Assessment of Geotechnical Parameter Uncertainty Using Probabilistic Methods in Slope Stability Analysis

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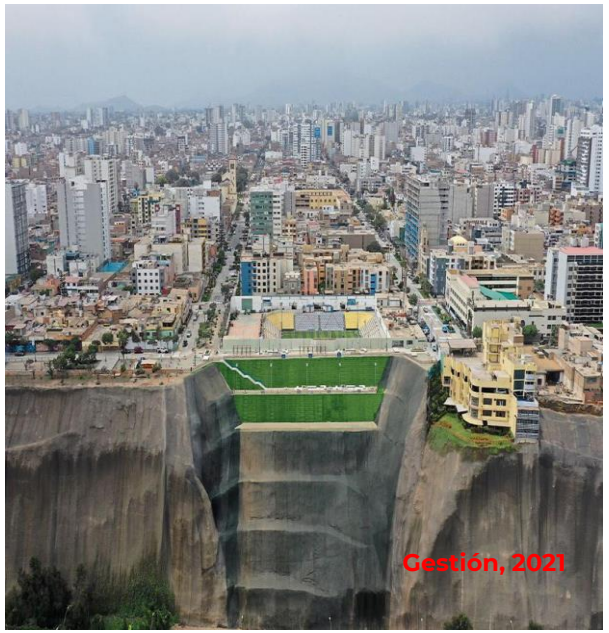
Introduction & Background

1. Geodynamics and climate change :

2. Infrastructure



3. Risk management

More than 400 destructive events per year (Economist, 2017)

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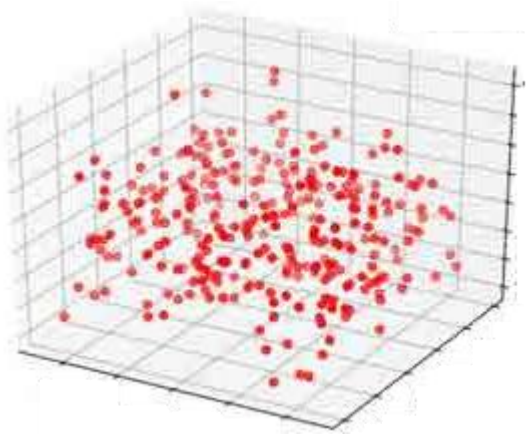
Aim, Objectives, and Scope

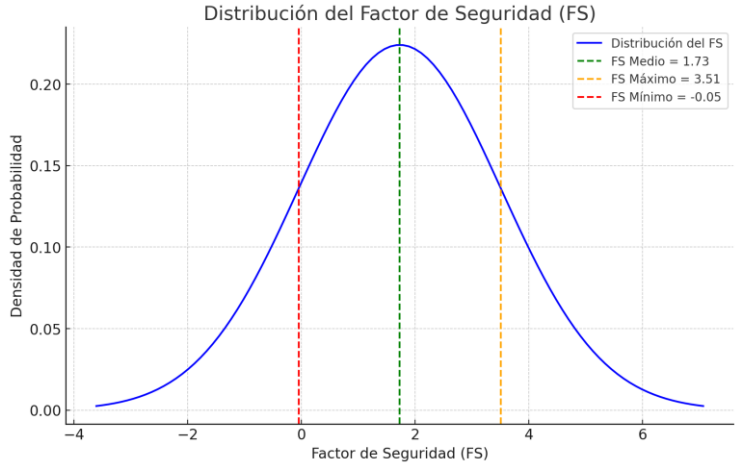
- Evaluate the uncertainty of geotechnical parameters using probabilistic methods in slope stability analysis,
- To define the geometry and characterize the geotechnical properties and boundary conditions of the synthetic slope models proposed for stability analyses based on a reference case from the literature.
- Determine the reliability and probability of failure of synthetic slopes by applying the probabilistic methods of Latin Hypercube and First Order - Second Moment, and compare them with deterministic evaluation methods.

