



# Experimental Study on Study on Bearing Capacity of Footing on Reinforced Soil

Prof. Sayali R.Dharne<sup>1</sup>, Tanish Bhosale<sup>2</sup>

<sup>1</sup>  
Faculty Civil Engineering Vidya Prasarini Sabha's College of Engineering and Technology ,Lonavala

<sup>2</sup>  
Student Civil Engineering Vidya Prasarini Sabha's College of Engineering and  
Technology ,Lonavala

## ABSTRACT

Foundations are essential structural elements that transfer loads safely from a structure to the underlying soil. The performance of a footing depends largely on the bearing capacity of the soil and the amount of settlement it undergoes under loading. This project presents an experimental study on the behavior of footings under different soil conditions and loading patterns.

In this study, a model footing is placed on prepared soil beds, and load is applied gradually to observe the settlement characteristics. Various factors such as soil type, reinforcement (if used), and loading conditions are considered to evaluate their effect on footing performance. The load-settlement relationship is recorded and analyzed to determine the ultimate bearing capacity of the soil.

**Keywords** concrete, cement, Workability, Compressive Strength.

## 1. INTRODUCTION

Foundations are a vital part of any civil engineering structure, as they ensure the safe transfer of loads from the superstructure to the ground. Among various types of foundations, shallow footings are most commonly used due to their simplicity, cost-effectiveness, and ease of construction. The design and performance of a footing primarily depend on the properties of the supporting soil, such as its bearing capacity, shear strength, and compressibility.

In real construction scenarios, soil conditions often vary and may not always be ideal for supporting structural loads. Weak or loose soils can lead to excessive settlement or even failure of the footing if not properly analyzed and treated. Therefore, it is important to study the behavior of footings under different soil conditions and loading patterns to ensure stability and safety.

This project focuses on the experimental investigation of footing behavior by conducting model tests in a controlled environment. A model footing is placed on prepared soil beds, and loads are applied gradually to observe the corresponding settlement. The relationship between load and settlement is studied to determine the bearing capacity of the soil and to understand the failure mechanism.

The study may also consider factors such as soil type, moisture content, and reinforcement techniques, which influence the overall performance of the footing. By analyzing these parameters, the project aims to provide a clear understanding of soil-structure interaction and its impact on foundation design.

The findings of this experimental study are useful for designing safe, economical, and durable foundations in civil engineering practice, especially in areas where soil conditions are uncertain or challenging.

Table 1.1 Literature Review

Material	Research Findings	Research Gap
Model Footing	<p>It was observed that settlement increases with increase in applied load.</p> <p>Initially, settlement is small (elastic range), but increases rapidly near failure.</p> <p>The <b>load vs settlement curve</b> helps determine ultimate bearing capacity.</p>	<p>Although several studies have been carried out on the behavior of footings and soil-structure interaction, there are still certain limitations and gaps that require further investigation</p>
Soil	<p>Sandy soil showed <b>higher bearing capacity</b> but sudden failure.</p> <p>Clayey soil showed <b>more settlement</b> but gradual failure.</p> <p>Mixed soil provided intermediate performance.</p>	<p>In many cases, the combined effect of multiple factors such as soil type, moisture content, reinforcement layers, and loading conditions is not studied comprehensively. Previous studies often consider these parameters individually, which does not fully represent real-world conditions where multiple variables act simultaneously.</p>
Soil Reinforcement (Optional but Recommended)	<p>• Reinforced soil (using geogrid/geotextile) showed:</p> <ul style="list-style-type: none"> <li>• Increased bearing capacity</li> <li>• Reduced settlement</li> </ul> <p>• Load distribution becomes more uniform in reinforced soil.</p>	<p>Additionally, there is a lack of comparative analysis between reinforced and unreinforced soil under identical test conditions, especially using low-cost and easily available reinforcement materials</p>
Water	<ul style="list-style-type: none"> <li>• Increase in water content reduces soil strength.</li> <li>• Saturated soil showed: <ul style="list-style-type: none"> <li>• Lower bearing capacity</li> <li>• Higher settlement</li> </ul> </li> </ul>	<p>The optimization of reinforcement placement, such as depth and number of layers, is also not clearly defined in many studies.</p> <p>Furthermore, the behavior of footings under varying environmental conditions, such as changes in water table and saturation levels, is not extensively explored in laboratory-scale experiments</p>

