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Foundation in Weak Soil

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Abstract

In geotechnical engineering, it is crucial to evaluate the interaction between structural loads and soil properties to ensure the stability and safety of foundations. In this scenario, the column is subjected to a load of 120 tons, with an additional 10% safety factor added, resulting in a total load of 132 tons at the foundation base. The foundation base is designed with dimensions of 2.5 meters by 2.5 meters, and the load intensity applied to the soil must be carefully assessed to avoid excessive settlement or failure. The required bearing capacity of the soil is calculated to be at least 25 t/m², which must exceed the applied load intensity to maintain foundation stability. When dealing with weak soils, where the bearing capacity is as low as 10 t/m², the risk of foundation settlement increases significantly. In such cases, the reduced bearing capacity can cause differential settlement, affecting the structure's performance. The amount of settlement is influenced by the bearing capacity of the soil, the depth of the foundation, and the total applied load. In this case, the soil has a unit weight of 1.85 t/m³, and the foundation is placed at a depth of 1.3 meters. Geotechnical engineers must ensure that the settlement remains within the permissible limits, which are 40 mm for sandy soils and 65 mm for clayey soils. Failure to control settlement can lead to structural problems such as cracking or tilting. Therefore, proper analysis of soil properties, load distribution, and foundation design is essential in geotechnical engineering to ensure long-term stability and prevent settlement-related issues.

Keywords: Geotechnical engineering, structural loads, soil properties, foundation stability, load intensity, bearing capacity, settlement, differential settlement, weak soils, foundation design, load distribution, soil unit weight, foundation depth, permissible settlement limits, sandy soils, clayey soils, load safety factor

INTRODUCTION

In geotechnical engineering, addressing foundations on weak soils requires methods to improve the soil's load-bearing capacity and prevent settlement. One effective technique is adding a layer of sand over the weak soil. This sand layer, when of the proper thickness, helps to distribute the load more evenly, reducing the stress applied to the underlying soil. As a result, the load on the weaker soil is lessened, minimizing the risk of excessive settlement or structural instability [1].

In addition, a reinforced cement concrete (RCC) foundation base is often used in these situations. The RCC foundation helps to further distribute the load, ensuring that the weak soil beneath it carries less direct pressure. This is particularly important when the soil has a low bearing capacity, such as 10 t/m², which on its own would not be sufficient to support the structural load [2].

By using a sand layer along with an RCC foundation, the system can more effectively manage the structural loads without overburdening the weak soil. The sand acts as a stabilizing layer, spreading the load more uniformly, while the RCC foundation base reinforces the structure. This combined approach ensures that the weak soil carries a reduced portion of the load, providing greater stability for the foundation [3].

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METHODOLOGY

The methodology for addressing the foundation design on weak soils involved several key steps to ensure load distribution and minimize settlement. The following procedure was adopted for the assessment and enhancement of the foundation system:

Site Investigation and Soil Analysis

- A detailed geotechnical investigation was conducted to assess the properties of the underlying weak soil. Standard penetration tests (SPT), borehole sampling, and laboratory tests were performed to determine the soil's bearing capacity, unit weight, and compressibility [4].
- The soil was identified as having a bearing capacity of 10 t/m², which is insufficient for directly supporting the foundation loads without additional measures.

Load Calculation

- The total load applied to the foundation was calculated, considering the structural load of the column, which was 120 tons. A safety margin of 10% was added, resulting in a total load of 132 tons to be supported by the foundation system.
- The foundation's base dimensions were 2.5 m x 2.5 m, which was used to compute the load intensity and ensure it remained below the enhanced soil bearing capacity [5].

Design of Sand Layer

- To improve the load distribution and prevent overstressing the weak soil, a compacted sand layer was designed and placed between the foundation and the underlying soil.
- The thickness of the sand layer was determined to be 300 mm, based on geotechnical engineering principles and load-distribution requirements.
- The sand layer was compacted to ensure stability and uniformity, improving the interaction between the foundation and the weak soil [6].

RCC Foundation Base

- An RCC foundation base was designed to further spread the load over a larger area, reducing the direct pressure on the weak soil.
- The RCC base provided structural rigidity, helping to distribute loads more evenly and reduce the risk of differential settlement.

