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

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Abstract

Safe Bearing Capacity (SBC) plays a vital role in the design and performance of structural foundations. Variation in SBC significantly influences footing dimensions, reinforcement requirements, construction cost, and overall project execution. This study focuses on analyzing the impact of different Safe Bearing Capacity values on the structural footing design of a residential building. The research evaluates how changes in soil bearing capacity affect footing size, depth, reinforcement detailing, excavation quantity, concrete consumption, and project deliverables. Different SBC values were considered for the analysis, and footing designs were carried out using relevant Indian Standard codes and structural design software. Comparative analysis was performed to assess variations in material quantities and construction cost under different soil conditions. The study highlights that lower SBC values result in larger footing dimensions and increased consumption of concrete and steel, thereby increasing project cost and execution time. On the other hand, higher SBC values lead to economical footing designs and reduced material requirements. The research emphasizes the importance of proper geotechnical investigation and optimized foundation planning for achieving safe, economical, and efficient construction practices. The findings of this study can assist structural engineers and project planners in understanding the relationship between soil bearing capacity and foundation design optimization.

Keywords: *Safe Bearing Capacity (SBC), Footing Design, Foundation Engineering, Structural Analysis, Reinforcement, Construction Cost, Residential Building, Soil Investigation.*

1. Introduction

Foundation is one of the most important components of any civil engineering structure, as it safely transfers the load of the superstructure to the underlying soil. The strength and stability of a structure largely depend upon the bearing capacity of the soil supporting the foundation. Safe Bearing Capacity (SBC) refers to the maximum load that soil can safely withstand without experiencing shear failure or excessive settlement. Therefore, accurate determination of SBC is essential for ensuring the safety, serviceability, and economy of any structure.

In structural engineering, footing design is directly influenced by the Safe Bearing Capacity of soil. Variations in SBC can significantly affect footing dimensions, depth, reinforcement requirements, and overall construction cost. When soil possesses low bearing capacity, larger footing areas and higher quantities of construction materials are required to safely distribute structural loads. On the other hand, higher SBC values allow the use of smaller and

more economical footings. Hence, SBC plays a vital role in optimizing foundation design and controlling project expenses.

Rapid urbanization and increasing construction activities have created a growing need for economical and efficient foundation systems. In residential construction projects, improper estimation of soil bearing capacity may lead to unsafe designs, differential settlement, structural cracks, and even failure of foundations. Additionally, overestimation of SBC may compromise structural safety, while underestimation may unnecessarily increase material consumption and project cost. Therefore, understanding the relationship between soil properties and footing behavior has become an important aspect of modern construction practices.

With advancements in structural analysis and design software such as and ETABS and SAFE, engineers can perform detailed footing analysis under varying soil conditions. These tools help in evaluating the impact of different SBC values on footing geometry, reinforcement detailing, and load distribution. Comparative analysis using software applications enables engineers to select the most suitable and economical foundation system for a particular site condition.

This study focuses on analyzing the impact of variation in Safe Bearing Capacity on structural footing design, project cost, and construction deliverables for a residential building. Different SBC values are considered to examine their influence on footing size, concrete quantity, steel reinforcement, excavation work, and overall project economy. The study also aims to highlight the importance of proper geotechnical investigation and optimized foundation planning for achieving safe, economical, and sustainable construction practices.

The outcomes of this research will help structural engineers, designers, and project planners understand how variations in soil bearing capacity influence foundation behavior and project execution. The findings can further assist in improving decision-making during the planning and design stages of residential building projects.

2. Literature Review

The design of structural foundations and their performance are highly dependent on the bearing capacity of soil. Several researchers have studied the influence of soil properties, footing behavior, and foundation optimization under varying loading and ground conditions. The following literature review summarizes previous studies related to Safe Bearing Capacity (SBC), footing design, cost optimization, and the impact of soil conditions on structural performance.

Patil and Sharma (2023) conducted a study on the effect of varying soil bearing capacities on isolated footing dimensions for residential buildings. The study concluded that lower SBC values considerably increased footing area, reinforcement quantity, and concrete consumption. The researchers emphasized the importance of accurate soil investigation for economical foundation design.

Kumar and Singh (2022) analyzed the relationship between soil bearing capacity and structural safety in reinforced concrete foundations. Their research highlighted that improper estimation of SBC may lead to differential settlement and structural instability. The study recommended adopting proper geotechnical investigations before finalizing foundation systems.

