Proceedings of the 11th ICPMG 2026
11th International Conference on Physical Modelling in Geotechnics
8-12 June 2026, Zurich, Switzerland

Assessment of topographic amplification factor for slopes by centrifuge tests

Moon-Gyo Lee, Chang-Guk Sun
Korea Institute of Geoscience and Mineral Resources, Daejeon, Republic of Korea,
mglee@kigam.re.kr, pungsun@kigam.re.kr

ABSTRACT: Topographic irregularities such as slopes and ridges significantly influence seismic ground motions by altering their amplitude and frequency characteristics. However, the conventional approach of defining a single-valued topographic amplification factor often fails to capture the period-dependent nature of these effects. In this study, a series of dynamic centrifuge tests were conducted to investigate the variation of seismic amplification on slopes with different inclinations. Two single-sided slope models with varying slope angles were prepared using dry silica sand, and both sine-sweep and spectrally matched earthquake motion were applied at 60 g centrifugal acceleration. Accelerations were measured at the slope crest and the adjacent free field to evaluate topographic effects on seismic response. The results revealed that amplification at the slope crest was strongly period-dependent, with distinct peaks associated with slope geometry, while the effect of slope inclination was relatively minor. These findings highlight the limitations of simplified amplification assumptions and emphasize the importance of considering period-dependent behavior in seismic design for topographically complex regions.

1 INTRODUCTION

Topographic irregularities can markedly reshape earthquake ground motions, yet their routine incorporation in seismic design remains limited because reported amplification levels vary widely and isolating pure topographic effects is difficult in both numerical simulations and field records (Lee et al., 2025). Consequently, the few provisions that address topography often adopt simplified, geometry-based period-independent amplification factors applied uniformly over the response spectrum; representative formulations in Eurocode 8 and the French AFPS guidance are summarized in Table 1.

However, crest amplification is increasingly recognized to be period-dependent rather than well represented by a single constant; accordingly, characteristic periods have been introduced to interpret topography–soil interaction, including the topographic period T_f proposed by Ashford et al. (1997) and the site (soil-column) period T_n, defined as:

$$T_f = 5H/V_s \tag{1}$$

$$T_n = 4Z/V_s \tag{2}$$

where V_s is the average shear-wave velocity of the soil, H is the slope height, and Z is the soil thickness.

In this study, dynamic centrifuge tests are employed to evaluate crest-to-free-field amplification over the full period range and to examine how slope inclination—one of the primary parameters adopted in current code frameworks—affects period-dependent topographic amplification relative to the T_f and T_n bands.

2 CENTRIFUGE TESTING PROGRAM

Dynamic centrifuge tests were conducted at 60 g on two single-sided dry-sand slope models with identical H and Z but different inclinations (i = 33.7° and 25°; Figure 1).

Table 1. Topographic amplification factor definitions provided in seismic codes (modified from Lee et al. (2025)).

Reference	Slope height	Slope inclination	Topographic amplification factor
Eurocode 8	$H \geq 30$ m	$i \geq 15°$	$S_T = 1.0$ ($i < 15°$) $S_T \geq 1.2$ ($i \geq 15°$)
AFPS	$H \geq 10$ m	$i > 21.8°$	$S_T = 1.0$ ($i \leq 21.8°$) $S_T = 1 + 0.8 \cdot (\tan i - 0.4)$ ($i > 21.8°$) $S_T = 1.4$ ($i > 42°$)

The models were prepared using dry, poorly graded silica sand (D_{50} = 0.16 mm; C_u = 2.82, C_c = 1.04; e_{min} = 0.660, e_{max} = 1.004) placed by pluviation. Accelerometers were installed at the crest, adjacent free field, and base to evaluate crest-to-free-field amplification and define the input motion. Multiple bender-element pairs were embedded to measure V_S for evaluating the characteristic periods T_f and T_n.

The input motions comprised a sine-sweep and a spectrally matched earthquake motion based on the 2016 Gyeongju record (Figure 2), facilitating future work on improving seismic design provisions for topographic effects (Lee et al., 2025).