Research Design and Methodology

1. Latin Hypercube Sampling (LHS)



2. First order second moment method (FOSM)



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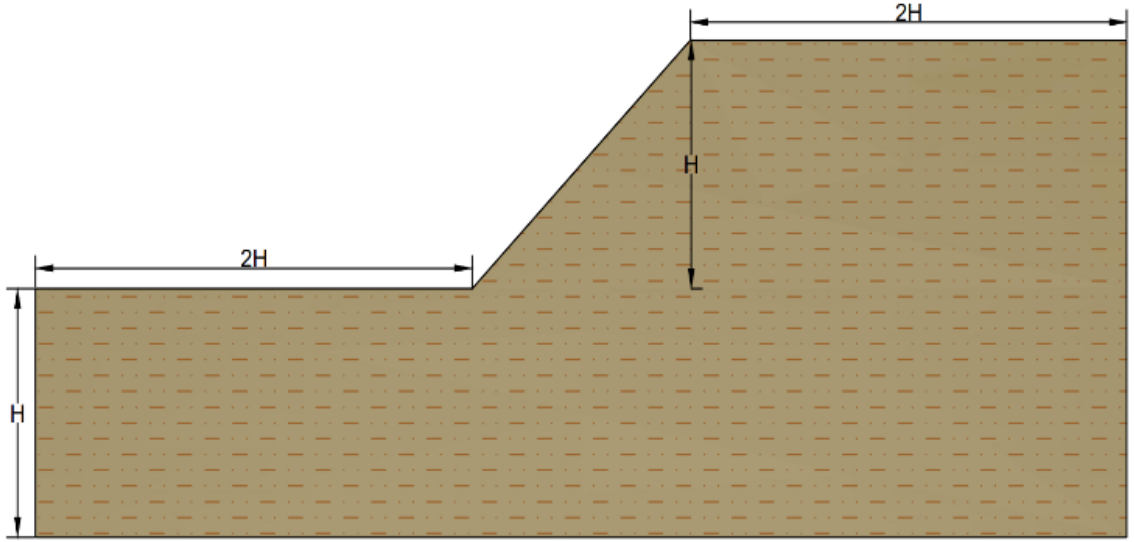
Research Design and Methodology

Table 2. Summary of data for this study

Parameters		Units	Values
Geometrics	Height (h)	m	10, 20, 30
	Slope (H:V)	-	1, 1.5, 2
Geotechnical	Cohesion (c)	kN/m^2	18 (CV=20.0%)
	Specific weight (γ)	kN/m^3	18 (CV=3.00%)
	Friction angle (ϕ)	°	30 (CV=3.70%)



Results (1)

Casos	Incertidumbre	Condición estática				Condición pseudoestática			
		Spencer		M-P		Spencer		M-P	
		FSd	FSm	FSd	FSm	FSd	FSm	FSd	FSm
1A	$CV_{mín}$	2.364	2.365	2.363	2.365	1.480	1.481	1.483	1.480
	$CV_{máx}$	2.364	2.375	2.363	2.374	1.480	1.488	1.483	1.487
1B	$CV_{mín}$	1.608	1.604	1.602	1.602	1.151	1.152	1.145	1.151
	$CV_{máx}$	1.608	1.610	1.602	1.609	1.151	1.152	1.145	1.156
1C	$CV_{mín}$	1.189	1.126	1.192	1.107	0.965	1.051	0.909	0.875
	$CV_{máx}$	1.189	1.080	1.192	1.051	0.965	1.113	0.909	0.739
2A	$CV_{mín}$	1.894	1.893	1.892	1.894	1.178	1.178	1.179	1.181
	$CV_{máx}$	1.894	1.901	1.892	1.901	1.178	1.185	1.179	1.185
2B	$CV_{mín}$	1.214	1.211	1.210	1.210	0.849	0.856	0.849	0.854
	$CV_{máx}$	1.214	1.216	1.210	1.215	0.849	0.857	0.849	0.858
2C	$CV_{mín}$	0.849	0.863	0.850	0.855	0.673	0.638	0.629	0.599
	$CV_{máx}$	0.849	0.847	0.850	0.853	0.673	0.620	0.629	0.581

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Results (2)

Casos	Incertidumbre	Condición pseudoestática							
		Spencer				M-P			
		FSd	FSm	Pf (%)	RI-n	FSd	FSm	Pf (%)	RI-n
1A	$CV_{mín}$	1.480	1.481	0.000	4.009	1.483	1.480	0.000	3.990
	$CV_{máx}$	1.480	1.488	1.120	2.184	1.483	1.487	1.190	2.178
1B	$CV_{mín}$	1.151	1.152	7.720	1.420	1.145	1.151	8.740	1.356
	$CV_{máx}$	1.151	1.152	20.97	0.803	1.145	1.156	21.49	0.780
1C	$CV_{mín}$	0.965	1.051	32.61	0.561	0.909	0.875	98.05	-1.23
	$CV_{máx}$	0.965	1.113	26.12	0.666	0.909	0.739	88.06	-1.03
2A	$CV_{mín}$	1.178	1.178	0.720	2.350	1.179	1.181	0.700	2.386
	$CV_{máx}$	1.178	1.185	11.78	1.204	1.179	1.185	11.70	1.206
2B	$CV_{mín}$	0.849	0.856	98.06	-2.11	0.849	0.854	97.64	-2.04
	$CV_{máx}$	0.849	0.857	86.60	-1.11	0.849	0.858	85.87	-1.07
2C	$CV_{mín}$	0.673	0.638	100.0	-9.28	0.629	0.599	100.0	-9.12
	$CV_{máx}$	0.673	0.620	100.0	-4.56	0.629	0.581	100.0	-4.78