According to Reddy and Chavan (2020), soil-structure interaction plays an important role in determining footing performance. Their research focused on settlement behavior under different soil conditions and concluded that foundations constructed on low SBC soils require additional strengthening and stabilization measures.

Sharma and Kulkarni (2022) studied the economic implications of foundation design in residential construction projects. The researchers compared construction costs for various footing configurations under different soil bearing capacities and found that foundation cost can increase substantially for weaker soils due to larger footing dimensions and increased excavation work.

A study conducted by Joshi and Mehta (2023) focused on the optimization of footing design using SAFE software. The research demonstrated that optimized footing analysis helps reduce excessive reinforcement and concrete usage while maintaining structural safety. The study highlighted the importance of software-based analysis in modern foundation engineering.

Gaikwad and Pawar (2021) investigated the impact of soil properties on settlement and structural behavior of buildings. Their findings indicated that improper consideration of SBC during design stages often results in structural cracks and uneven settlement in residential buildings.

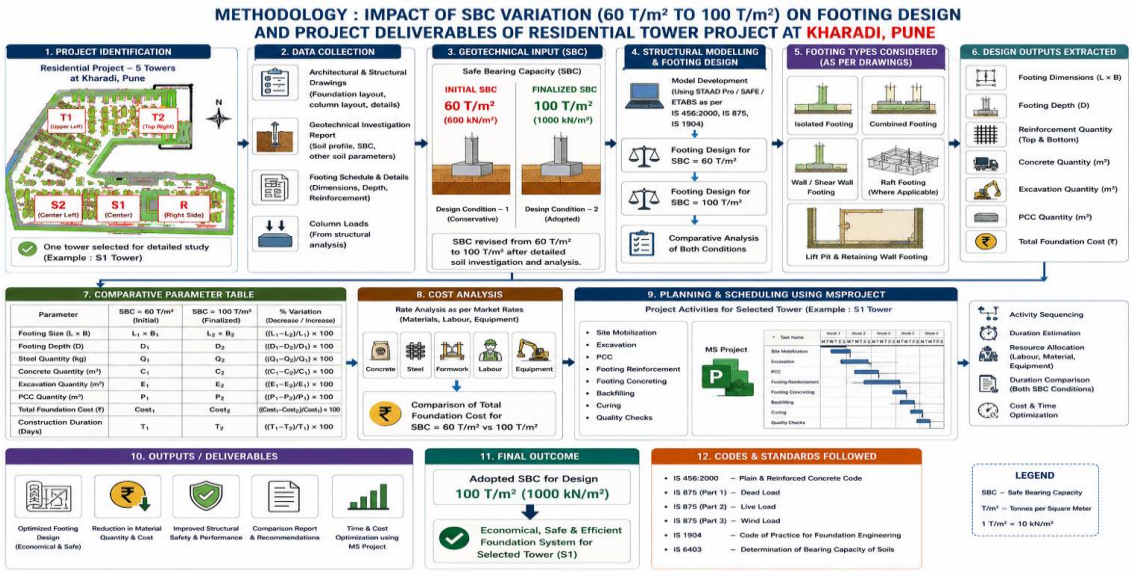
According to IS 6403:1981, determination of Safe Bearing Capacity is essential for safe foundation design. The code specifies guidelines for calculating bearing capacity and allowable settlement limits for shallow foundations. Similarly, IS 456:2000 provides design provisions for reinforced concrete footings and foundation elements.

Previous studies mainly focused on structural safety and footing analysis, while limited research has been conducted on the combined impact of SBC variation on footing design, construction cost, and project deliverables in residential buildings. Therefore, this study aims to analyze the influence of different SBC values on structural footing design along with its effect on excavation, reinforcement, concrete quantity, and overall project economy.

3. Problem Statement

Variation in Safe Bearing Capacity (SBC) significantly affects the design, safety, and economy of structural foundations. Improper estimation of SBC often leads to oversized or unsafe footing designs, increased material consumption, excessive construction cost, and project delays. Although several studies have been carried out on footing design and soil behavior, limited research is available on analyzing the combined impact of SBC variation on footing dimensions, reinforcement requirements, project cost, and overall project deliverables in residential buildings.In the context of residential construction projects, different soil conditions result in major variations in excavation work, concrete quantity, and reinforcement detailing. However, very few studies are available that comparatively evaluate these variations using structural analysis and design approaches. Therefore, there is a need to study the influence of different SBC values on structural footing design and project economy to achieve safe, efficient, and optimized foundation systems.