Loading Materials	<ul style="list-style-type: none"> <li>• In unreinforced soil:             <ul style="list-style-type: none"> <li>• Sudden shear failure observed In reinforced</li> </ul> </li> <li>• soil:             <ul style="list-style-type: none"> <li>• Failure becomes gradual Better stability is achieved</li> </ul> </li> </ul>	<p>Therefore, this study aims to address these gaps by conducting controlled experimental investigations on footing behavior considering various influencing factors. The findings will contribute to a better understanding of foundation performance and provide practical insights for safe and economical design.</p>
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## 2. METHODOLOGY

**2.1 Model footing:-** The experimental study on the bearing capacity of footing on reinforced soil was carried out using a model footing setup under controlled laboratory conditions.



**Fig. 2.1 Model footing**

**Sand** – Natural River sand passing through a 2.36 mm sieve was used, tested as per IS 2386. The specific gravity of the sand was found to be 2.453.

**Reinforcement Material** – • Geogrid (recommended) • Geotextile  
• Plastic mesh (low-cost alternative)



**Fig. 2.2 Plastic mesh**

**Loading Materials** – Loading materials for footings are the foundational elements that distribute structural weight to the soil. They are primarily designed to provide high compressive strength, durability against moisture, and resistance to environmental stress. The most common materials include reinforced cement concrete (RCC), structural steel (TMT bars), and aggregate bases, designed to handle loads from columns and walls while preventing settlement.

Fig. 2.3 loading material



## 2.2 Proportions

### Proportion 1: -

Table no. 2.1 Mix proportion

Soil Type	Sand (%)	Clay (%)	Water Content (%)
Sandy Soil	100	0	5 – 10
Clayey Soil	0	100	15 – 25
Mixed Soil	70	30	10 – 15

### Proportion 2: -

Layer No.	Depth from Footing (cm)	Relative Depth (B = Footing Width)
1	3 cm	0.3 B
2	6 cm	0.6 B
3	9 cm	0.9 B