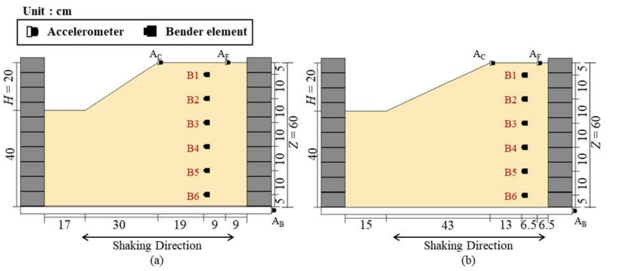

Figure 1. Schematic illustration of centrifuge test models in model scale: (a) Case 1 and (b) Case 2. (model scale)

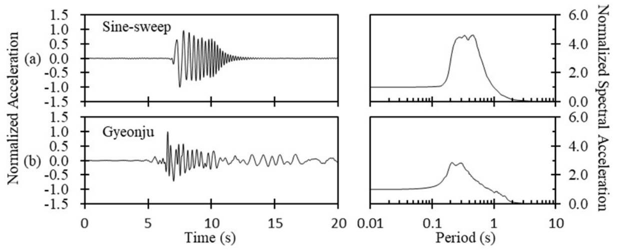

Figure 2. Normalized acceleration time histories and response spectra of input motions.

3 RESULTS

Figure 3 compares the crest-to-free-field response-spectrum ratio, $RRS_{C\text{-}F} = RS_{A_C}/RS_{A_F}$, for Case 1($i$=33.7 ◦) and Case 2($i$=25 ◦), where A_C and A_F denote the crest and adjacent free field accelerometers (Figure 1).

Both cases show the same overall, period-dependent trend reported in prior centrifuge studies (Dafni and Wartman, 2021; Lee et al., 2025)—contrary to the conventional assumption of uniform topographic amplification factors applied over the entire spectrum—with $RRS_{C\text{-}F}$ slightly elevated in the short-period range, developing a pronounced peak around T_f, and then decays to approximately unity before T_n and remains near unity thereafter.

In this context, the two inclination cases display highly similar spectral shapes and amplification levels, with only minor local differences, suggesting that—under the tested geometry (H, Z) and input motions—the inclination effect is secondary to the resonance-controlled response, which merits further evaluation when applying single-valued inclination-based factors in design.

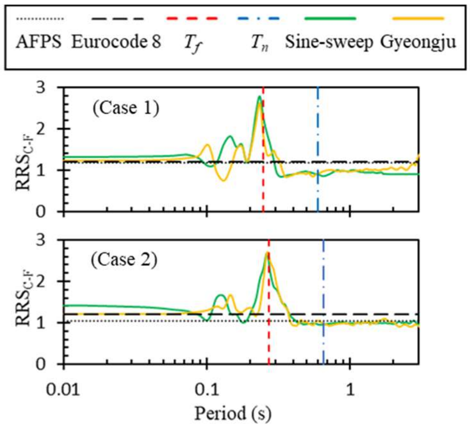

Figure 3. $RRS_{C\text{-}F}$ values during broadband motions, T_f and T_n, and corresponding topographic amplification factor values in each seismic code.

4 CONCLUSIONS

Centrifuge tests on two single-sided dry-sand slopes show that crest amplification relative to the adjacent free field is strongly period-dependent, peaking near T_f and approaching unity beyond T_n. The two cases yield similar spectra, indicating a minor inclination effect relative to resonance-controlled behavior. These results suggest that single-valued inclination-based topographic factors warrant refinement.

ACKNOWLEDGEMENTS

This research was supported by the Basic Research Project of Korea Institute of Geoscience and Mineral Resources (KIGAM).

REFERENCES

Ashford, S. A. and Sitar, N. (1997). Analysis of topographic amplification of inclined shear waves in a steep coastal bluff. *Bulletin of the seismological society of America*, 87(3): 692-700.

Dafni, J. and Wartman, J. (2021). Centrifuge studies of topographic effects: Parametric investigation. *Bulletin of the Seismological Society of America*, 111(4): 2087-2100.

Lee, M. G., Sun, C. G., Kim, H. S., Choo, Y. W. and Cho, H. I. (2025). Experimental study on site and topographic effects on seismic responses in single-sided slopes. *Engineering Geology*, 345: 107868.