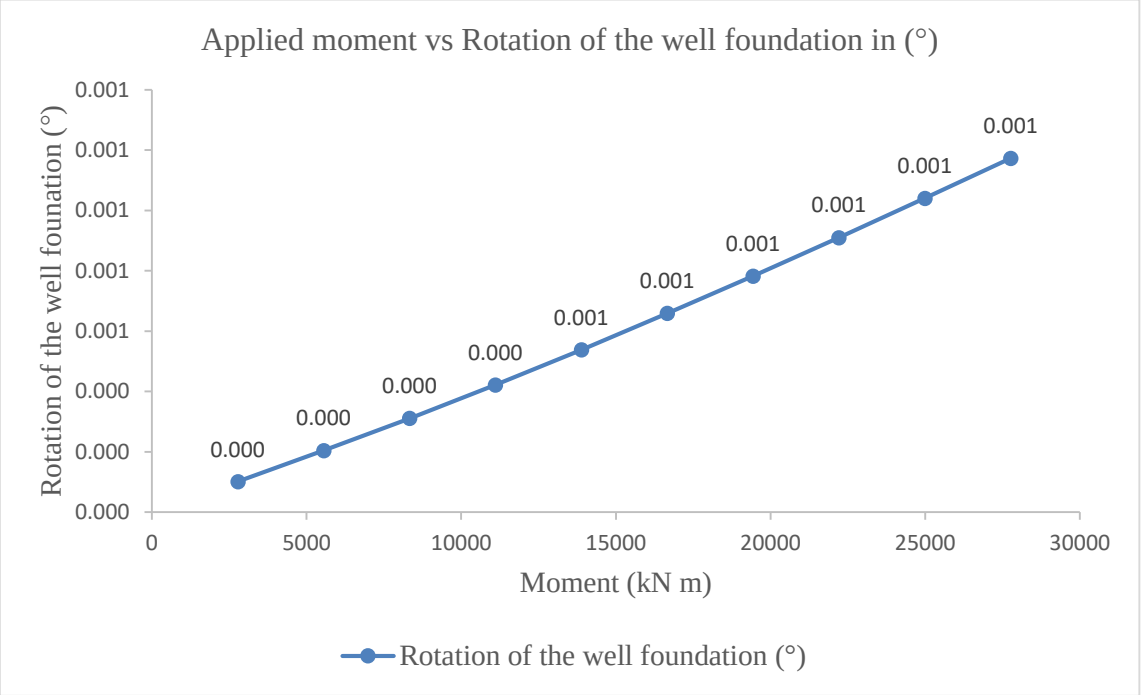


Figure 20. Moment vs Rotation of the well foundation

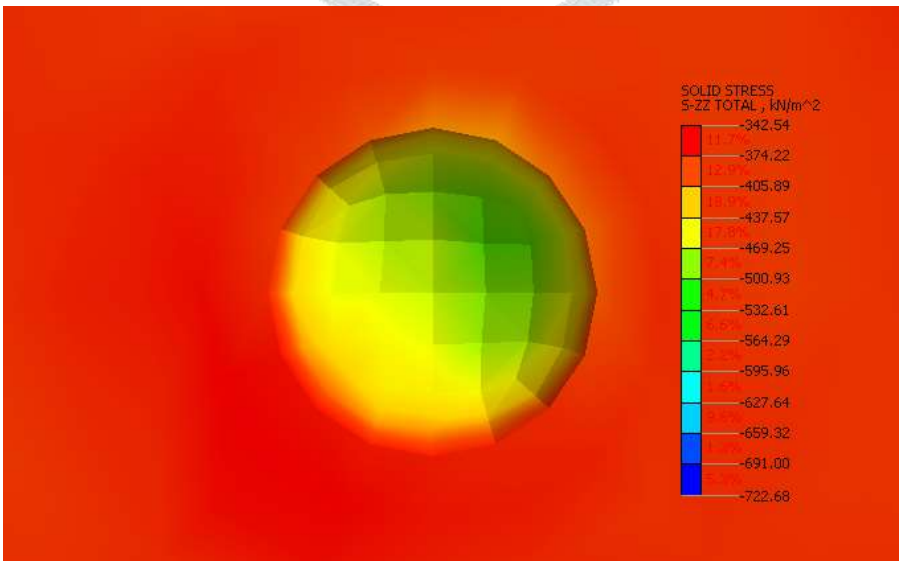


Figure 21. solid stress generate below the base of well foundation

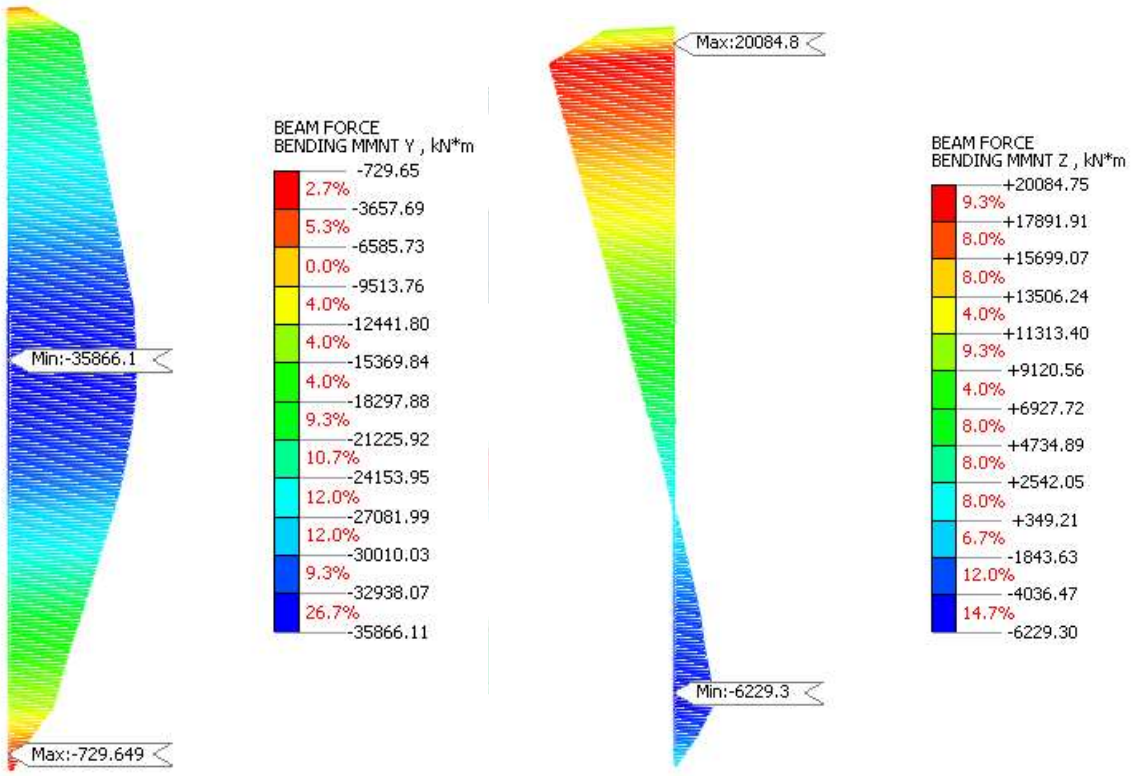


Figure 22. Bending Moment Y-Direction and Z-Direction in kN m

Fig.16 shows the vertical settlement of the well foundation embedded in homogeneous sandy soil. As per given Table 2 in loading condition will be applied and I got max. settlement 42.83 mm. Fig.17 shows lateral Y-direction in top of well cap displacement 13.73 mm, scour displacement 5.68 mm. Generated moment applied in the well foundaion got the rotation 0.001°. Fig.21 shows loading condition applied then after of well foundation solid stresses will be generated max. 500.93 kN/m^2 and min. 437.57 kN/m^2. Fig.22 shows got the bending moment in Y-direction max. 35866.11 kN m & min. 729.65 kN m and Z- direction max. 20084.82 kN m & min. 6229.30 kN m. As well as shown the Fig.18 plot the load vs settlement curve in iteration number and got the settlement in given load. Fig.19 shows the plot the lateral load vs displacement curve of well cap displacement, scour displacement. Fig.20 shows the plot the curve of moment vs rotation in the well foundation I got rotation.

	Solid stress (KN/m^2)		Bending Moment (KN m)		Resisting Moment(KN m) Mr>M (Safe)
	Max	Min	Y-Direction	Z-Direction	
FEM Analysis	482.99	399.46	36702.04	20084.82	-
IRC:45	580.08	421.15	-	-	36462.66

Compare the result of FEM analysis and IRC:45-1972

Result of Model 1 - Loose sand

Table 6. comparison b/w the FEM result and irc:45-1972 problem 1

Result of Model 2 - Medium sand

	Solid stress (KN/m^2)		Bending Moment (KN m)		Resisting Moment(KN m) Mr>M (Safe)
	Max	Min	Y-Direction	Z-Direction	
FEM Analysis	494.57	432.25	36092.53	20084.82	-
IRC:45	567.65	411.70	-	-	68401.68

Table 7. comparison b/w the FEM result and irc:45-1972 problem 2