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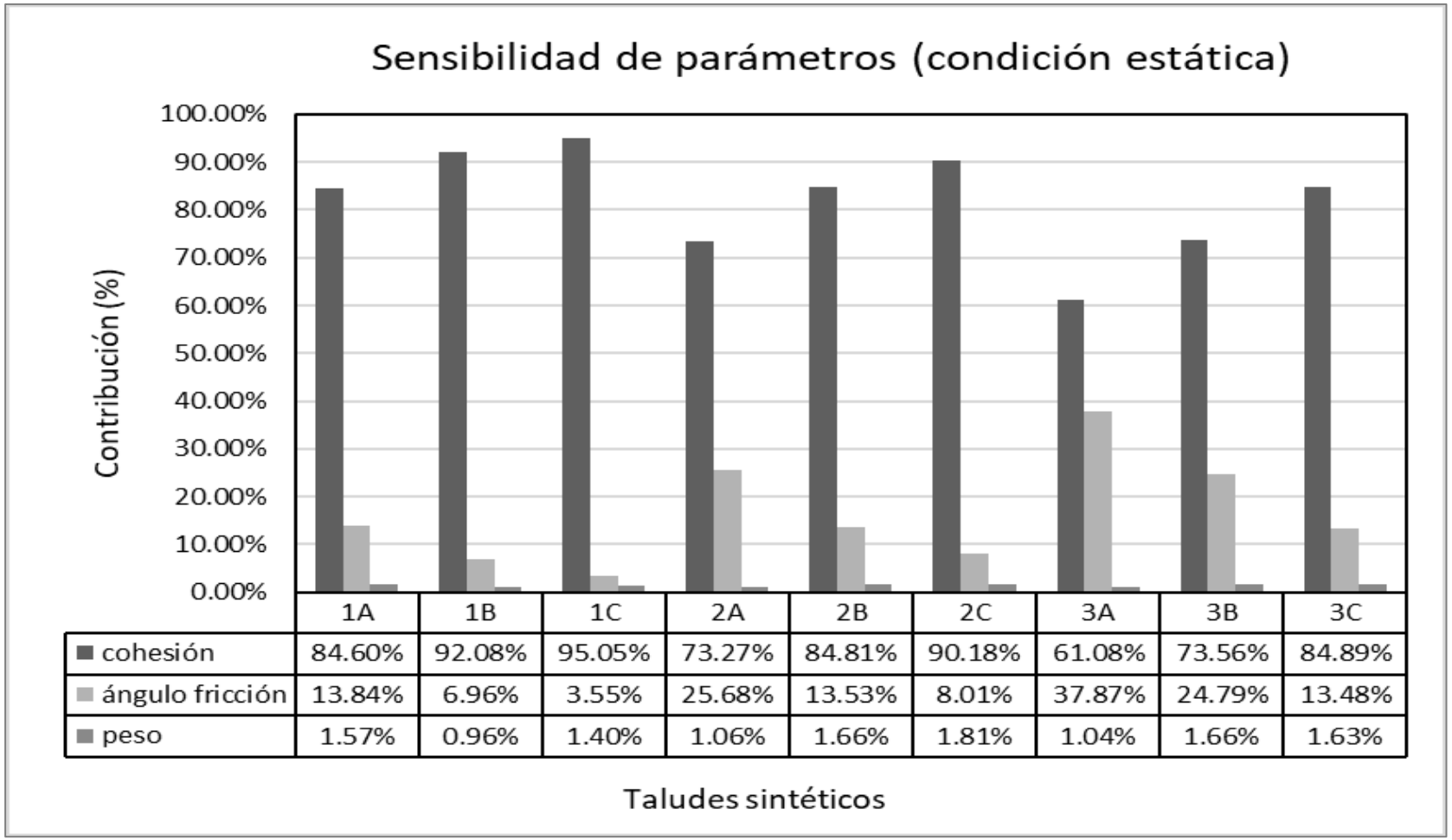
Results (3)



	1A	1B	1C	2A	2B	2C	3A	3B	3C
cohesión	84.60%	92.08%	95.05%	73.27%	84.81%	90.18%	61.08%	73.56%	84.89%
ángulo fricción	13.84%	6.96%	3.55%	25.68%	13.53%	8.01%	37.87%	24.79%	13.48%
peso	1.57%	0.96%	1.40%	1.06%	1.66%	1.81%	1.04%	1.66%	1.63%

Discussions, Conclusions & Recommendations (1)

- No significant differences are observed between the deterministic and probabilistic FS. It is impossible to detect the effect of uncertainty if the information provided by the probabilistic approach is ignored.

- The results of the slope analysis allowed us to identify cases where the stability criteria are verified, but not those of reliability. That is to say, although in these cases the slope is stable, it is not reliable.

Discussions, Conclusions & Recommendations (2)

- The parameters with the greatest influence on stability are cohesion, friction angle and soil weight, in that order of importance, although this may be altered in scenarios of maximum uncertainty and/or seismic activity.

- Reliability analyses in slope assessment do not guarantee that the designs proposed based on the results will never fail, but they do provide a broader overview for future decision-making.