PROJECT REVIEW:

Effect of Vertical Shaking on the Displacement of Earth Retaining Structures

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Research funded by the Earthquake Commission (EQC) was carried out to assess the effect of vertical ground motions on the seismic displacement performance of retaining walls. In near-fault areas, vertical shaking can be significant. The research included a literature review and numerical analyses of a Reinforced Earth wall. The model analyses were carried out for a wall with an aspect ratio (the ratio of reinforcement length to height of wall) of one. Four different near-fault earthquake time histories from California were used in the analyses and were modified to vary the intensity of earthquake shaking. The study was effective in assessing the displacement performance of walls and the parameters that have a significant influence on wall displacement behaviour when there is significant vertical ground shaking.

The effects of vertical earthquake shaking have not been seriously considered until recently. Recent papers highlight the importance of vertical shaking to the assessment and design of retaining walls. These recent studies have involved pseudo-static analyses. No model studies, either physical or numerical, have been carried out to verify the effects of vertical shaking or to assess parameters that might be important.

The authors' project was the first model study of the influence of vertical shaking on seismic displacement and was carried out using the finite-difference numerical program FLAC, incorporating both vertical and horizontal shaking.

The analyses confirmed the vulnerability of the upper strips to pullout during earthquake shaking, a factor that has long been recognised in the practical design of reinforced earth structures.

Calculated outward displacement of this robust wall was less than 25 mm for a modest energy of shaking associated with the four earthquakes chosen, and up to 200 mm for more intense shaking, both horizontal and vertical. The maximum calculated displacement (other than at the top where reinforcement pullout occurred) with horizontal shaking alone was only 23 mm.

The study showed that peak ground acceleration was a poor predictor of seismic displacement. The sum of the power spectral density , which reflects the earthquake energy content, was found to better relate to the displacements in these different earthquakes.

Vertical shaking had a significant effect on the displacement of the wall. The calculated displacements varied significantly depending on the earthquake input, with vertical shaking than with horizontal shaking alone. The magnitude of the displacements was found to depend on both the energy content of horizontal and vertical earthquake shaking and the frequency content. This may be due to the relationship between the frequency content of the earthquake and the natural response frequency of the retaining structure and indicates that the frequency content of the earthquake and resonance effects can be important.

The authors postulate that the vertical shaking could modify the flexibility of the retaining wall, and hence its natural period. Where this shifts the period of the structure to a frequency similar to a frequency of ground shaking with significant energy content, resonance effects and hence greater displacements can result.

Currently design is based on pseudo-static methods using horizontal peak ground accelerations. The study shows the importance of the energy and frequency content of both horizontal and vertical shaking to the seismic displacement performance of flexible retaining structures. This is important to the design of retaining systems that support other structures, particularly in near-field areas where vertical shaking can be strong.

Further research is recommended to assess the performance of different wall systems under earthquakes with different characteristics, and to develop appropriate design parameters and methods for situations where vertical shaking is important.

References

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