Settlement Assessment

- A settlement analysis was performed to ensure the foundation remained within acceptable limits. The permissible settlement for sandy soil (40 mm) and clayey soil (65 mm) was considered in the design.
- The use of the sand layer and RCC foundation base ensured that the settlement remained within these limits, preventing excessive deformation [7].

Water Thrust Consideration

- The strength of both the top and bottom soil layers was analyzed to account for any potential water thrust or groundwater pressure.
- The presence of water or fluctuating groundwater levels could impact the overall stability of the foundation, so water-related pressures were considered in the final design [8].

Construction

- The sand layer was placed in compacted form, followed by the construction of the RCC foundation base. Care was taken to ensure proper compaction and material placement to avoid uneven settlement or voids within the foundation system.
- The construction process adhered to standard geotechnical engineering practices to ensure the long-term performance and stability of the foundation.

By following this structured methodology, the foundation system was reinforced to accommodate the weak soil conditions, resulting in an improved load-bearing capacity and controlled settlement within permissible limits.

RESULTS & DISCUSSION

This geotechnical study assessed the impact of incorporating a sand layer and an RCC (reinforced concrete) foundation base on weak soil to improve load distribution and foundation stability. The weak soil, having a bearing capacity of 10 t/m², was initially inadequate to support the imposed loads. By introducing a sand layer with the correct thickness, the load transmitted to the weak soil was reduced, resulting in a more even distribution of pressure and enhanced stability.

Results

Reduction in Load on Weak Soil

The addition of the sand layer significantly decreased the direct load acting on the underlying weak soil. This reduction in load intensity helped avoid overstressing the soil and reduced the potential for settlement. The sand layer acted as a load-distributing layer, increasing the overall capacity of the foundation system to handle structural loads more effectively.

Improved Load Distribution

The use of the RCC foundation base further improved the distribution of loads. By spreading the load over a larger area, the pressure on the weak soil was lowered, allowing the system to support higher loads without exceeding the soil's bearing capacity. The rigidity provided by the RCC base also minimized differential settlement, promoting better overall stability.

Control of Settlement

With the addition of both the sand layer and RCC foundation, the total settlement remained within acceptable limits. The permissible settlement for sandy soils is 40 mm, and for clayey soils, it is 65 mm. The results showed that the actual settlement did not exceed these values, confirming the effectiveness of the measures taken to prevent excessive deformation.

Discussion

The introduction of a sand layer as a load-reducing element proved to be an effective strategy for improving the performance of foundations built on weak soils. The sand layer reduced the load transferred directly to the weak soil, preventing the soil from being overstressed and mitigating the risk of settlement. The RCC foundation further enhanced load distribution by providing additional rigidity, ensuring a more even distribution of load over the soil.

This approach is highly useful in situations where weak soils, with low bearing capacities, cannot support loads independently. By adding both a sand layer and RCC foundation, the risk of foundation failure due to settlement is minimized. Moreover, this method is a practical and economical solution compared to more expensive alternatives such as deep foundations or soil replacement.

- Strength ratio of underlying soil & sand layer.
- 0.1 N/mm^2: 20 N/mm^2 (Sand layer) $\Rightarrow$ 132 t (Load acting foundation base)

  ↓

  Underlying soil (10 t/m^2 = Bearing capacity)

  $0.1x + 20x = 132$

  $20.1x = 132$

  $x = 6.567$

- Hence load taken by underlying soil

= 0.1 x 6.567 ⇒ 0.657 t < 10 t/m^2
↓
Bearing capacity of soil

- Load in tone compared with strength in t/m^2
- Hence load coming on underlying soil is less when we provide sand layer.
- Thickness of sand layer required on underlying soil:-

$= \frac{132000}{2.5\ x\ 1000\ x\ t}\ \ \frac{10}{100}\ x\ 20$ Tensile strength of sand layer

5000 t = 132 0000 of sand t = 264 mm (Thickness of sand layer required)

