RESEARCH PAPER

Impact of Variation in Safe Bearing Capacity on Structural Footing Design, Cost, and Project Deliverables

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ABSTRACT

Safe Bearing Capacity (SBC) is of paramount importance for the design and performance of structural foundations. Variation of SBC has significant effect on footing sizes, reinforcement requirement, construction cost and overall project execution. The purpose of this study is to investigate the effect of different Safe Bearing Capacity values on the design of structural footing for a residential building. The present study investigates the effect of variations in soil bearing capacity on footing size, depth, reinforcement details, excavation quantity, concrete consumption and project deliverables. Different values of SBC were considered for analysis, and footing design was done using relevant Indian Standard codes and structural design software. The variations were found by comparing different material quantities and construction cost for different soil conditions. The study reveals that lower SBC values would result in larger footing dimensions and more consumption of concrete and steel that increases project cost and time of execution. Higher SBC values, on the other hand, lead to economical footing designs and less material requirements. The study highlights the importance of proper geotechnical investigation and optimized foundation planning for attaining safe, economical and efficient construction practices. The findings of this study can assist structural engineers and project planners to better understand the correlation between soil bearing capacity and optimization of foundation design. Keywords Safe Bearing Capacity (SBC), Footing Design, Foundation Engineering, Structural Analysis, Reinforcement, Construction Cost, Residential Building, Soil Investigation.

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1. INTRODUCTION

The foundation is one of the most important parts of any civil engineering structure as it safely transmits the load of the superstructure to the underlying soil. Strength of a structure and its stability is largely dependent on bearing capacity of the soil on which the foundation is supported. Safe Bearing Capacity (SBC) is the maximum load which the soil can safely support without any shear failure or excessive settlement. The accurate determination of SBC is therefore of great importance for the safety, serviceability and economy of any structure.

In structural engineering, the design of footing is directly affected by the Safe Bearing Capacity of soil. Variations in SBC can have a significant impact on the dimensions of footings, depth, reinforcement requirements and overall cost of construction. In cases where soil has low bearing capacity, it is necessary to increase the footing area and also to increase the quantities of construction materials to distribute the structural loads safely. Higher values of SBC on the other hand permit smaller and more economical footings. So, SBC plays a vital role in optimizing the design of foundations and controlling project costs.

The increasing pace of urbanization and construction activities has driven up the need for cost-effective and efficient foundation systems. In residential construction projects, inaccurate estimation of soil bearing capacity may result to unsafe designs, differential settlement, structural cracks and even foundation failure. Moreover, the overestimation of SBC may lead to structural safety problems, and the underestimation may result in unnecessary increase of material consumption and project cost. Therefore, the study of the effect of soil properties on footing behavior is of great importance for the modern construction practices.

With the advent of structural analysis and design softwares like ETABS and SAFE, engineers can perform detailed footing analysis under different soil conditions. These tools aid in assessing the impact of various SBC values on footing geometry, detailing of reinforcement and load distribution. Engineers can use the software applications for comparative analysis and choose the most suitable and economic foundation system for the site condition.

The study is an analysis of the influence of variation of Safe Bearing Capacity on the design of structural footings, project cost and construction deliverables of a residential building. The effect of different SBC values on the size of footing, volume of concrete, amount of steel reinforcement, excavation work and overall economy of the project is investigated. The study also aims to highlight the significance of proper geotechnical investigation and optimized foundation design to ensure safety, economy and sustainability in construction practices.

The results of this study will give structural engineers, designers and project planners information on the effect of soil bearing capacity variations on foundation performance and project execution.

Moreover, the results can help in enhancing the decision-making during the planning and design phases of residential building projects

2. LITERATURE REVIEW

The foundation design and performance of structures are greatly influenced by soil bearing capacity. Several researchers have studied the influence of soil properties, footing behavior and foundation optimization under different loading and ground conditions. The literature review presented in the following summarizes the previous studies related to Safe Bearing Capacity (SBC), footing design, cost optimization and the effect of soil conditions on structural performance.

The effect of different soil bearing capacities on the dimensions of isolated footing for residential buildings was studied by Patil and Sharma (2023). The study showed that lower values of SBC increased the footing area, the amount of reinforcement and the amount of concrete consumed considerably. The researchers emphasized the need for proper soil investigation for economical design of foundations

The correlation between the bearing capacity of soil and the structural safety of reinforced concrete foundations was studied by Kumar and Singh (2022). Their research showed that a wrong estimate of SBC may lead to differential settlement and structural instability. The study recommended that proper geotechnical investigation should be carried out before finalizing the foundation systems.

