The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2025

Volume 38, Pages 433-443

IConTES 2025: International Conference on Technology, Engineering and Science

Factors Affecting the Sliding Stability of a Gravity Retaining Wall

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Abstract: This study investigates the sliding stability of gravity retaining walls by integrating the spatial variability of soil properties into a probabilistic framework. Unlike traditional deterministic methods, which assume fixed soil parameters and rely solely on safety factors, this approach employs Monte Carlo simulations in MATLAB to account for the inherent uncertainties in soil behavior. The analysis focuses on how variations in key geotechnical parameters, specifically the internal friction angle of the backfill, the cohesion of the foundation soil, the unit weight of the backfill, and the foundation friction angle, affect the probability of failure for different levels of safety factors. The results show that the spatial variability of the backfill's internal friction angle and the cohesion of the foundation soil plays a critical role in sliding failure. When a commonly used safety factor of 1.5 is applied, the corresponding failure probabilities often exceed the acceptable threshold of 10^{-4}. Conversely, the variability in backfill unit weight and foundation friction angle has minimal influence on failure risk. These findings underscore the limitations of conventional design approaches and demonstrate the necessity of incorporating probabilistic analyses to achieve more reliable and robust designs. The study supports the adoption of reliability-based methods for safer and more resilient retaining wall structures under uncertainty.

Keywords: Gravity retaining wall, Sliding stability, Probabilistic analysis, Spatial variability, Monte Carlo simulation

Introduction

Gravity retaining walls represent one of the oldest and most commonly used structures for resisting lateral earth pressures. Their stability is primarily ensured by their self-weight. The design of these structures traditionally relies on the concept of a safety factor $(FS)_{sli}$, whose value is typically derived from practical experience and the analysis of past failures (Goh, Zhang, Zhang, Zhang, & Liu, 2017; Mokeddem, 2018; Zhou, Xie, Huang, & He, 2019).

In a deterministic framework, the geomechanical parameters of the soil are assumed to remain constant during stability analysis (Zhou et al., 2019). However, these parameters, such as unit weight, internal friction angle, and cohesion, are inherently uncertain. Consequently, although the safety factor approach is widely applied, it often fails to provide a rigorous representation of the true behavior of soil (Zhou et al., 2019). Probabilistic methods, including reliability analysis and Monte Carlo simulations, offer a more comprehensive way to account for these uncertainties (Sert, Luo, Xiao, Gong, & Juang, 2016).

The specialized literature (Harr, 1987; Kulhawy, 1993; Lumb, 1974; Singh, 1972) reports that soil unit weight may vary by 3-7%, the internal friction angle by 2-13%, and cohesion by as much as 10-50%. Reliability-based design provides a systematic means of incorporating these variations into the design process. Accordingly, many studies have employed this method to evaluate the safety of gravity retaining walls (Guha Ray & Baidya, 2012). The need for an optimized and balanced design has been emphasized in several works, particularly for gravity

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walls (Höeg & Murarka, 1974). It has been demonstrated that a high safety factor obtained through deterministic methods does not necessarily ensure structural safety. Indeed, accounting for the variability of soil mechanical properties can lead to significant probabilities of failure.

Guha Ray & Baidya (2012) showed that even with a high safety factor, a structure may still present a considerable risk of failure when the variability of soil parameters is incorporated into the analysis. In most studies, soil parameters are assumed to be constant for a given calculation. Therefore, for a set of *n* simulated random variables, *n* corresponding safety factor values are obtained, particularly when Coulomb's theory is used to estimate lateral earth pressures (Guha Ray & Baidya, 2012). The Random Finite Element Method (RFEM) has also been employed to investigate the influence of one-dimensional spatial variability of the internal friction angle on both wall and soil responses (Sert et al., 2016). In this context, computing the safety factor requires modeling variability through an equivalent number of random soil layers.

In parallel, design approaches based on a target failure probability have been developed, combining the principles of structural optimization and reliability. However, the literature review reveals that two key aspects, the sensitivity analysis of random variables and the evaluation of failure probabilities for different modes, are often addressed separately. A methodology that simultaneously integrates these two components could lead to designs that are both safer and more cost-effective.

In this study, a design and optimization approach is proposed based on the combined use of a target failure probability and the safety factor against sliding. An analytical strategy was implemented to assess the vulnerability of gravity retaining walls to sliding by varying, independently, the coefficients of variation of soil parameters. This analysis makes it possible to identify the influence of each parameter on the probability of failure for different safety factor values using Monte Carlo simulations.

