Geotechnical Centrifuge Modeling To Determine Soil Liquefaction Potential

Engineering

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ABSTRACT   *Soil liquefaction describes a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid . A geotechnical centrifuge is used to test models of geotechnical problems such as The strength, stiffness and capacity of soil in the foundations for bridges and buildings, settlement of embankments, stability of slopes, earth retaining structures, tunnel stability and seawalls. Other applications include explosive crate ring, contaminant migration in ground water, frost heave and sea ice. The centrifuge may be useful for scale modeling of any large-scale nonlinear problem for which gravity is a primary driving force.*

INTRODUCTION

Geotechnical centrifuge modeling is a technique for testing physical scale models of Geotechnical Engineering systems such as natural and man-made slopes and earth retaining structures and building or bridge foundations. The scale model is typically constructed in the laboratory and then loaded onto the end of the centrifuge, which is typically between 0.2 and 10 meters (0.7 and 32.8 ft) in radius. The purpose of spinning the models on the centrifuge is to increase the g-forces on the model so that stresses in the model are equal to stresses in the prototype. For example, the stress beneath a 0.1-metre-deep (0.3 ft) layer of model soil spun at a centrifugal acceleration of 50 g produces stresses equivalent to those beneath a 5-metre-deep (16 ft) prototype layer of soil in earth's gravity.

"fig"1. 9-metre-radius (30 ft) geotechnical centrifuge at the University of California, Davis

The idea to use centrifugal acceleration to simulate increased gravitational acceleration was first proposed by Phillips (1869). Pokrovsky and Fedorov (1936) in the Soviet Union and Bucky (1931) in the United States were the first to implement the idea. Andrew N. Schofield (e.g. Schofield 1980) played a key role in modern development of centrifuge modeling.
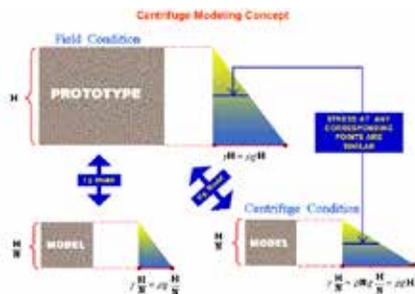
"fig"2.   Ground Centrifuge Modelling Concept

This indicates that we can prepare a model as small as possible based on the following scaling laws:

$$x^* = \frac{x_m}{x_p} \qquad (1)$$

The subscript m represents "model" and the subscript p represents "prototype" and x^* represents the scale factor for the quantity x (Garnier et al. 2007).

The reason for spinning a model on a centrifuge is to enable small scale models to feel the same effective stresses as a full scale prototype. This goal can be stated mathematically as

$$\sigma'^* = \frac{\sigma'_m}{\sigma'_p} = 1 \qquad (2)$$

Where the σ' isk * represents the scaling factor for the quantity $\partial', \partial', \sigma'_m$ is the effective stress in the model and is the effective stress in the prototype.

In soil mechanics the vertical effective stress, for example, is typically calculated by

$$\sigma' = \sigma^t - u \qquad (3)$$

Where σ^t the total is stress and u is the pore pressure. For a uniform layer with no pore pressure,

the total vertical stress at a depth may be calculated by:

$$\sigma^t = \rho g H \qquad (4)$$

Where represents the density of the layer and represents gravity. In the conventional form of centrifuge modeling (Garnier et al. 2007), it is typical that the same materials are used in the model and prototype; therefore the densities are the same in model and prototype, i.e.,

$$\rho^* = 1 \qquad (5)$$

Furthermore, in conventional centrifuge modeling all lengths are scaled by the same factor. To produce the same stress in the model as in the prototype, we thus require

$$\rho^* g^* H^* = (1) g^* L^* = 1 \qquad (6)$$

Which may be rewritten as?

$$g^* = \frac{1}{L^*} \qquad (7)$$

OBJECTIVES
General objective
- To understand the liquefaction potential of the soil using the centrifugal modelling in the area of geotechnical foundations.
- Specific objectives
- To identify the behaviour of the soil in different conditions of stress using different models
- To provide high quality geotechnical foundations for construction in order to save life and resources from damage.
- To know the centrifugal modelling using scaling methods for stress

AIMS OF THE STUDY
To understand the scaling model in different geotechnical applications.

The main purpose of this study is to understand the liquefaction potential of the soil by increasing its stress using scale model of the centrifugal acceleration.

APPLICATIONS OF THE MODEL
A geotechnical centrifuge is used to test models of geotechnical problems such as The strength, stiffness and capacity of foundations for bridges and buildings, settlement of embankments, stability of slopes, earth retaining structures, tunnel stability and seawalls. Other applications include explosive crate ring, contaminant migration in ground water, frost heave and sea ice. The centrifuge may be useful for scale modeling of any large-scale nonlinear problem for which gravity is a primary driving force. Some of the wide commercial applications of this model are:

- In soil mechanics, centrifuges utilize centrifugal acceleration to much soil stresses in a scale model to those found in reality for the intention of understanding soil liquefaction phenomena.
- Large industrial centrifuges are commonly used in water and wastewater treatment to dry sludge's. The resulting dry product is often termed cake, and the water leaving a centrifuge after most of the solids have been removed is called centrate.
- Large industrial centrifuges are also used in the oil industry to remove solids from the drilling fluid.
- Disc-stack centrifuges used by some companies in Oil Sands industry to separate small amounts of water and solids from bitumen
- Centrifuges are used to separate cream (remove fat) from milk..
- Centrifuges are used in the sugar industry to separate the sugar crystals from the mother liquor.
- Standalone centrifuges for drying (hand-washed) clothes – usually with a water outlet.
- Centrifuges are used in the attraction Mission: SPACE, located at Epcot in Walt Disney World, which propels riders using a combination of a centrifuge and a motion simulator to simulate the feeling of going into space.

Reason for model testing on the centrifuge
Geotechnical materials such as soil and rock have non-linear mechanical properties that depend on the effective confining stress and stress history. The centrifuge applies an increased "gravitational" acceleration to physical models in order to produce identical self-weight stresses in the model and prototype. The one to one scaling of stress enhances the similarity of geotechnical models and makes it possible to obtain accurate data to help solve complex problems such as earthquake-induced liquefaction, soil-structure interaction and underground transport of pollutants such as dense non-aqueous phase liquids. Centrifuge model testing provides data to improve our understanding of basic mechanisms of deformation and failure and provides benchmarks useful for verification of numerical models

SUMMARY
The above scaling law states that if lengths in the model are reduced by some factor, n, then gravitational accelerations must be increased by the same factor n, in order to preserve equal stresses in model and prototype. The main application of this model in this paper is for geotechnical foundations by comparing the soil stress in the model with the real once.

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