Reddy and Chavan (2020) states that soil-structure interaction is very important for the determination of the performance of the footing. The settlement behavior under different soil conditions was studied in their research and it was found that the foundations constructed on low SBC soils require additional strengthening and stabilization measures.

Sharma and Kulkarni (2022) studied the economic aspects of foundation design in residential construction projects. Studies found that construction costs for different footing types vary depending on soil bearing capacity, and that the costs of foundations can increase significantly for weaker soils because of increased footing sizes and excavation work.

Joshi and Mehta (2023) described a study on the optimization of footing design by SAFE software. The study concluded that optimized footing analysis helps in reducing overuse of reinforcement and concrete while ensuring safety. The study emphasized the significance of software-based analysis in modern foundation engineering.

Gaikwad and Pawar (2021) studied the effect of soil properties on settlement and structural behavior of buildings. The researchers found that if SBC is not properly considered in the design stage, it can lead to cracks and uneven settlement of the structure in residential buildings.

IS 6403:1981, requires determination of safe bearing capacity for safe foundation design. The code gives guidance for the calculation of bearing capacity and allowable limits of settlement for shallow foundations. Similarly, IS 456:2000 gives design provisions for reinforced concrete footings and foundation elements.

Prior research has concentrated mainly on structural safety and footing analysis. The combined effect of variation in SBC on footing design, construction cost, and project deliverables for residential buildings has received very little attention. Therefore, the present study is intended to investigate the effect of various SBC values on the design of structural footing along with the effect on excavation, reinforcement, concrete quantity and overall project economy.

3. PROBLEM STATEMENT

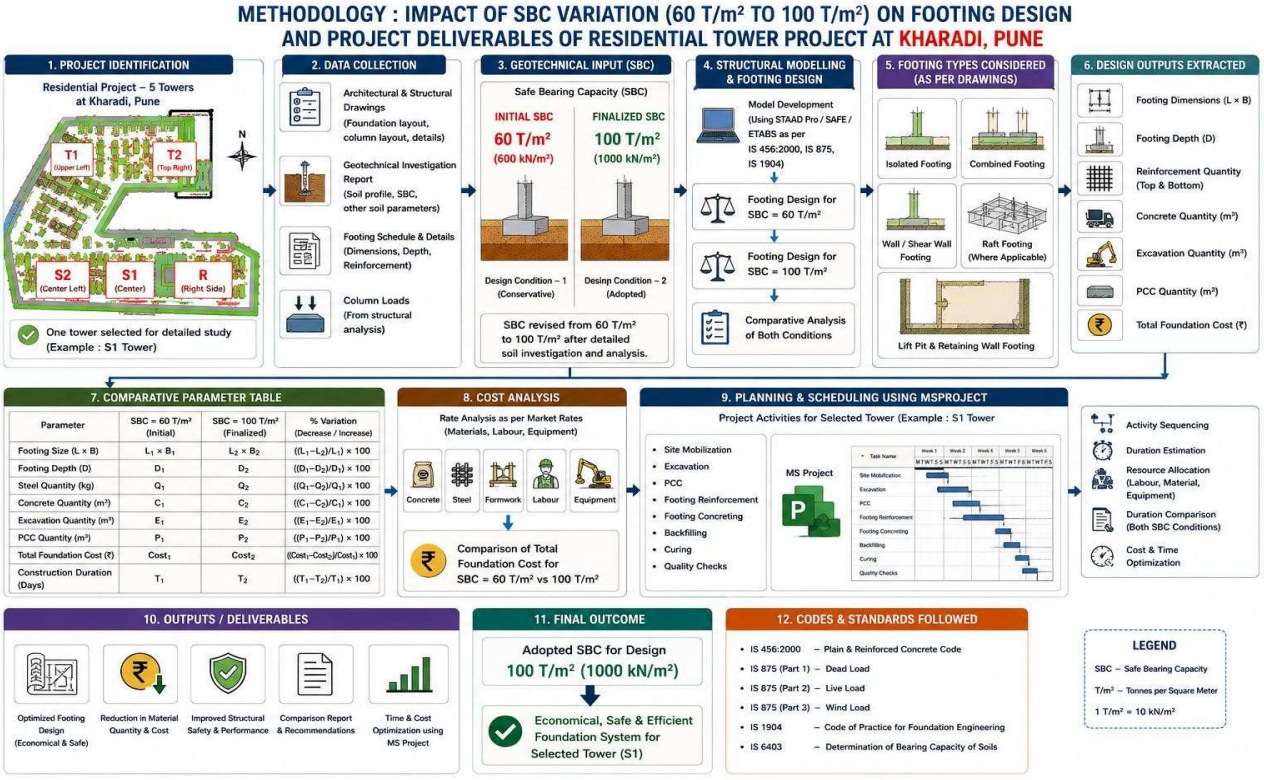
The variability in Safe Bearing Capacity (SBC) has a great influence on the design, safety and economy of structural foundations. Oversized or unsafe footing designs, increased material consumption, excessive construction cost and project delays are the consequence of improper estimation of SBC. There are few studies conducted on footing design and soil behavior. However, limited research is available on the analysis of the combined effect of SBC variation on footing dimensions,