STRUCTURAL FOUNDATION ANALYSIS FRAMEWORK



4. Methodology

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

The analysis was carried out under two different SBC conditions:

Initial SBC Condition (60 T/m²)

This represents the preliminary soil bearing capacity obtained from the initial geotechnical investigation report and conservative design assumptions during the early planning stage.

Finalized SBC Condition (100 T/m²)

This represents the revised and finalized SBC adopted after detailed soil investigation, structural analysis, and design optimization.

DATA COLLECTION

Collection of Primary Data

Primary project data was collected from actual construction drawings, structural foundation layouts, footing schedules, reinforcement details, and geotechnical investigation reports of the residential tower project.

The collected data included:

- Footing layout plans
- Column and shear wall locations
- Footing dimensions
- Reinforcement details

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- Excavation depth
- PCC details
- Soil investigation data
- Structural loading information

The project consists of five residential towers namely:

- Tower-R
- Tower-S1
- Tower-S2
- Tower-T1
- Tower-T2

GEOTECHNICAL INVESTIGATION AND SBC ANALYSIS

The soil investigation report was studied to evaluate 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 considered:

- Soil strata conditions
- Foundation depth
- Load transfer mechanism
- Settlement considerations
- Bearing capacity requirements

The variation in SBC directly influenced:

- Footing dimensions
- Footing depth
- Reinforcement quantity
- Concrete quantity
- Excavation quantity
- Overall foundation cost

STRUCTURAL MODELLING AND FOOTING DESIGN

Structural analysis and footing design were carried out using structural design principles and software tools such as ETABS, SAFE, and MS Project for planning and scheduling activities.

Footing designs were studied for both SBC conditions using relevant Indian Standard codes including:

- IS 456:2000
- IS 875
- IS 1904
- IS 6403

Different footing types considered in the project included:

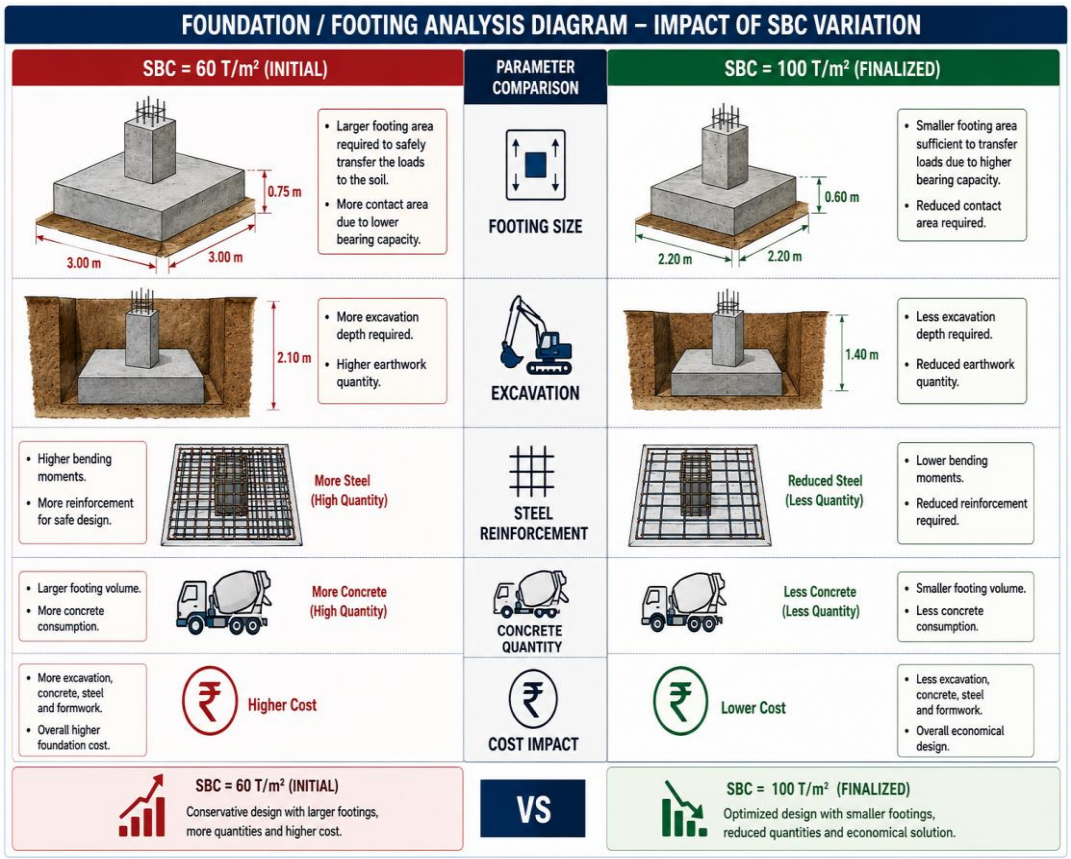
- Isolated footing
- Combined footing
- Shear wall footing
- Lift pit footing
- Raft footing (where applicable)