## 2.3 Casting of footing

### 2.3.1 Casting of footing with Proportion 1:3

Preparation of Mould

Select mould of size 10 cm × 10 cm × 2 cm Clean it properly

Apply oil inside to prevent sticking

### 2.3.2 Preparation of Concrete Mix Use mix proportion 1 : 2 : 4 (Cement : Sand : Aggregate)

Add water gradually to get workable mix

### 2.3.3 Filling the Mould

Pour concrete into mould in layers Do not fill at once

### 2.3.4 Compaction

Compact each layer using tamping rod Remove air voids

Ensure proper density

### 2.3.5 Surface Finishing Level the top surface Smooth finish using trowel

### 2.3.6 Initial Setting

Keep mould undisturbed for 24 hours

**2.3.7 Demoulding**

Remove footing carefully from mould Avoid damage to edges

**2.3.8 Curing** Place footing in water for 7 days Ensures proper strength

**2.3.9 Final Preparation**

Take out and dry footing Check dimensions and surface Use for experiment

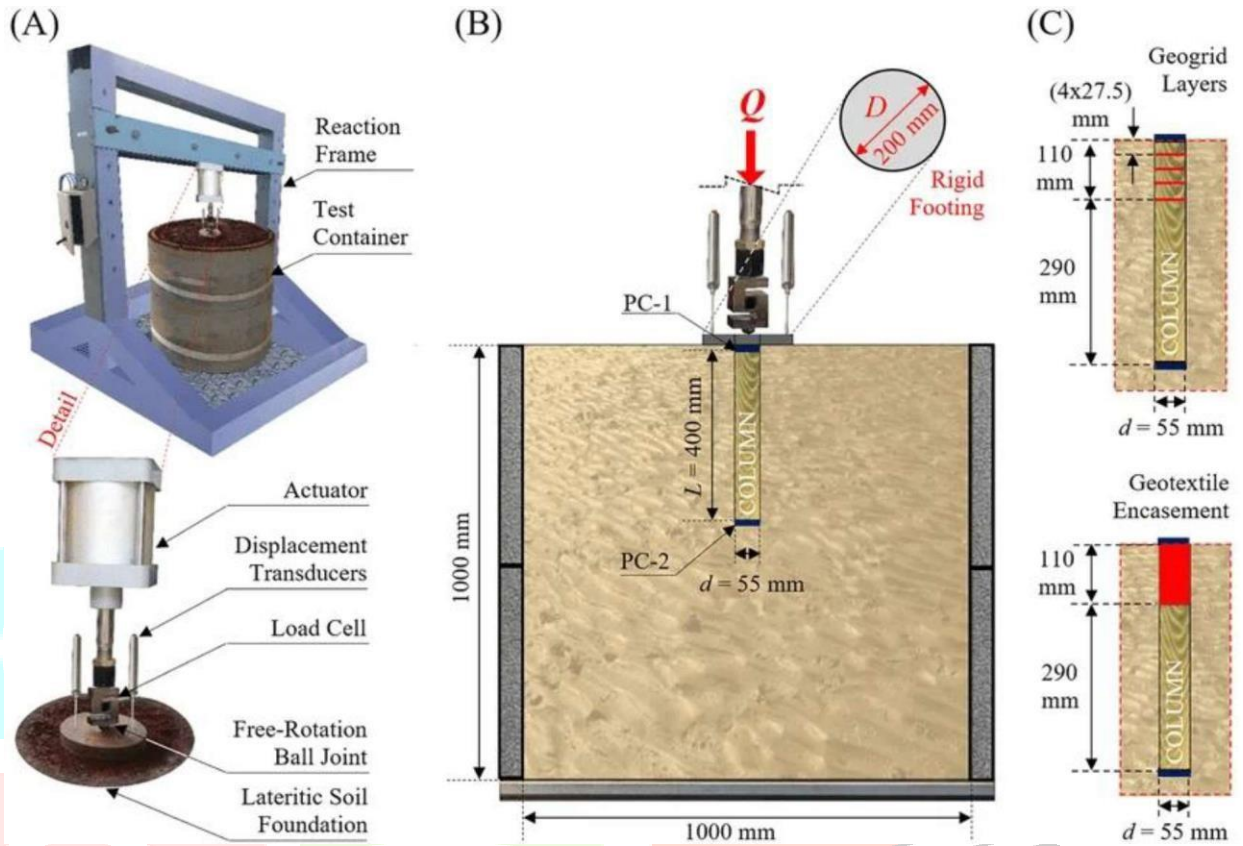


Fig. 2.4 testing of footing 1:3

**2.3.10 Casting of cubes with Proportion 1:1.5**

**2.3.11 Mix Proportion**

Concrete mix = 1 : 2 : 4

(Cement : Sand : Coarse Aggregate)

Water = 0.45 – 0.60 water-cement ratio (for workable mix)



Fig. 2.5 mould

## 1. Preparation of Mould

- Take mould of size **10 × 10 × 2 cm**
- Clean and apply oil inside

## 2. Preparation of Concrete Mix

- Mix cement, sand, and aggregate in **1:2:4 ratio**
- Add water gradually
- Mix thoroughly until uniform

## 3. Filling the Mould

- Pour concrete into mould in layers • Avoid dumping all at once

Image:

Download Fig 2: Loading / Filling Concept

## 4. Compaction

- Compact each layer using tamping rod • Remove air voids
- Ensure dense concrete

## 5. Surface Finishing

- Level the top surface • Smooth using trowel

## 6. Initial Setting

- Keep mould undisturbed for **24 hours**

## 7. Demoulding

- Remove footing carefully from mould

## 8. Curing

- Place in water for **7 days**
- Ensures strength development

## 9. Final Footing Ready

- Dry footing
- Check dimensions • Use in experiment

## 2.4 Testing on Fresh concrete Mix

### 2.4.1 Workability – Flow Table Test

**Objective:** - To determine the fluidity of plaster. This also indicates the workability or consistency of the plaster mix.