Objectives

The main objective of this study is to develop a methodology for identifying the most influential soil parameters affecting the sliding failure mode of a gravity retaining wall. It also aims to analyze the extent of influence of each random variable, namely, the internal friction angle (φ), cohesion (c), and unit weight (γ), on sliding stability. The study seeks to establish a relationship between the probability of failure associated with this failure mode and the different values of safety factors, while accounting for the variability of soil properties. To achieve this objective, a case study is conducted on a typical gravity retaining wall. A deterministic analysis is first carried out using Coulomb's method to evaluate lateral earth pressures and to calibrate the safety factors related to sliding. Then, the failure probability is estimated using the Monte Carlo Simulation (MCS) method implemented in MATLAB, incorporating probability distributions derived from the literature for the random variables. This approach makes it possible to combine the analysis of the influence of soil parameters with the evaluation of sliding failure probability for different safety factor values, thereby providing a more comprehensive assessment of the risks associated with the instability of gravity retaining walls.

Problem Description

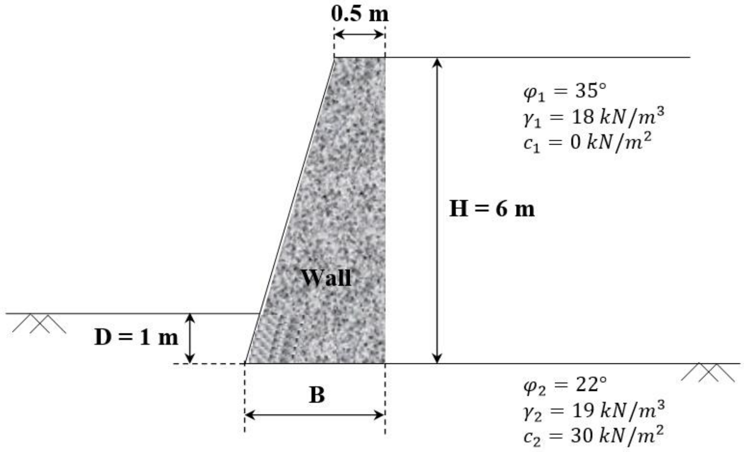

Figure 1. Cross-section of the gravity retaining wall

A typical gravity retaining wall, as illustrated in Figure 1, is considered in the present study. All soil properties are assumed to be homogeneous, statistically independent, and spatially constant. Table 1 summarizes the mean values of the geotechnical properties of both the backfill and foundation soils.

Table 1. Statistics of input parameters

Variables	Mean μ	COV (%)	Distribution
$\gamma_1\left(kN/m^3\right)$	18	[5% - 10%]	Normal
$\varphi_1\left(degrees\right)$	35	[5% - 15%]	Log-normal
$\gamma_2\left(kN/m^3\right)$	19	[5% - 10%]	Normal
$\varphi_2\left(degrees\right)$	22	[5% - 15%]	Log-normal
$c_2\left(kN/m^2\right)$	30	[30% - 50%]	Log-normal

Deterministic Analysis

Coulomb's earth pressure theory is used to evaluate the external stability of the retaining wall under static conditions. The total active lateral force exerted by the backfill is given by:

$$F_a = \frac{1}{2} K_a \gamma H^2 \tag{1}$$

According to Coulomb, the active earth pressure coefficient Ka can be expressed as follows:

$$K_a = \frac{\sin^2 \sin^2\left(\eta-\varphi\right)}{\sin^2 \sin^2 \eta \sin\sin\left(\eta+\delta\right)\left[1+\sqrt{\frac{\sin\sin\left(\varphi+\delta\right)\sin\sin\left(\varphi-\beta\right)}{\sin\sin\left(\eta+\delta\right)\sin\sin\left(\eta-\beta\right)}}\right]^2} \tag{2}$$

The wall is specifically designed to resist the sliding failure mode, and the limit equilibrium equation used to calculate the safety factor is expressed as:

$$F_G = \frac{c.B + N.\tan\tan\delta}{T} \tag{3}$$

For soil–concrete interfaces, it is assumed that the friction coefficient between the soil and the wall base is identical to that of the wall face (SCHLOSSER, 1995). This friction angle is defined as:

$$\delta = \frac{2}{3}\varphi \tag{4}$$

Here, *N* and *T* represent the total vertical force and the destabilizing horizontal force acting on the structure, respectively. The design of the gravity retaining wall is performed by adjusting the deterministic safety factors according to the values specified in Table 2. These safety factors $(FS)_{sli}$ are calculated specifically for the sliding failure mode, providing a measure of the available margin of safety before failure occurs. The deterministic $(FS)_{sli}$ values serve as reference points for the subsequent probabilistic analyses, which assess the uncertainty associated with the soil parameters influencing wall stability and estimate the corresponding probabilities of failure for this mode.

