

HARMONY IN PROGRESS:

**INTEGRATING SCIENCE, TECHNOLOGY,
AND
SOCIAL INNOVATION
FOR SUSTAINABLE DEVELOPMENT GOALS**



**e-Book of Extended Abstract
Negeri Sembilan International (NSIEx) & Research Symposium
2025**

PST005 - EMPOWERING SUSTAINABLE INFRASTRUCTURE WITH SCDesignPro: AN INNOVATIVE EVALUATION OF STONE COLUMN PERFORMANCE

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ABSTRACT

Stone columns are widely used as a ground improvement technique to enhance bearing capacity and reduce settlement in soft soils. However, most conventional design approaches assume only vertical and concentric loadings, which may not reflect actual field conditions where complex load combinations often occur. SCDesignPro is an innovative solution developed to evaluate the bearing capacity of stone columns under inclined and eccentric loading conditions, addressing a critical gap in current geotechnical engineering practices. The tool integrates advanced numerical modelling using PLAXIS 3D with comprehensive parametric studies to develop practical and reliable design formulas. The novelty of SCDesignPro lies in its ability to account for combined inclined and eccentric loading effects, significantly enhancing design reliability for structures constructed on soft and challenging ground conditions. This contributes to safer and more efficient foundation performance, reducing the risk of failure. With its user-friendly interface and smart computational features, SCDesignPro offers an efficient and accessible design tool for engineers, consultants, and researchers. Its wide applicability and strong commercial potential position it as a valuable contribution to digital geotechnical engineering solutions. SCDesignPro aligns with SDG 9: Industry, Innovation and Infrastructure, by promoting resilient infrastructure through smart, data-driven design tools, and SDG 11: Sustainable Cities and Communities, by enhancing the safety and durability of urban development through improved ground improvement strategies.

Keywords – Stone Column, Bearing Capacity, Inclined Load, Eccentric Load, Sustainable

INTRODUCTION

Stone columns have become a preferred solution for ground improvement due to their proven effectiveness in reinforcing weak soils, offering both enhanced bearing capacity and reduced settlement (Ghazavi, Rouhani, & Khoshghalb, 2024). Conventionally, design approaches assume only vertical and concentric loads; however, real-world conditions often involve inclined and eccentric loadings due to factors such as sloping terrain, asymmetrical superstructures, or seismic events (Ng, Idrus, & Chew, 2021). These

complex loading scenarios challenge traditional design assumptions and can potentially compromise foundation performance under actual field conditions.

Recent studies have confirmed that bearing capacity diminishes significantly as load eccentricity increases, and that failure mechanisms shift from uniform shear to modes such as bulging and bending in stone columns (Ng, Idrus, & Chew, 2022). Additionally, investigations into inclined loading have shown that neglecting these load conditions can lead to non-conservative design outcomes.

SCDesignPro was developed to address this critical gap. It integrates PLAXIS 3D numerical modelling with extensive parametric analysis to accurately assess stone column performance under realistic, combined loading conditions. By generating design formulas that reflect actual field complexities, the tool aims to enhance design accuracy, improve foundation resilience, and support geotechnical engineers in developing sustainable infrastructure solutions.

OBJECTIVE

The primary objectives of developing SCDesignPro are as follows:

- i. To develop a smart and user-friendly tool that accurately evaluates the bearing capacity of stone columns under inclined and eccentric loading conditions, reflecting realistic field scenarios often overlooked in conventional design methods.
- ii. To enhance the safety, efficiency, and reliability of stone column designs in soft soils by addressing the limitations of existing design approaches.
- iii. To support sustainable infrastructure development by providing a solution that aligns with the principles of resilient foundation engineering and contributes to the relevant Sustainable Development Goals (SDGs).

DESCRIPTION OF THE PROJECT

SCDesignPro is a user-friendly tool developed to evaluate the bearing capacity of stone columns under inclined and eccentric loading conditions. Its development involved four primary stages: numerical modelling, parametric analysis, formulation of predictive equations, and software design. The tool features an easy-to-navigate interface, allowing users to input key parameters such as soil properties, footing and stone column size, inclination angle and eccentricity value. The tool uses formulas derived from advanced PLAXIS 3D modelling and parametric studies to deliver fast and accurate results. These formulas are developed for two soil conditions of drained and undrained, reflecting different soil behaviour under loading.