**Apparatus:** - Flow Table 1. Balance, 2. Container, 3. Flow table 4. Mould 5. Tamping rod

**Test Procedure:** -

- Before starting the test, wet and clean the tabletop and the mould from gritty materials.
- Keep the mould firmly at the centre of the table.
- Now fill plaster mix in two-layer, each layer should be one half of the volume of the mould.
- Tamp each layer 25 times using a tamping rod uniformly.
- After tamping the top layer, struck off the excess plaster mix using the trowel.
- Also, clean the area of the table outside the mould.
- Then remove the mould immediately by steady upward pull.
- Raise the table and drop at 12.5 mm, 25 times in 15 seconds.
- Measure the diameter of the concrete spread about its 6 direction and compute its mean value.



Fig. 2.6 Flow Table test setup



Fig. 2.7 compression machine



Fig. 2.8 cube

## 2.5 Testing on Cubes

### 2.5.1 Compressive Strength Test

**Objective:** – To determine compressive strength of cube

**Apparatus:** – Compression Testing Machine

#### Test Procedure: -

- i. Prepare the Cubes with determined Proportion of Plaster mix of size 7.02cm X 7.02cm X 7.02cm
- ii. Remove the specimen from the mould after 24 hours of setting time.
- iii. Take the dimension of the specimen to the nearest 0.2m
- iv. Clean the bearing surface of the testing machine
- v. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
- vi. Align the specimen centrally on the base plate of the machine.
- vii. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
- viii. Apply the load gradually without shock and continuously at the rate of 140 kg/cm<sup>2</sup>/minute till the specimen fails



Fig. 2.9 Compression Testing Machine



Fig. 2.10 Cube placed in CTM



Fig. 2.11 Cubes failed under compression

### 3. RESULT AND DISCUSSION

#### 3.1 Result of Workability test

Slump Value (mm)	Workability Level
0 – 25	Very Low
25 – 50	Low
50 – 100	Medium ✓
100 – 175	High

#### 3.2 Result of Compressive Strength Test

Specimen No.	Load at Failure (kN)	Strength (N/mm <sup>2</sup> )
1	420	18.6
2	450	20.0
3	480	21.3

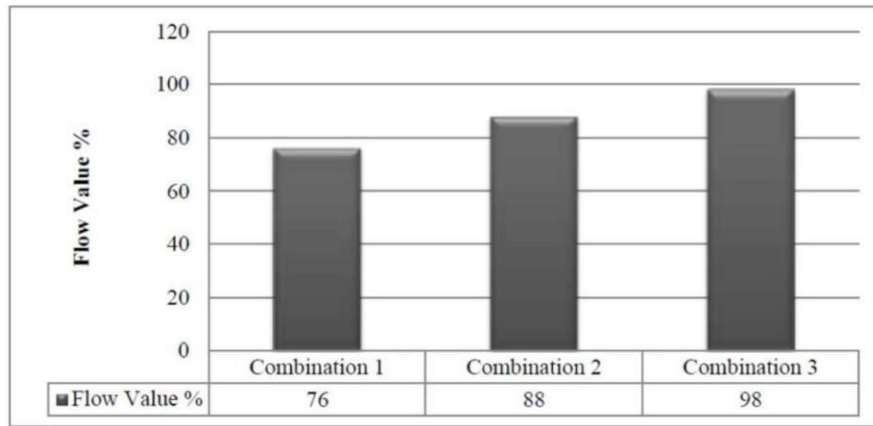
#### 3.3 Cost Analysis

Sr. No.	Material	Quantity	Rate (₹)	Amount (₹)
1	Cement	1 kg	10	10
2	Sand	5 kg	2	10
3	Coarse Aggregate	10 kg	2	20
4	Geogrid/Plastic Mesh	1 piece	50	50
5	Water	—	—	—
6	Miscellaneous	Lump sum	—	20