COMPARATIVE ANALYSIS

Comparative analysis was performed between SBC = 60 T/m² and SBC = 100 T/m² for evaluating:

- Footing dimensions
- Reinforcement quantity
- Concrete quantity
- PCC quantity
- Excavation quantity
- Foundation cost
- Construction duration

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



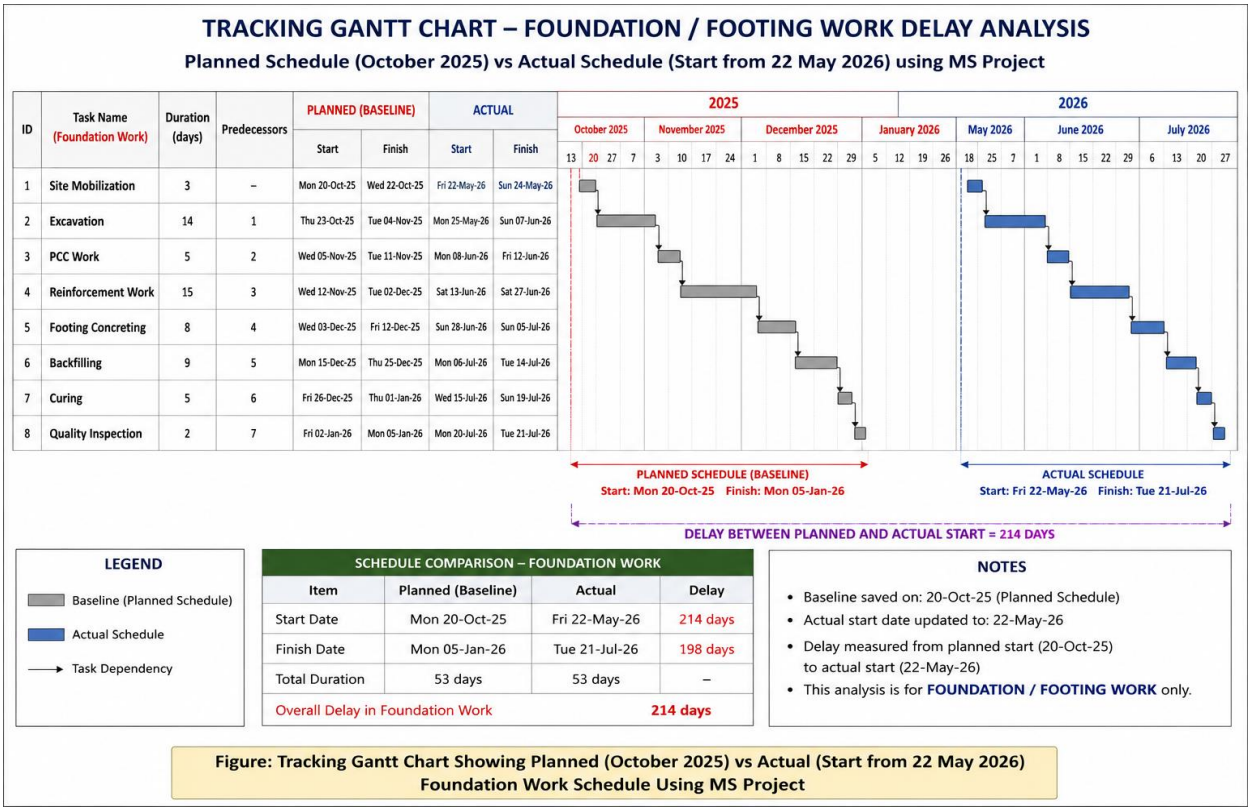
PLANNING AND SCHEDULING ANALYSIS

MS Project software was used for planning and scheduling activities related to footing construction works.