reinforcement requirements, project cost and overall project deliverables in residential buildings.

The different soil conditions in residential construction projects cause large differences in the excavation work, the quantity of concrete and the reinforcement details. However, there are very few studies available that comparatively evaluate these variations in the context of structural analysis and design approaches. Hence, studying the effect of different SBC values on structural footing design as well as project economy is necessary to achieve safe, efficient and optimized foundation systems.

4. METHODOLOGY

STRUCTURAL FOUNDATION ANALYSIS FRAMEWORK



To study the effect of change in Safe Bearing Capacity (SBC) on footing design, construction cost and project deliverables of a residential tower project at Kharadi, Pune a comparative structural foundation analysis framework has been adopted. The study focuses on one selected tower in a multi-tower residential development project.

The analysis was carried out under two different SBC conditions:

Initial SBC Condition (60 T/m²)
This is the preliminary soil bearing capacity based on the preliminary geotechnical investigation report and conservative design assumptions at the early planning stage.

Finalized SBC Condition (100 T/m²)
This is the preliminary soil bearing capacity based on the preliminary geotechnical investigation report and conservative design assumptions at the early planning stage.

DATA COLLECTION

Collection of Primary Data

The primary project data were gathered from the construction drawings, the structural foundation layouts, the footing schedules, the reinforcement details and the geotechnical investigation reports of the residential tower project.

The data collected included:

- Footing layout drawings
- Position of columns and shear walls
- Footing sizes
- Details of reinforcements
- Depth of excavation
- PCC details
- Geotechnical data Structural load information

- Tower-R
- Tower-S1
- Tower-S2 (Note: The answer content has been truncated.
- Tower- T1
- Tower-T2

GEOTECHNICAL INVESTIGATION AND SBC ANALYSIS

The soil investigation report was studied for the variation in Safe Bearing Capacity for the selected tower. The initial SBC value of 60 T/m2 was compared with the finalized SBC value of 100 T/m2 adopted during the design stage.

The analysis took into account:

- Soil strata condition
- Depth of foundation
- Mechanism of load transfer
- Considerations of settlement
- Requirements for bearing capacity The variation in SBC directly affected:
- Dimensions of the footing
- Depth of footings
- Number of reinforcements
- Concrete figure
- Volumes of excavation
- Total foundation cost

STRUCTURAL MODELLING AND FOOTING DESIGN

Structural analysis and footing design was carried out on the basis of structural design principles and software tools like ETABS, SAFE and MS Project for planning and scheduling activities.

Relevant Indian Standard codes including: were used to do footing designs for both SBC conditions.