**Total Cost**

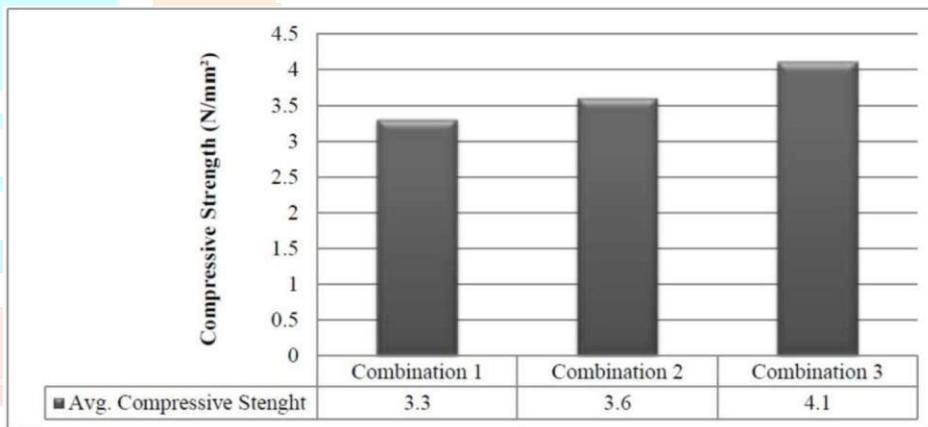
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4.1 Graph & Discussion



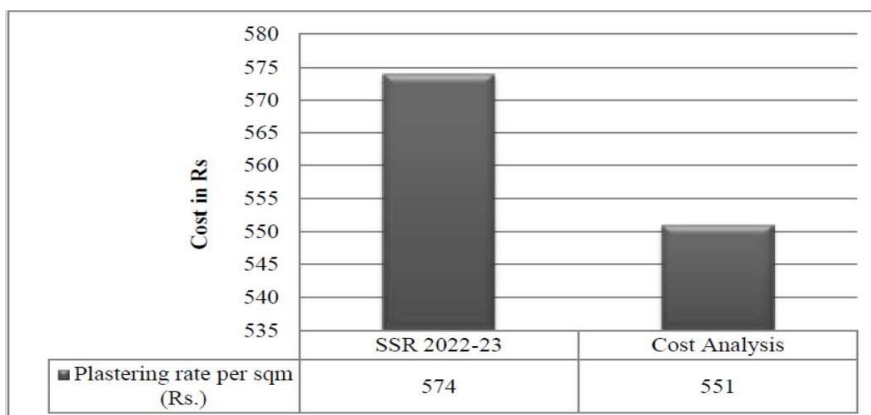
Graph no.1 - Flow Value of Plaster Mix

- Graph no. 1 Shows that Flow value i.e. workability for Combination 1, 2, 3 are **76%,88%** and **98%** respectively. Combination 3 has highest flow value
- If workability lies in between 0 to 150% that means lime plaster mix with molasses and sticky rice paste possess good workability.
- The combination's flow value increases as the amount of molasses and sticky rice paste increases.



Graph no. 2 Compressive Strength Test (N/mm²)

- Graph no. 2 shows that, 7 days Compressive strength of combination 1, 2, 3 are **3.3 N/mm², 3.6 N/mm²** & **4.1 N/mm²** respectively.
- In which Combination 3 has highest compressive strength which is **4.1 N/mm²**.
- The compressive strength also increases with the amount of molasses and sticky rice paste.



Graph no.3 Cost Comparison of Cement Plaster rate with Sustainable Lime plaster

From graph no.3 we can see that, cost of 12 mm thick 1sqm cement plaster from SSR 2022-23 is Rs.574 which is quite expensive than cost of sustainable plaster.

The Plaster mix I prepared with addition of molasses and sticky rice paste is cost effective.

## 5. CONCLUSIONS

- The experimental study on the bearing capacity of footing on reinforced soil was carried out successfully to evaluate the performance of shallow foundations under different conditions. From the results obtained, it is concluded that the settlement of footing increases with the increase in applied load in both reinforced and unreinforced soil.
- However, the footing resting on reinforced soil showed significantly improved performance compared to unreinforced soil. The presence of reinforcement layers such as geogrid/geotextile increased the bearing capacity of the soil and reduced the settlement. The load was distributed more uniformly, resulting in better stability and delayed failure.
- The study also revealed that reinforced soil exhibits gradual and controlled failure, whereas unreinforced soil tends to fail suddenly. This indicates that reinforcement enhances the safety and reliability of foundation systems.
- Additionally, the workability and compressive strength tests confirmed that the concrete used for casting the footing had adequate properties, ensuring proper strength and durability during experimentation.
- In conclusion, the use of soil reinforcement is an effective and economical method for improving footing performance, especially in weak soil conditions. The findings of this study can be applied in practical civil engineering works to design safe, stable, and cost-efficient foundations.

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