Behaviour of Raft Foundations in the Alluvial Region of India

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Abstract:
A comprehensive study was conducted to investigate the behaviour of raft foundations in the alluvial region of India, considering key factors such as raft foundation design, soil characteristics, and load distribution. Raft foundations are commonly employed to distribute the load of a structure over a larger area, thereby minimizing the risk of settlement and ensuring structural stability. The study employed the use of Pasternak foundation models, which consider the interaction between the soil layers and the raft. This model considers the stiffness and damping characteristics of the soil, providing a more accurate representation of the behaviour of raft foundations. To analyse the raft foundation’s response in alluvial soil, the study utilized the thick plate theory. This theory assumes the raft to be infinitely rigid, enabling a more realistic portrayal of the foundation’s behaviour under varying loading conditions. The findings of the study indicated that raft foundations in alluvial soil experienced significant settlements due to the soil's low bearing capacity and compressibility. The Pasternak foundation models proved valuable in understanding stress distribution and settlement behaviour in such soil conditions. The study's outcomes offer insights that can enhance the design and construction of more efficient and reliable raft foundations in the alluvial regions of India. By incorporating the knowledge gained from this research, engineers and architects can optimize the stability and performance of structures in these areas. Moreover, the study highlights the importance of considering site-specific soil characteristics, such as alluvial soil properties, when designing raft foundations. By accounting for the unique behaviour of alluvial soil, engineers can mitigate potential issues and ensure the long-term durability of structures in this region.

Keywords: raft foundation, Pasternak foundation, thick plate, Alluvial soil

Introduction
The study aims to investigate the behaviour of raft foundations in the alluvial region of India, considering various analytical methods and techniques. Raft foundations play a vital role in ensuring the stability and performance of structures by distributing the load over a larger area, particularly in regions with alluvial soil, which is known for its soft and compressible nature. The conventional method of analysing raft foundations has been widely used in the past. However, this method often oversimplifies the soil-structure interaction, neglecting important factors that influence the foundation’s behaviour. To address these limitations, alternative approaches such as the non-rigid or elastic method, Finite Element Method (FEM), and Finite Grid Method (FGM) have gained prominence. The non-rigid or elastic method considers the flexibility of both the raft and the soil, providing a more accurate representation of their interaction. This method incorporates the concept of Pasternak foundation models, which account for the stiffness and damping characteristics of the alluvial soil. Finite Element Method (FEM) and Finite Grid Method (FGM) are numerical techniques that can simulate complex soil-structure interactions. FEM breaks down the foundation and soil into smaller elements, solving the governing equations for each element to obtain an overall behaviour. On the other hand, FGM discretizes the soil and raft into a grid, allowing for the analysis of stress and settlement distribution. By applying these advanced analytical methods, the study
aims to provide a comprehensive understanding of raft foundation behaviour in alluvial soil. It seeks to assess factors such as settlement, stress distribution, and load-bearing capacity, with a focus on the stability and performance of structures in the alluvial region of India. The findings of this study have the potential to enhance the design and construction practices for raft foundations in alluvial regions. By incorporating the knowledge gained from advanced analytical methods, engineers can develop more accurate and reliable designs, ensuring the long-term durability and safety of structures in alluvial soil conditions.

Modelling of raft with Finite element

Modelling a raft foundation using the Finite Element Method (FEM) involves dividing the foundation and surrounding soil into discrete elements to analyse their behaviour under different loading conditions. FEM is a numerical technique widely used for structural analysis and provides a detailed understanding of stress distribution, deformation, and settlement.

The process of modelling a raft foundation with FEM typically includes the following steps:

- Geometry and Mesh Generation: The geometry of the raft foundation is defined, including its shape, dimensions, and any irregularities. The model is then discretized by generating a mesh, dividing the foundation and soil into smaller finite elements. The type and size of the elements depend on the complexity of the analysis and desired accuracy.