Table 2. Deterministic safety factors

Sliding safety factor $(FS)_{sli}$	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
Corresponding base width B (m)	1.533	1.911	2.289	2.668	3.046	3.424	3.802	4.181

Probabilistic Analysis

Table 1 presents the detailed statistical data of the input parameters used in the stability analysis of the gravity retaining wall. It is important to note that the coefficients of variation (COV) listed in Table 1 are assumed values, adopted in the absence of site-specific data, in accordance with the recommendations of (Duncan, 2000; Schneider, 1997). Moreover, the probability distributions of the random variables were selected based on previous studies, such as those proposed by (Harr, 1987; Kulhawy, 1993) to reflect realistic conditions commonly encountered in geotechnical practice. In the framework of the probabilistic analysis of the retaining wall, the performance functions, denoted as $G_i(x)$, are defined by:

$$G_i(x) = (FS)_i - 1 \tag{5}$$

Where i refers to the different potential failure modes.

Failure occurs when $G_i(x) < 0$.

The probability of failure (P_f) for each failure mode and for each soil parameter under study is computed using the Monte Carlo simulation method. This approach involves generating a large set of random data points ($n = 10^5$) for each random variable using MATLAB. The failure probability P_f is then determined as the percentage of simulations that do not satisfy the limit equilibrium condition, that is, when $G_i(x) < 0$. This study adopts a systematic approach to analyze the specific influence of each soil parameter on a given failure mode. Such an approach makes it possible to identify the most influential parameters and to better understand their impact on the stability of gravity retaining walls.

Sliding Failure Mode

In assessing the stability of retaining walls against sliding failure, it is essential to examine the influence of each geotechnical parameter on the associated probability of failure. This process involves a systematic analysis of the individual effects of each parameter while accounting for the inherent uncertainties in soil properties. Such an approach makes it possible to identify the parameters that have the most significant impact on the likelihood of wall sliding.

The analysis is based on the principles of structural reliability (Duncan, 2000) and rooted in soil mechanics fundamentals to evaluate the associated risks. For instance, variations in soil cohesion, internal friction angle, or unit weight can have different effects on sliding stability. As demonstrated by (Phoon & Kulhawy, 1999) it is crucial to rigorously quantify the uncertainties associated with geotechnical parameters to obtain an accurate estimation of the probability of failure. This quantification not only enhances understanding of the individual contributions of each parameter but also provides a foundation for developing more effective risk management strategies.

Influence of the Internal Friction Angle of the Backfill Soil (φ_1)

To evaluate the impact of the spatial variability of soil properties, particularly that of the internal friction angle of the backfill soil φ_1, a Monte Carlo simulation was conducted. In this study, all parameters of both the backfill and foundation soils were kept constant, except for the internal friction angle φ_1, which is the focus of the analysis. This parameter is considered as a random variable following the statistical distribution defined in Table 1. To highlight the influence of this variability on the probability of failure, the effect of changing the coefficient of variation (COV) of φ_1 on the results is examined. The coefficient variation is incrementally adjusted by 2%, ranging from 5% to 15%. This approach allows for assessing how fluctuations in φ_1 affect the sliding stability of the retaining wall.

For comparison purposes, the different failure probabilities obtained for each COV value of φ_1 are analyzed at a fixed safety factor, which serves as a reference for the sliding stability evaluation. This methodology not only identifies critical variability thresholds that increase the risk of failure but also provides a clearer understanding of the structure's sensitivity to variations in φ_1.

Table 3. Sliding failure probability for different calculation series as a function of COV (φ_1)

COV (φ_1)	Sliding safety factor $(FS)_{sli}$							
	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
5%	6.97E-04	0	0	0	0	0	0	0
7%	1.14E-02	2.67E-06	0	0	0	0	0	0
9%	4.02E-02	2.62E-04	3.33E-07	0	0	0	0	0
11%	7.86E-02	2.32E-03	1.23E-05	0	0	0	0	0
13%	1.19E-01	8.73E-03	1.79E-04	6.67E-07	0	0	0	0
15%	1.57E-01	2.04E-02	1.02E-03	1.57E-05	0	0	0	0

We graphically present the failure probability curves as a function of the coefficient of variation of the backfill internal friction angle φ_1. For each calculation series, a specific safety factor is assigned, and the resulting curves illustrate how the probability of failure evolves in response to fluctuations in this critical parameter. These representations enable a direct comparison of the influence of φ_1 variability on the sliding stability of the retaining wall, while accounting for the different safety scenarios considered. Table 3, which presents the sliding failure probabilities as a function of the coefficient of variation of the backfill soil's internal friction angle, together with the curves shown in Figure 2, clearly demonstrate the significant influence of this parameter's variability.