The scheduling activities included:

- Excavation
- PCC work
- Reinforcement work
- Footing concreting
- Backfilling
- Quality inspection

Comparative duration analysis was carried out for both SBC conditions to evaluate the effect on project execution and construction efficiency.



ID	Task Name (Foundation Work)	Duration (days)	Predecessors	PLANNED (BASELINE) Start	PLANNED (BASELINE) Finish	ACTUAL Start	ACTUAL Finish
1	Site Mobilization	3	–	Mon 20-Oct-25	Wed 22-Oct-25	Fri 22-May-26	Sun 24-May-26
2	Excavation	14	1	Thu 23-Oct-25	Tue 04-Nov-25	Mon 25-May-26	Sun 07-Jun-26
3	PCC Work	5	2	Wed 05-Nov-25	Tue 11-Nov-25	Mon 08-Jun-26	Fri 12-Jun-26
4	Reinforcement Work	15	3	Wed 12-Nov-25	Tue 02-Dec-25	Sat 13-Jun-26	Sat 27-Jun-26
5	Footing Concreting	8	4	Wed 03-Dec-25	Fri 12-Dec-25	Sun 28-Jun-26	Sun 05-Jul-26
6	Backfilling	9	5	Mon 15-Dec-25	Thu 25-Dec-25	Mon 06-Jul-26	Tue 14-Jul-26
7	Curing	5	6	Fri 26-Dec-25	Thu 01-Jan-26	Wed 15-Jul-26	Sun 19-Jul-26
8	Quality Inspection	2	7	Fri 02-Jan-26	Mon 05-Jan-26	Mon 20-Jul-26	Tue 21-Jul-26

Figure: Tracking Gantt Chart Showing Planned (October 2025) vs Actual (Start from 22 May 2026) Foundation Work Schedule Using MS Project

5. Implementation / Experimental Setup

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

The study focuses on analyzing the impact of variation in Safe Bearing Capacity (SBC) on footing design and project deliverables for the overall residential project. Initially, the footing design was considered for an SBC value of 60 T/m² based on preliminary soil investigation data. Later, after detailed geotechnical investigation and structural evaluation, the finalized SBC adopted for foundation design was 100 T/m².

Structural foundation data including footing dimensions, footing depth, reinforcement details, PCC thickness, excavation quantities, and column loads were collected from the project foundation drawings. Various footing

types used in the project included isolated footings, combined footings, shear wall footings, and lift pit foundations.

Structural analysis and footing design considerations were carried out using engineering design principles and software tools such as ETABS and SAFE in accordance with relevant Indian Standard codes including 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

MS Project software was further used for planning and scheduling foundation activities including excavation, PCC work, reinforcement work, concreting, curing, and backfilling operations. Comparative scheduling analysis was carried out to study the effect of SBC variation on project duration and construction efficiency.

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

6. Results and Discussion

The study evaluates the impact of variation in Safe Bearing Capacity (SBC) on footing design, material quantities, project cost, and foundation work scheduling for a residential project located at Kharadi, Pune. Comparative analysis was carried out between two SBC conditions, namely 60 T/m² and 100 T/m², using foundation design data, quantity estimation, and MS Project scheduling analysis.

The analysis revealed that increasing the SBC from 60 T/m² to 100 T/m² significantly reduced footing dimensions and excavation requirements. Higher SBC resulted in improved load carrying capacity of soil, which reduced the required footing area and depth for transferring structural loads safely to the ground.

Due to reduction in footing size and depth, substantial reduction was observed in:

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

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

The study also showed that reduced excavation and concreting quantities positively influenced foundation execution time. MS Project scheduling analysis indicated improvement in construction sequencing and reduction in foundation work duration under optimized footing conditions.

Tracking Gantt chart analysis further demonstrated the difference between planned and actual foundation work schedules. The planned foundation activities were scheduled to commence in October 2025; however, the actual execution started 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 confirm that accurate determination and optimization of Safe Bearing Capacity play an important role in achieving:

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

Thus, the study establishes that variation in SBC has a direct influence on structural foundation design as well as overall project deliverables in residential construction projects.