• IS 456:2000

• IS 875

• IS 1904

• IS 6403

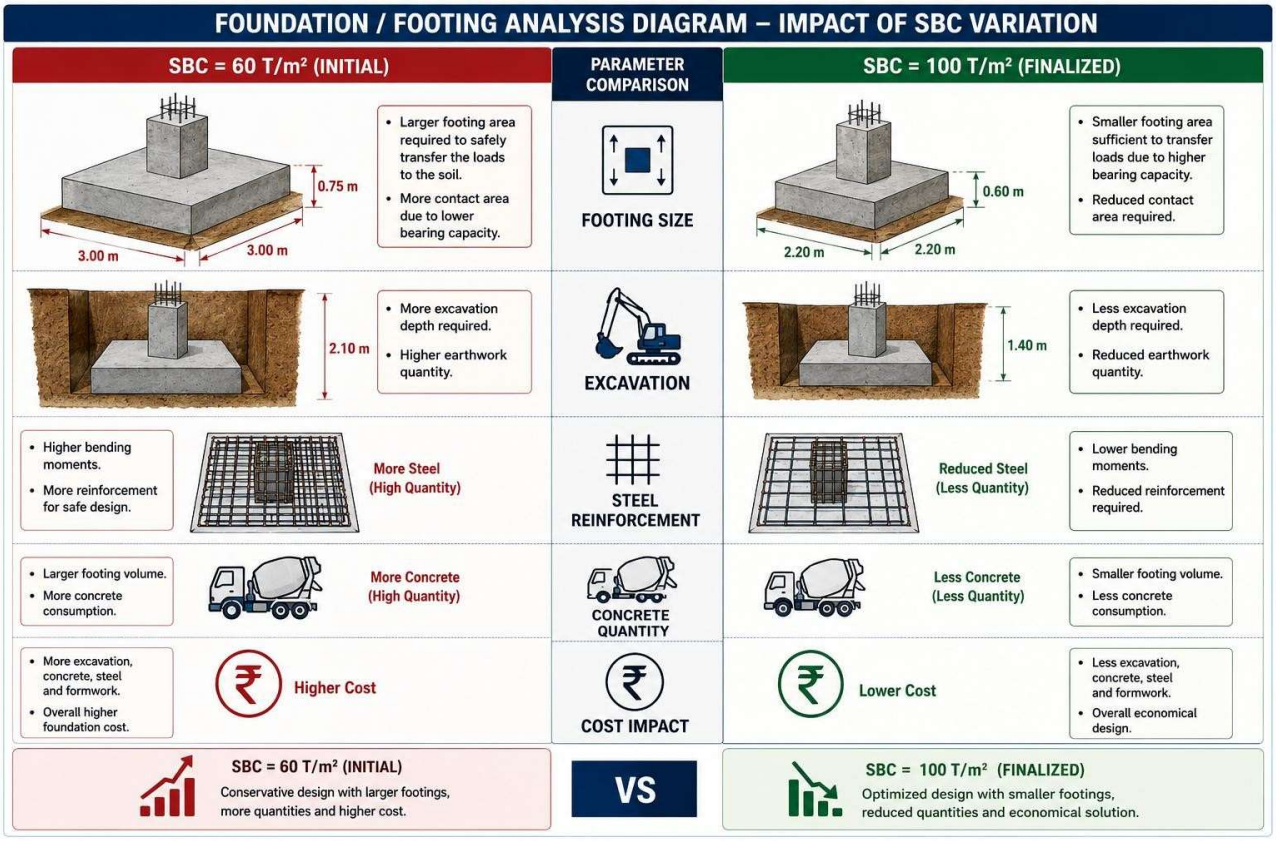
The project looked at different types of footings:

- Isolated footings
- Combined footings
- Footing of shear wall
- Base of lift pit
- Raft footing (if applicable) COMPARATIVE ANALYSIS

A comparative analysis was carried out between SBC = 60 T/m² and SBC = 100 T/m² to assess:

- Dimensions of footing
- Number of reinforcements
- volume of concrete
- Amount of PCC
- Excavation quantities
- Cost of foundation

Construction Schedule The percentage variation in quantities and cost was calculated to understand the impact of SBC variation on project deliverables.



PLANNING AND SCHEDULING ANALYSIS

The planning and scheduling of activities for the construction of the footing works were done using MS Project software.

The scheduling activities consisted of:

- Excavations
- Work on PCC
- Strengthening work
- Footings, Concrete

Backfilling

- Quality check

A comparative duration analysis was conducted for each SBC condition in order to measure the impact on project delivery and construction efficiency.

5. IMPLEMENTATION / EXPERIMENTAL SETUP

The study implementation work was performed using the actual structural foundation drawings, geotechnical investigation reports, footing schedules and construction planning data of a residential tower project at Kharadi, Pune. The project comprises of 5 residential towers namely T1, T2, S1, S2 and R tower.