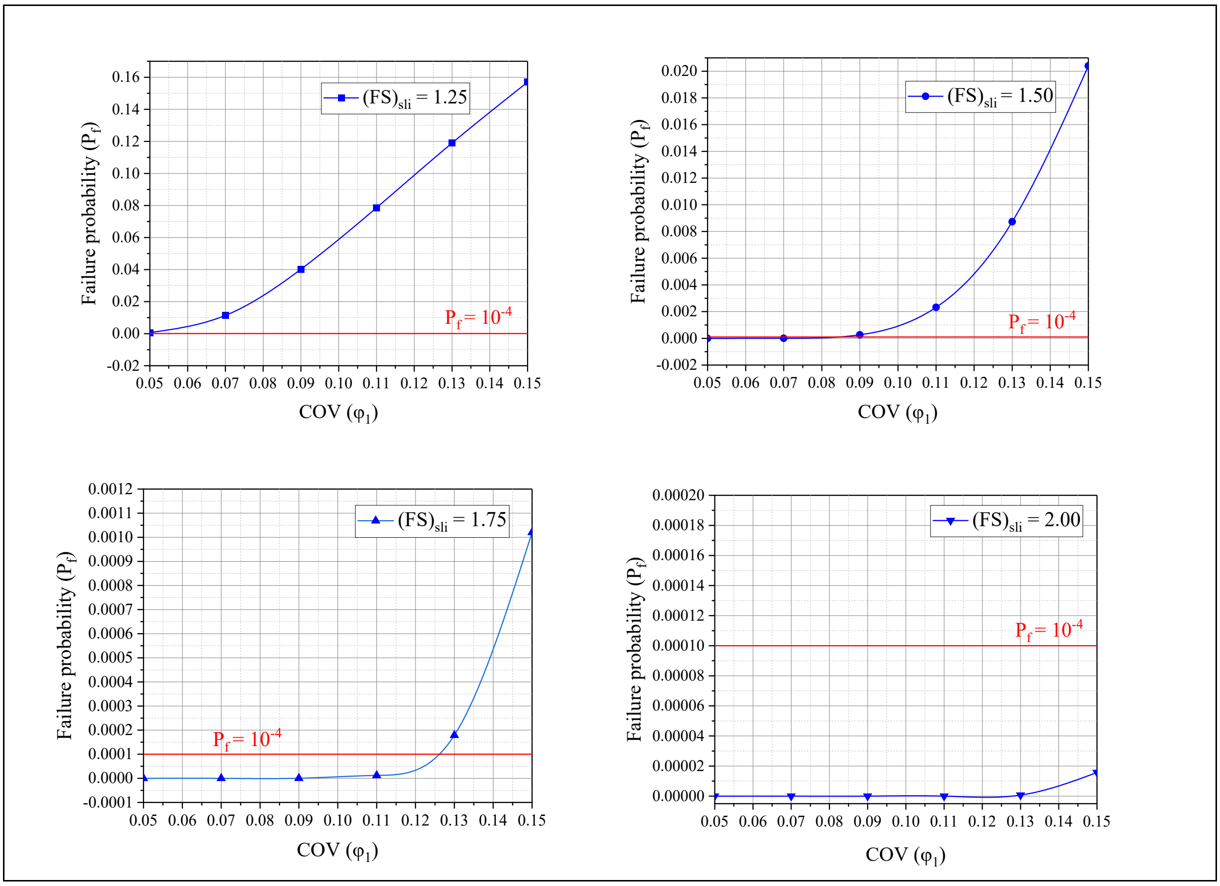

Figure 2. Failure probability as a function of COV (φ_1) for different sliding safety factors

When a deterministic sliding safety factor $(FS)_{sli}$ of 1.5 is applied, in accordance with standard recommendations, the resulting sliding failure probabilities consistently exceed the target failure probability, typically set at 10^{-4}. This finding highlights the necessity of adopting a safety factor of around 2 in deterministic analyses to ensure adequate stability of gravity retaining walls against sliding. Such caution becomes particularly important when the backfill soil exhibits an internal friction angle with a coefficient of variation greater than 9%.

Influence of the Backfill Soil Unit Weight (γ_1)

To assess the effect of spatial variability in soil properties, particularly the unit weight of the backfill soil (γ_1), a Monte Carlo simulation was performed. In this analysis, all parameters of both the backfill and foundation soils are kept constant, except for the backfill unit weight γ_1, which is treated as a random variable following a statistical distribution as presented in Table 1. To highlight the influence of the backfill unit weight on the failure probability, the variation of the coefficient of variation (COV) of γ_1 is examined. The COV is increased in increments of 1%, ranging from 5% to 10%. This approach makes it possible to explore how the variability of γ_1 affects the overall stability of the retaining wall. For comparison purposes, a specific sliding safety factor is assigned to each calculation series. This factor serves as a reference for the stability analysis, allowing for the assessment of the relative impact of γ_1 variability on the failure risk. This methodology provides valuable insight into the critical variability thresholds that may compromise the structural safety of the wall.