7. Conclusion

The present study analyzed the impact of variation in Safe Bearing Capacity (SBC) on footing design, material quantities, project cost, and foundation work scheduling for a residential project at Kharadi, Pune. Comparative analysis was carried out between SBC values of 60 T/m² and 100 T/m² using 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 foundation cost. Higher SBC provided a more economical and optimized foundation design by reducing material consumption and improving construction efficiency.

MS Project scheduling analysis further highlighted the difference between planned and actual foundation work schedules. The delay in commencement of foundation activities affected project planning and execution; however, proper scheduling analysis helped in understanding activity dependencies and project deliverables effectively.

The results demonstrate that accurate soil investigation and proper determination of SBC are essential for safe, economical, and efficient foundation design. Optimization of SBC not only improves structural performance but also contributes to cost reduction, material optimization, and better project management in residential construction projects.

Therefore, the study confirms that Safe Bearing Capacity plays a major role in structural footing design and overall project deliverables, making geotechnical investigation and planning analysis important aspects of modern construction projects.

References

1. IS 456:2000, Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi, India.
2. IS 875 (Part 1):1987, Dead Loads for Buildings and Structures, Bureau of Indian Standards, New Delhi, India.
3. IS 875 (Part 2):1987, Imposed Loads for Buildings and Structures, Bureau of Indian Standards, New Delhi, India.
4. IS 875 (Part 3):2015, Wind Loads on Buildings and Structures, Bureau of Indian Standards, New Delhi, India.
5. IS 1893 (Part 1):2016, Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi, India.

6. IS 1904:1986, Code of Practice for Design and Construction of Foundations in Soils, Bureau of Indian Standards, New Delhi, India.
7. IS 6403:1981, Code of Practice for Determination of Bearing Capacity of Shallow Foundations, Bureau of Indian Standards, New Delhi, India.
8. IS 2911 (Part 1/Sec 1):2010, Design and Construction of Pile Foundations, Bureau of Indian Standards, New Delhi, India.
9. Bowles, J.E., Foundation Analysis and Design, McGraw Hill Education, 5th Edition, 1996.
10. Das, B.M., Principles of Foundation Engineering, Cengage Learning, 8th Edition, 2015.
11. Punmia, B.C., Jain, A.K., and Jain, A.K., Soil Mechanics and Foundations, Laxmi Publications, New Delhi.
12. Murthy, V.N.S., Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering, Marcel Dekker Inc., 2002.
13. Teng, W.C., Foundation Design, Prentice Hall of India Pvt. Ltd., New Delhi.
14. Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, Wiley India Pvt. Ltd.
15. Tomlinson, M.J., Foundation Design and Construction, Pearson Education.
16. Braja M. Das and Khaled Sobhan, Principles of Geotechnical Engineering, Cengage Learning.
17. Kumar, R. and Singh, P., "Analysis of Footing Design under Different Soil Bearing Capacities," International Journal of Civil Engineering and Technology, Vol. 13, Issue 4, 2022, pp. 45–52.
18. Sharma, A. and Patil, S., "Effect of Soil Bearing Capacity on Foundation Cost and Structural Safety," International Research Journal of Engineering and Technology (IRJET), Vol. 9, Issue 6, 2022.
19. Reddy, K. and Chavan, M., "Comparative Study of Footing Design using SAFE Software," International Journal for Research in Applied Science and Engineering Technology (IJRASET), Vol. 8, Issue 7, 2020.
20. Deshmukh, P. and Kulkarni, R., "Optimization of Reinforced Concrete Footings under Varying Soil Conditions," International Journal of Engineering Research and Applications, Vol. 11, Issue 5, 2021.
21. Patil, S. and Joshi, A., "Influence of Soil Bearing Capacity on Foundation Design and Construction Cost," International Journal of Innovative Research in Science and Engineering, Vol. 7, Issue 3, 2021.
22. SAFE 2022 Documentation, CSI SAFE Integrated Analysis and Design Software for Foundation Systems, Computers and Structures Inc., USA.
23. Microsoft Corporation, Microsoft Project User Guide and Project Scheduling Documentation, Microsoft, USA.
24. Maharashtra State Schedule of Rates (SSR), Public Works Department (PWD), Government of Maharashtra, Latest Edition.