The study is based on the effect of variation in Safe Bearing Capacity (SBC) with respect to footing design and project deliverables for the overall residential project. The design of the footing was initially done for an SBC value of 60 T/m2 based on the preliminary soil investigation data. After detailed geotechnical investigation and structural evaluation, the final SBC adopted for the foundation design was 100 T/m².

The structural foundation data such as footing dimensions, footing depth, reinforcement details, PCC thickness, excavation quantities and column loads were collected from the project foundation drawings. The project had different types of footings, i.e. isolated footings, combined footings, shear wall footings and lift pit foundations.

Structural analysis and design of footings were carried out as per the engineering design principles and software tools such as ETABS and SAFE, following the relevant Indian Standard codes like IS 456:2000, IS 875, IS 1904 and IS 6403.

A comparative analysis was performed between the two SBC conditions to evaluate variations in:

- Footing dimensions
- Excavation quantity

- Concrete quantity
- Reinforcement quantity
- PCC quantity
- Overall foundation cost
- Construction duration

In addition, MS Project software was used for the planning and scheduling of foundation activities like excavation, PCC work, reinforcement work, concreting, curing and backfilling operations. To assess the influence of SBC variability on project duration and construction efficiency, a comparative scheduling analysis was performed.

The implementation framework assisted in determining the influence of SBC variation on structural safety, material optimization, cost reduction and the overall deliverables of the residential development project.

6. RESULTS AND DISCUSSION

The study focuses on the impact of variation in Safe Bearing Capacity (SBC) on footing design, quantity of materials, cost of the project and scheduling of the foundation work for a residential project situated at Kharadi, Pune. A comparative analysis was carried out between two SBC conditions i.e. 60 T/m 2 and 100 T/m 2 using foundation design data, quantity estimation and MS project scheduling analysis .

Analysis showed that the increased SBC from 60 T/m² to 100 T/m² reduced footing dimensions and excavation requirements significantly. Higher SBC improved soil load carrying capacity which decreased the footing area and depth required for transferring the structural loads to the ground safely.

The footing size and depth has been reduced significantly due to reduction in:

- Concrete quantity
- Reinforcement quantity
- Excavation quantity
- PCC quantity
- Overall foundation cost

The comparative parameter analysis showed that the footing designs developed using SBC = 100 T/m2 were more economical and construction efficient compared to the footing designs based on SBC = 60 T/m2.

The investigation also demonstrated that the reduced amounts of excavation and concreting positively affected the time of foundation execution. MS Project scheduling analysis indicated improvement in construction sequencing and reduction in foundation work duration under optimized footing conditions.

Further analysis of the tracking Gantt chart revealed the difference between planned and actual schedule for foundation work. The foundation activities were scheduled to commence in October 2025, but the actual execution began in May 2026. The scheduling comparison highlighted the delay in commencement of foundation activities and its influence on construction planning and project deliverables.

The results prove that the accurate determination and optimization of Safe Bearing Capacity have important role in achieving:

- Economical footing design
- Material optimization
- Reduced construction cost
- Improved project scheduling
- Better construction efficiency

The study thus concludes that variations in SBC have a direct influence on the design of structural foundations and the overall deliverables of projects in residential construction.

7. CONCLUSION

The present study examines the effect of variation in Safe Bearing Capacity (SBC) on footing design, material quantities, project cost and foundation works scheduling for a residential project at Kharadi, Pune. The SBC values of 60 T/m2 and 100 T/m2 were compared with actual foundation design data and planning analysis.

The study concluded that increase in SBC significantly reduced footing dimensions, excavation depth, reinforcement quantity, concrete quantity and overall cost of foundation. Higher SBC led to a more economical and optimized foundation design reducing the material consumption and enhancing the construction efficiency.

The MS Project schedule analysis was also done to see the difference between scheduled and actual foundation work schedules. The delay in the commencement of foundation activities affected the planning and execution of the project, but the proper scheduling analysis was helpful in understanding the activity dependencies and the deliverables of the project effectively.

The results indicate that adequate soil investigation and proper determination of SBC are critical for safe, economical and efficient foundation design. The optimization of SBC improves the structural performances and also helps in cost reduction, material

optimization and project management of the residential construction projects.

Thus the study confirms that Safe Bearing Capacity has major role in Structural footing design and overall project deliverables. Geotechnical investigation and planning analysis are important aspects of modern construction projects.

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