Table 4. Sliding failure probability for different calculation series as a function of COV (γ_1)

COV (γ_1)	Sliding safety factor $(FS)_{sli}$							
	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
5%	0	0	0	0	0	0	0	0
6%	1.00E-06	0	0	0	0	0	0	0
7%	2.50E-05	0	0	0	0	0	0	0
8%	2.21E-04	0	0	0	0	0	0	0
9%	8.67E-04	0	0	0	0	0	0	0
10%	2.42E-03	0	0	0	0	0	0	0

We plotted the curves illustrating the failure probabilities as a function of the coefficient of variation of the backfill unit weight (γ_1) for each safety factor defined in the different calculation series. These curves clearly depict the direct influence of γ_1 variability on the sliding stability of the retaining wall. By comparing the failure probabilities corresponding to the various safety factors, this graphical representation highlights the critical variability thresholds beyond which the risk of failure becomes significant. This approach provides a deeper understanding of the structure's sensitivity to unit weight variability, thereby helping to refine design criteria and improve risk management.

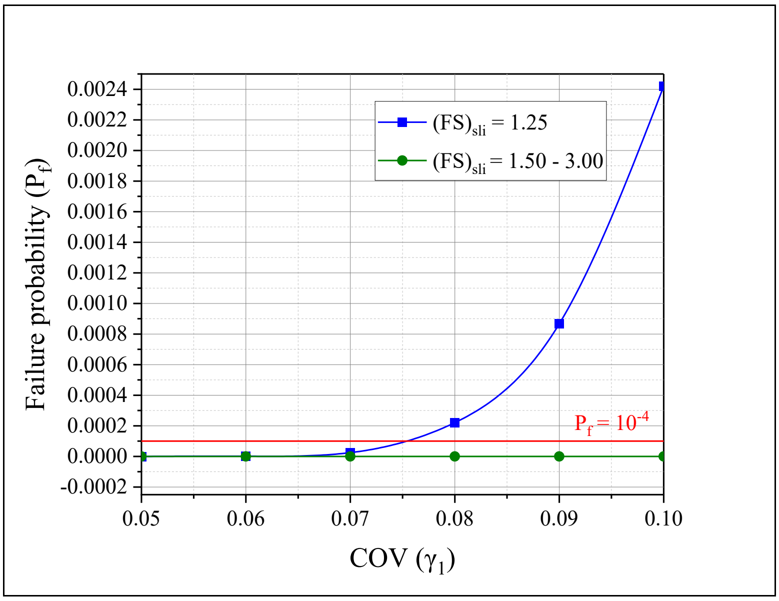

Figure 3. Failure probability as a function of COV (γ_1) for different sliding safety factors

Table 4, which presents the sliding failure probabilities as a function of the variation in the coefficient of variation of the backfill unit weight (γ_1), together with the curves illustrated in Figure 3, clearly indicates that this parameter has a negligible influence. The results show that, regardless of the value of the coefficient of variation of γ_1, the failure probabilities remain almost zero, particularly when the safety factor is equal to or greater than 1.5. Therefore, no specific recommendation is required regarding the choice of the sliding safety factor, as the variability of the backfill unit weight γ_1 has no significant effect on the failure probabilities. This stability, observed for all considered levels of variability, suggests that other parameters, such as cohesion or internal friction angle, are more critical in assessing sliding stability. Consequently, the variability of the unit weight γ_1 can be considered less influential under the studied conditions.

Influence of the Internal Friction Angle of the Foundation Soil (φ_2)

To evaluate the effect of spatial variability in soil properties, specifically the internal friction angle of the foundation soil (φ_2), a Monte Carlo simulation was carried out. In this analysis, all parameters of both the backfill and foundation soils are kept constant, except for the internal friction angle of the foundation soil φ_2, which is the focus of this study. This parameter is treated as a random variable following the statistical distribution described in Table 1. To highlight the influence of φ_2 on the failure probability, the coefficient of variation of this parameter is varied incrementally by 2% within a range of 5% to 15%. This approach makes it possible to explore the impact of different levels of variability on the sliding stability of the retaining wall. For each series of calculations, a specific safety factor is fixed to serve as a reference for the stability analysis. This enables a direct comparison of the resulting failure probabilities and helps determine how the variability of φ_2 affects the likelihood of sliding failure. This systematic approach allows for the identification of critical variability thresholds and provides valuable insight into the sensitivity of the structure to this parameter, contributing to a more reliable and secure design.