- Material Properties: The material properties of the raft foundation and soil layers are assigned to the corresponding finite elements. These properties include elastic modulus, Poisson's ratio, shear modulus, and other relevant parameters that describe the mechanical behaviour of the materials.

- Boundary Conditions: Boundary conditions are applied to simulate real-world scenarios. Fixed supports, applied loads, and constraints representing interactions with the surrounding structures, or the ground are specified. These conditions ensure the model accurately represents the foundation's behaviour.

- Load Application: The loads acting on the raft foundation, such as dead loads, live loads, and soil pressures, are applied to the model. The magnitude, distribution, and nature of the loads are considered based on design requirements and project-specific conditions.

- Solution and Analysis: The FEM software solves the equations representing the behaviour of the finite elements, calculating the displacements, stresses, and strains within the model. The results provide insights into the response of the raft foundation under different loading scenarios.

- Evaluation and Design Optimization: The results obtained from the FEM analysis are evaluated to assess factors like settlement, stress concentrations, and bearing capacity. Based on these findings, design modifications can be made to optimize the performance and stability of the raft foundation.

Through FEM modelling, engineers gain valuable insights into the behaviour of raft foundations, allowing them to make informed decisions regarding design improvements and ensure the structural integrity and safety of the foundation. FEM provides a powerful tool for analysing complex soil-structure interactions and aids in optimizing the design of raft foundations for various loading conditions.

In this, with the help of Finite element method the raft which is assumed as a plate and soil as elastic foundation have been transformed into a matrix structural analysis. The raft or plate have been transformed into a mesh of finite elements which are interconnected at the corners or nodes and the soil has been modelled in form of isolated springs like Pasternak foundation. This analysis of raft with the help of finite element is based on theory of thick plates resting on Pasternak foundation as shown in Figure 1. Transverse shear deformation of the plate is considered during analysis with FEM. It is assumed that the deflection in the plate is very small as compared with the thickness of the plate.
A parametric study was conducted to investigate the behaviour of raft foundations in the alluvial region of India. The study aimed to analyse the impact of various design parameters on the performance of raft foundations in alluvial soil conditions. Factors such as raft dimensions, soil properties, and loadings were varied systematically to assess their influence on settlement, stress distribution, and bearing capacity. The study utilized advanced analytical methods, such as finite element analysis, to simulate and analyse the behaviour of raft foundations. The findings from this parametric study provide valuable insights for optimizing the design and construction practices of raft foundations in the alluvial region of India, ensuring their stability and performance in this specific geological setting.

The effect of following parameters will be studied on the rectangular raft foundation system using Finite element method.

1. Raft Thickness (0.45m, 0.9m, 1.5m)
2. Modulus of subgrade reaction (40000, 100000, 200000, 400000) kN/m3,
3. Loads of Column on Raft (three load patterns LP-I, LP-II, LP-III as indicated in Figure 3)

The effect of variation of raft thickness and soil modulus on specific load patterns have been studied. Different raft dimensions have been taken for different Load Patterns for the study, Raft dimension of 10 x 10 has been considered for load pattern I, Raft dimension of 15 x 12 for load pattern II and Raft dimension of 20 x 14 for load pattern III.
Figure-3, Shows Loading pattern 1

Figure-4, Shows Loading pattern 2

Figure-5, Shows Loading pattern 3
Loading Pattern
In Figure 6 (a) deflection pattern at different position in the raft has been presented and in Figure 6 (b) deflection along central line at different thickness of raft has been compared. Figure shows deflection at the centre line is more, as the thickness of the raft increases the deflection curve becomes flat. For different thickness of raft, Maximum deflection with the help of soil modulus has been shown in Table 2. With increase in raft thickness and soil modulus it was seen that maximum deflection decreases. Bending moment at different thicknesses of raft has been shown in Figure 7. It can be seen from the figure that, there is no effect of thickness of raft on Bending moment.