Result of Model 3 - Dense sand

	Solid stress (KN/m^2)		Bending Moment (KN m)		Resisting Moment(KN m) Mr>M (Safe)
	Max	Min	Y-Direction	Z-Direction	
FEM Analysis	500.93	437.57	35866.11	20084.75	-
IRC:45	566.09	410.51	-	-	106341.2

Table 8. comparison b/w the FEM result and irc:45-1972 problem 3

Conclusion :

Using MIDAS GTS NX, the study performs a thorough numerical analysis of well foundations and compares the findings to the IRC:45-1972 criteria. The investigation leads to the following conclusions:

- The MIDAS GTS NX model demonstrated a strong degree of correlation between the code-specified parameters and the numerical results, and it was successfully tested against the requirements of IRC:45-1972.

The fact that the observed discrepancies fell within reasonable bounds supports the numerical model's dependability.

- The analysis underscored the significant impact of soil properties on the behavior of well foundations. Cohesionless soils exhibited higher displacement.

- The patterns of stress distribution in the soil surrounding the well foundation aligned with the theoretical predictions defined in IRC:45-1972. The stress concentration zones, which are essential for the structural integrity of well foundations, were clearly explained by the numerical model.

- It was discovered that the distribution of bending moment over the well foundation's depth closely matched the predictions made by IRC:45-1972. The peak values and their locations were precisely represented by the numerical model, confirming the IRC-recommended design processes.
- The IRC recommendations were followed by the displacement profiles that MIDAS GTS NX produced, indicating that the foundation is stable under different loading scenarios. As predicted by theory, maximum displacements were seen at the top and progressively decreased with depth.

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