The bearing capacity of stone columns under drained soil conditions can be determined using Equation 1 and Equation 2, which represent the modified inclination factor, i_γ and eccentricity factor, e_γ , respectively, for inclined and eccentric loading.

$$i_\gamma = \frac{1.07}{1 + e^{(0.17\beta - 16)}} \quad (1)$$

$$e_\gamma = 1 - 2.78e_x \quad (2)$$

For undrained soil conditions, Equation 3 and Equation 4 present the modified bearing capacity factor under inclined loading, $N_{c,i}$, while Equation 5 provides the eccentricity factor, e_y , used to account for load eccentricity.

$$N_{ci} = kN_c \quad (3)$$

$$k = 0.2 + \frac{1}{1.15 + e^{(0.1b\beta - 2.3)}} \quad (4)$$

$$e_y = 1 - 1.55e_x \quad (5)$$

SCDesignPro was developed using Microsoft Excel and is designed to streamline the design process by integrating the equations of this study. SCDesignPro is practical for engineers, researchers, and students, as it simplifies complex analysis, reduces design time, and improves the reliability of foundation design on soft soils. Its ability to address real-world loading conditions makes it a valuable and efficient tool for both professional practice and academic use.

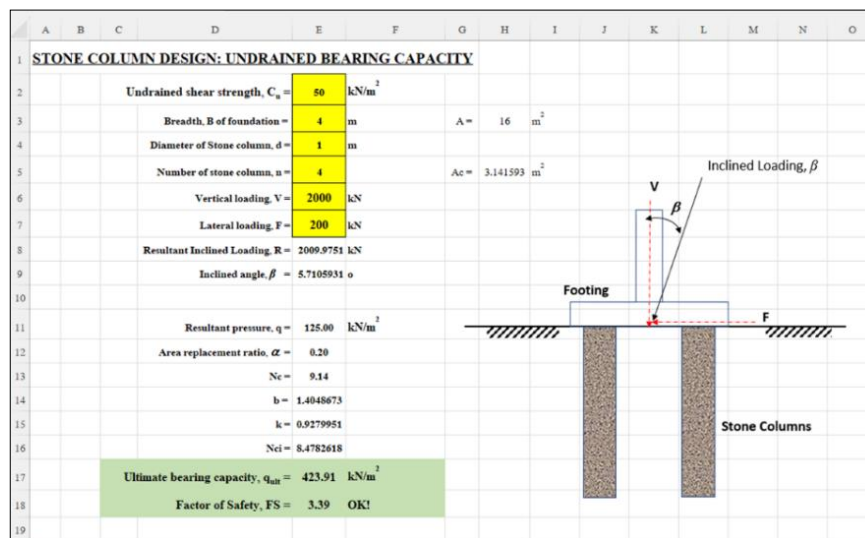


Figure 1: The interface of SCDesignPro software

NOVELTY

The novelty of SCDesignPro lies in its ability to evaluate the bearing capacity of stone columns under combined inclined and eccentric loading conditions, which are commonly neglected in conventional design methods. Using a groundbreaking approach that integrates PLAXIS 3D modelling with a detailed parametric study, the tool generates design formulas for both drained and undrained soil conditions. This dual-condition formulation, along with the ability to simulate complex load effects, provides new insights into the performance of stone columns in real-world applications. Therefore, SCDesignPro offers a unique, data-driven solution that not only fills a critical gap in geotechnical design practice but also contributes to the advancement of knowledge in foundation engineering.

SCDesignPro offers significant advantages to engineers, including the automated handling of complex design calculations, the flexibility to quickly adjust design parameters and a reduction in design-related errors. SCDesignPro demonstrates strong potential for commercialization, making it a valuable asset for engineering firms aiming to streamline their design workflows and improve project outcomes.

CONCLUSION

SCDesignPro is a practical and innovative tool that helps engineers evaluate the bearing capacity of stone columns under inclined and eccentric loading conditions, which are often overlooked in conventional design methods. It provides reliable design formulas for both drained and undrained soil conditions, improving the safety and accuracy of foundation

designs, especially in soft soil. In addition to its technical value, SCDesignPro supports the Sustainable Development Goals (SDGs), particularly SDG 9, by promoting innovation in infrastructure, and SDG 11, by contributing to safer and more sustainable cities and communities.

REFERENCES

- Ghazavi, M., Rouhani, M., & Khoshghalb, A. (2024). Evaluation of the Methods Used for Estimating the Bearing Capacity of Stone Columns. *Transportation Geotechnics*, 49, Article 101405.
- Ng, K. S., Idrus, J., & Chew, Y. M. (2022). Bearing Capacity of Stone Column-Reinforced Soil under Eccentric Load. *International Journal of Geosynthetics and Ground Engineering*, 8, Article 53.
- Ng, K. S., Idrus, J., & Chew, Y. M. (2021). Bearing Capacity of Stone Column–Reinforced Foundation Subjected to Inclined Loadings. *International Journal of Geosynthetics and Ground Engineering*, 7(3), Article 62.