Table 5. Sliding failure probability for different calculation series as a function COV (φ_2)

COV (φ_2)	Sliding safety factor $(FS)_{sli}$							
	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
5%	0	0	0	0	0	0	0	0
7%	0	0	0	0	0	0	0	0
9%	0	0	0	0	0	0	0	0
11%	4.33E-06	0	0	0	0	0	0	0
13%	6.10E-05	0	0	0	0	0	0	0
15%	4.50E-04	0	0	0	0	0	0	0

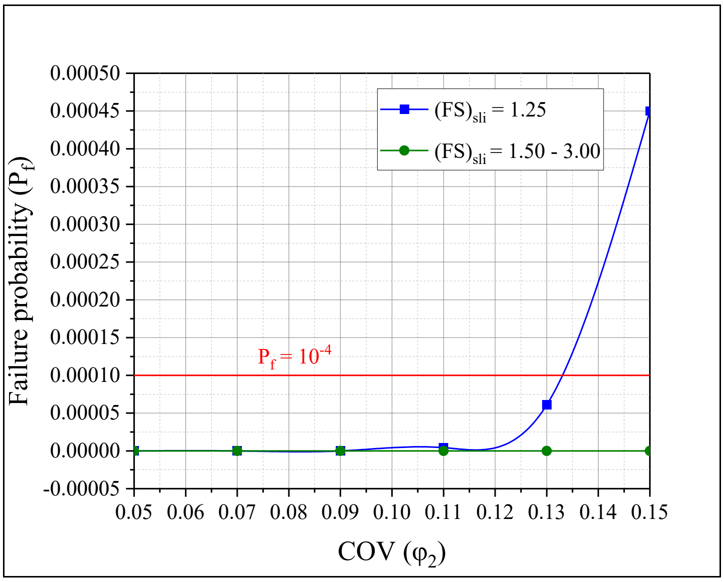

Figure 4. Failure probability as a function of COV (φ_2) for different sliding safety factors

We plotted curves showing the evolution of failure probabilities as a function of the coefficient of variation of the foundation soil internal friction angle (φ_2) for each safety factor defined in the different calculation series. These graphs provide a visual assessment of how φ_2 variability influences the sliding stability of the retaining wall. By comparing the curves corresponding to each safety factor, it becomes possible to identify general trends and determine how fluctuations in φ_2 affect the likelihood of failure. This graphical representation serves as a valuable tool for understanding the structure's sensitivity to φ_2 variability, thereby supporting the development of more robust design strategies that account for the inherent uncertainties in soil properties.

Table 5 and the curves shown in Figure 4, which present the sliding failure probabilities as a function of the coefficient of variation of the foundation soil internal friction angle (φ_2), demonstrate that variations in this parameter have a minimal influence. The results indicate that, regardless of the value of the coefficient of variation of φ_2, the failure probabilities remain nearly zero, particularly when the sliding safety factor is set to 1.5 or higher. Therefore, it is not necessary to adjust the sliding safety factor based on the variability of φ_2, as this parameter does not significantly affect the probability of failure. This finding suggests that other parameters, such as cohesion, may play a more decisive role in assessing sliding stability. Consequently, the influence of the internal friction angle φ_2 can be considered secondary under the specific conditions examined.

Influence of Foundation Soil Cohesion (c_2)

To evaluate the impact of the spatial variability of soil properties, specifically, the influence of the foundation soil cohesion (c_2), a series of Monte Carlo simulations was carried out. In this analysis, all parameters of the backfill and foundation soils are kept constant, except for c_2, which is treated as the variable of interest. The cohesion c_2 is considered a random variable whose statistical distribution is presented in Table 1. To highlight the influence of foundation soil cohesion on failure probability, the coefficient of variation of c_2 is varied in increments of 5% within the range of [30% - 50%]. This range allows for a detailed assessment of how cohesion variability affects the sliding stability of the retaining wall.

The main objective of this study is to compare the failure probabilities associated with different values of the coefficient of variation of c_2. For each simulation series, the safety factor used to assess sliding stability is kept constant. This approach isolates the specific influence of the studied parameter and provides a clearer understanding of its role in determining the sliding failure probability of the retaining wall.