<table>
<thead>
<tr>
<th>Raft Thickness (m)</th>
<th>Maximum Deflection (mm) for soil Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40000</td>
</tr>
<tr>
<td>0.5</td>
<td>4.84</td>
</tr>
<tr>
<td>1.0</td>
<td>4.66</td>
</tr>
<tr>
<td>1.5</td>
<td>4.75</td>
</tr>
</tbody>
</table>

Figure 6, Deflected shapes at Loading pattern -1
In Figure 8 and Figure 9, the effect of variation of raft thickness on deflection and bending moment has been shown. In Table -3, the effect of variation of raft thickness and soil modulus on maximum deflection has been shown, Table shows that with increase in soil modulus, there is decrease in maximum deflection. In Table-4 the effect of variation of raft thickness on Bending moment has been shown. Table -4 shows that with variation in raft thickness, the positive Bending moment increases and negative Bending moment decreases, but in case of variation of soil Modulus this is opposite.

### Table -3, Effect of soil modulus and thickness on Deflection

<table>
<thead>
<tr>
<th>Soil Modulus</th>
<th>Maximum Deflection in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 m</td>
</tr>
<tr>
<td>40000</td>
<td>3.23</td>
</tr>
<tr>
<td>100000</td>
<td>1.54</td>
</tr>
<tr>
<td>200000</td>
<td>1.12</td>
</tr>
<tr>
<td>400000</td>
<td>0.53</td>
</tr>
</tbody>
</table>
In Figure 10 and Figure 11, effect of variation of raft thickness on deflection and Bending Moment have been shown. In Table -6, Effect of variation in raft thickness on deflection and Bending moment have been shown. Table shows that with increase in raft thickness the deflection in raft is decreasing and the positive bending moment is increasing with increase in raft thickness and negative bending moment remain constant with variation in raft thickness.

<table>
<thead>
<tr>
<th>Raft Thickness</th>
<th>Max. Positive BM</th>
<th>Max. Negative BM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Second</td>
<td>Quarter</td>
</tr>
<tr>
<td>0.5</td>
<td>80.56</td>
<td>47.65</td>
</tr>
<tr>
<td>1.0</td>
<td>95.09</td>
<td>71.23</td>
</tr>
<tr>
<td>1.5</td>
<td>99.98</td>
<td>89.87</td>
</tr>
</tbody>
</table>
Conclusions
The study on the behaviour of raft foundations in the alluvial region of India provides significant insights into their performance in this specific soil condition. The findings indicate that raft foundations in alluvial soil experience notable settlements due to the soil’s low bearing capacity and compressibility. The utilization of advanced analytical methods, such as finite element analysis, enables a better understanding of stress distribution and settlement behaviour. This study’s outcomes contribute to the optimization of raft foundation design and construction practices in the alluvial region, ensuring the stability and performance of structures. By considering site-specific factors, such as alluvial soil properties, engineers can mitigate potential issues and enhance the durability of structures in these areas. Further research and
implementation of the study's recommendations will lead to more efficient and reliable raft foundation designs in the alluvial regions of India.

In this study, raft foundation system has been studied in alluvial region and the effect of variation of raft thickness, soil modulus and load pattern on raft have been observed. It can be seen from the above studies that, deflection in the raft is increasing at lower soil modulus and increasing at higher soil modulus at a given raft thickness. It can also be seen that, with variation in thickness of the raft, positive bending moment is increasing, and negative bending moment is decreasing. In case of soil modulus, positive bending moment are decreasing with increasing soil modulus and negative bending moment is reducing with increasing soil modulus.

References

8. International conference on planning and design of tall buildings, Le high University 1972 - System and concepts foundation design -Technical Committee 11.
15. Method of test for soils, Part XII, Determination of shear strength parameters of soil from consolidated undrained triaxial test with measurement of pore water pressure (first version), IS: 2720 (Part XII) 1981.
22. Thirteenth international conference on soil mechanics and foundation engineering, Delhi, January 1994