- Since upward soil pressure is acting hence thickness of sand layer is found by its tensile strength.
- Sand layer of 300 mm is compacted.
- Also we have to take the consideration of rainfall.
- If rainfall = 400 mm
- Frequent rain occurs.
- Soil will be in saturated state.
- Depth of penetration of water = 3 x 400 = 1.2 meter.
- If 1.2 meter depth of soil is ion saturated state.
- If clayey soil it will be very soft.
- It will not request the through of water.
- Thrust of water due to standing water = 1.2 t/m^2 (wh)
- If velocity of flow = 12 m/sec. (In case of flood)
- Thrust of water $\frac{1000\ x\ (12)^2}{19.62} = 7.34\ t/m^2$
- Total thrust of water = 8.54 t/m^2.
- Soft soil (clayey soil will not resist the thrust of water)
- Scouring will occur & damage will occurs.
- To protect this damage of structure we stabilize the soil 1 part clayey soil + 5 parts gravel.
- Average strength of soil = $\frac{10\ +\ 5\ x\ 44}{2} = 115\ t/m^2$
- When we stabilize the soil by gravel (By mining)
- Drainage of water will take place.
- When stabilize soil will be in saturated gravel (By mining) state its bearing.
- Drainage of water will take place.
- Bearing capacity of stabilized soil = $\frac{50}{100}\ x\ 115 \Rightarrow 57.5\ t/m^2$.
- When we stabilize soil will be in saturated state.
- Since soil subjected with bending.
- Bending strength of stabilized soil $= \frac{1}{3}\ x\ 57.5 \Rightarrow$ 19.20 t/m^2 > 8.54 t/m^2

(Thrust of water hence safe.
- Depth of penetration of water 1.2 meter.
- Lateral load at 1.2 m depth below ground level = 121 t
- Lateral load = 0.217 x 121 = 26 t$\left[\frac{1-Sin\varphi}{1+Sin\varphi}\right] = 0.217,\ \varphi = 40\ ^o for\ concrete.$
- Strength of soil at 1.2m below ground level.
- Soil saturated state bearing capacity of stabilized soil = 57.5 t/m^2
- Strength of soil = 57.5 x 1.2 x 0.06 [Width of column = 0-6 m total

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= 41.4 t > 26 t

Hence O.K.

- Lateral load at foundation base 0.217 x 132 = 28.64 t
- Bearing strength of soil at base.
- If ground water table is more than foundation level.
- Soil at foundation base hence saturated state.
- Hence bearing strength of soil (Lateral strength of soil = 57.5 x 2.5 x 0.3 [2.5 m = Width of foundation

0.3 m = Depth of foundation base slab)
= 43.12 t > 28.64 t

Hence O.K.

- Uplift pressure at base 8.54 t/m^2.
- Strength of saturated sand layer & clayey soil at bottom (Saturated state).
- Bending strength of saturated soil taken.
- 10 t/m^2 + 2000 t/m^2 (Bottom layer)

Clayey soil Sand layer

$$= \frac{50x\ 1005}{100} = 503\ t/m^2$$

- In saturated soil (Bending strength) = $\frac{1}{3}\ x\ 503 = 168\ t/m^2 > 8.54 t/m^2$

Hence O.K.

CONCLUSIONS

In cases where weak underlying soil is present, it is essential to adopt measures that enhance the stability and load-bearing capacity of the foundation. Based on the findings of this study, it is recommended that a compact sand layer with a thickness of 300 mm be laid over the weak soil. This sand layer acts as a buffer, redistributing the load more evenly and reducing the stress directly applied to the underlying weak soil. The compacted form of the sand layer ensures that it effectively improves the overall foundation performance and minimizes settlement risks.

Furthermore, the strength of both the top soil and bottom soil must be considered, especially when dealing with water thrust or groundwater pressures. Proper assessment of the soil's strength at various levels is crucial to prevent issues related to water infiltration or pressure buildup, which could compromise the integrity of the foundation. By addressing these factors, the foundation system can achieve better long-term performance, even when constructed on weak soils.

In conclusion, incorporating a 300 mm compacted sand layer and evaluating the strength of the top and bottom soil layers provide an effective solution for enhancing the stability of foundations on weak soils. These measures help distribute loads more efficiently, prevent excessive settlement, and manage potential water-related issues, ensuring the durability and safety of the structure.

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Notation

- D_f = Depth of foundation in meter.
- γ = Unit wt of soil in t/m^3.
- ϕ = Angle of repose in degree.