Table 6. Sliding failure probability for different calculation series as a function COV (c_2)

COV (c_2)	Sliding safety factor $(FS)_{sli}$							
	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
30%	5.85E-02	5.27E-04	0	0	0	0	0	0
35%	9.41E-02	2.54E-03	6.67E-06	0	0	0	0	0
40%	1.33E-01	7.55E-03	3.67E-05	0	0	0	0	0
45%	1.69E-01	1.66E-02	2.70E-04	0	0	0	0	0
50%	2.04E-01	2.89E-02	9.63E-04	0	0	0	0	0

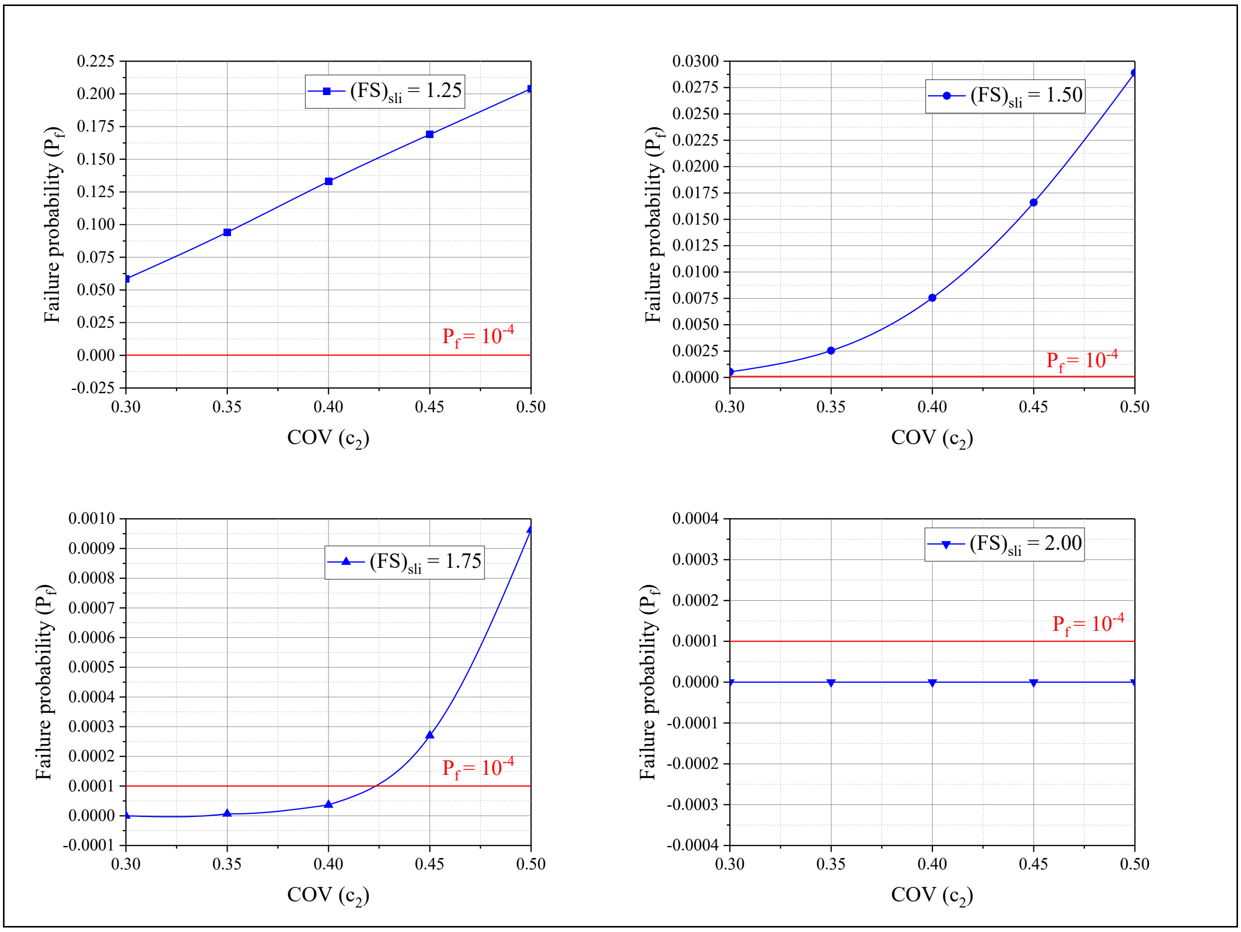

Figure 5. Failure probability as a function of COV (c_2) for different sliding safety factors

We plotted the failure probability curves as a function of the variations in the coefficient of variation of c_2 for each predefined safety factor value. For each simulation series, the resulting curves clearly illustrate the impact of fluctuations in c_2 on the sliding stability of the retaining wall. These curves are essential for understanding how the variability of foundation soil cohesion influences the probability of failure while considering different safety levels.

The results presented in Table 6, which detail the sliding failure probabilities as a function of the coefficient of variation of the foundation soil cohesion (c_2), along with the curves shown in Figure 5, clearly highlight the significant impact of this parameter's variability. When a deterministic sliding safety factor $(FS)_{sli}$ of 1.5 is applied, consistent with standard recommendations, the computed sliding failure probabilities consistently exceed the target failure probability, generally set at 10^{-4}. This finding emphasizes the need to adopt a safety factor of around 2 in deterministic analyses to ensure adequate stability of gravity retaining walls against sliding failure.

Conclusion

This study focused on assessing the vulnerability of gravity retaining walls by accounting for the spatial variability of soil properties. Unlike a purely deterministic approach, the adopted methodology explicitly integrates geotechnical uncertainty, allowing for a broader exploration of possible behavior scenarios. In this context, the rigorous definition of limit states for each potential failure mode is a key step in evaluating the reliability of the structure. The analysis concentrated on the sliding failure mode at the base, corresponding to a horizontal displacement of the wall under the effect of applied loads. A specific analysis strategy was developed, based on the separate variation of the coefficients of variation of the main soil parameters, to determine their influence on the failure probability for each safety factor, using Monte Carlo simulations.

The main conclusions derived from this study can be summarized as follows:

Influence of the internal friction angle of the backfill (φ_1): Its variability has a significant effect on the probability of sliding failure. For a deterministic safety factor $(FS)_{sli}$ = 1.5, as commonly recommended by standards, the computed failure probabilities consistently exceed the target probability of 10-4. This finding suggests that a higher safety factor, close to 2, is required to ensure an acceptable level of reliability.

Influence of the unit weight of the backfill (γ_1): The effect of its variability on sliding failure is negligible. Regardless of the coefficient of variation, the failure probabilities remain nearly zero for $(FS)_{sli} \geq 1.5$. Hence, this parameter is less critical under the studied conditions.

Influence of the internal friction angle of the foundation soil (φ_2): The variability of this parameter has a minimal impact on the sliding mode. The failure probabilities remain insignificant, particularly for $(FS)_{sli} \geq 1.5$, indicating that φ_2 plays a secondary role in the present analysis.

Influence of the cohesion of the foundation soil (c_2): The variability of this parameter has a major influence on the sliding stability. For a safety factor of 1.5, the failure probabilities systematically exceed the target value of 10^{-4}. Therefore, a safety factor of about 2 is recommended to ensure the stability of the retaining wall against sliding.

These results clearly demonstrate that ignoring the spatial variability of soil properties can lead to a significant underestimation of failure risks, making traditional deterministic design potentially insufficient to guarantee long-term stability. It is therefore essential to reassess conventional safety criteria by incorporating the effects of geotechnical variability within a structural reliability framework. Such an approach is crucial to ensure that retaining walls are designed to withstand inherent geotechnical uncertainties, thereby improving their performance, robustness, and durability.

Recommendations

The findings of this study demonstrate that the spatial variability of soil properties, particularly the cohesion of the foundation soil and the internal friction angle of the backfill, plays a decisive role in the sliding stability of gravity retaining walls. Based on the probabilistic analyses conducted, the following recommendations can be made:

1. Adoption of reliability-based design: Deterministic design methods relying solely on safety factors should be complemented by probabilistic approaches to better account for geotechnical uncertainties.
2. Revision of conventional safety factors: A deterministic sliding safety factor $(FS)_{sli}$ of 1.5 may be insufficient to ensure the required level of reliability. It is therefore recommended to adopt a minimum safety factor of 2.0 for design purposes, particularly when the foundation soil exhibits significant variability in cohesion.
3. Characterization of soil variability: Site investigations should include statistical characterization of key geotechnical parameters, including cohesion and internal friction angle, to provide reliable input data for probabilistic analyses.
4. Integration of uncertainty in design standards: Future design codes should explicitly incorporate spatial variability effects and reliability-based concepts to improve the accuracy and safety of geotechnical structures.

By applying these recommendations, engineers can achieve safer, more resilient, and economically optimized designs for retaining structures under uncertain ground conditions.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

Funding

* This research received no external funding. The study was carried out as part of the authors' academic work within the Department of Civil Engineering, Mouloud Mammeri University of Tizi-Ouzou, Algeria.

Acknowledgements or Notes

* This article was presented as a poster presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Türkiye on November 12-15, 2025.

* The authors would like to express their sincere gratitude to the Department of Civil Engineering, Mouloud Mammeri University of Tizi-Ouzou, for providing the academic environment and resources necessary to conduct this study. Special thanks are also extended to colleagues and students who contributed to discussions and provided valuable feedback during the development of this research.

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To cite this article:

Baziz, K., & Kahil, A. (2025). Factors affecting the sliding stability of a gravity retaining wall. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 38,* 433-443.