TWO-DIMENSIONAL NON-LINEAR DYNAMIC RESPONSE OF A HEAP LEACH PAD LOCATED IN PERÚ

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Presented by José Ale

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STRUCTURE OF PRESENTATION

INTRODUCTION OF THE ANALYZED CASE

GEOTECHNICAL CHARACTERIZATION

GEOTECHNICAL ANALYSIS

ANALYSIS RESULTS

CONCLUSIONS
The technology of leaching process has been widely used in Peru in the last years, in gold, silver and copper mining projects.

Important mining operations in regions with a high seismic activity have the leaching process as their main mineral extraction method.

This scenery have generated the necessity of a better understanding of dynamic geotechnical characterization of materials which constitute a heap leach facility.

This paper studies a real case of a heap leach facility which the ore stack is composed of quartz-sandstone material.

This presentation will be focused in the geotechnical characterization of the ore stack of granular material.
INTRODUCTION OF THE ANALYZED CASE

Main Components of a Heap Leach Facility
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Main Components of a Heap Leach Facility

- LINER SYSTEM
- SOIL LINER
- ORE STACK
- GEOMEMBRANE INSTALLATION
- SOLUTION COLLECTION SYSTEM
INTRODUCTION OF THE ANALYZED CASE

Main Components of a Heap Leach Facility

ORE STACK

ORE STACK
INTRODUCTION OF THE ANALYZED CASE

Main Components of a Heap Leach Facility
For this case, the ore stack is constituted of a ROM (run of mine) material from the Chimu Formation (a sedimentary formation in the northern Andes of Peru).

Chimu Formation is mainly composed of an interbedding of claystone and quartz-sandstone, and of quartzite. It is commonly used as borrow material source.
Geological-Geotechnical Description
Previous geotechnical characterization in the ore material from Chimu Sedimentary Formation (Ale et al., 2014)
For a new expansion of the heap leach facility analyzed, some geotechnical site investigation were conducted in the existing ore stack material.

Three samples from the ore stack material were extracted and tested (grain-size distribution, unit weight, CU triaxial compression tests of 6”).

One geophysical survey (multi-channel analysis of surface waves, MASW) was performed in-situ (same place of M-3 sample), to measure shear waves velocities in the existing ore stack.
Grain-size distribution of samples from the existing ore stack.
### GEOTECHNICAL CHARACTERIZATION

**Heap Leach Facility Analyzed**

<table>
<thead>
<tr>
<th>Id</th>
<th>UCSC classification</th>
<th>Dry unit weight $\gamma_d$ (kN/m$^3$)</th>
<th>Initial confining stresses, $\sigma'_3$ (kPa)</th>
<th>$c'$ (kPa)</th>
<th>$\phi'$ (°)</th>
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<tbody>
<tr>
<td>M-1</td>
<td>SP-SM</td>
<td>17.1</td>
<td>600; 300; 150</td>
<td>7</td>
<td>36.4</td>
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<td>M-2</td>
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<td>M-3</td>
<td>GP-GM</td>
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<th>ID</th>
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<th>Average dry unit weight $\gamma_d$ (kN/m$^3$)</th>
<th>Unit weight $\gamma$ (kN/m$^3$)</th>
<th>$\phi$ (°)</th>
<th>$\Delta\phi$ (°)</th>
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<tbody>
<tr>
<td>M-1 to M-3</td>
<td>GP-GM</td>
<td>17.5</td>
<td>19.0</td>
<td>37</td>
<td>5</td>
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</tbody>
</table>

(M-1 to M-3 Mixture)
Profile of shear-wave velocity (MASW) in the existing ore stack.
The $K_{2,\text{max}}$ value (shear modulus number) is obtained by:

$$K_{2,\text{max}} = \frac{2203.8}{21.7} = 101.55$$
The Peruvian Andes, region where this analyzed geostructure is located, were formed as tectonic effect of the subduction of the Nazca Plate under the South American Plate.
For the non-lineal dynamic analysis was selected an input signal considering an Operating Basis Earthquake (OBE), usually defined as the earthquake for which a structure is designed to remain its operational condition.

Considering that the OBE is likely to occur during the operation life of the structure and considering the seismicity of the region, a seismic event of 5.7 Mw (occurred in 01-03-2015) was selected.
Location of earthquake 5.7 Mw occurred in 01-03-2015 (www.usgs.gov/).
This design site response spectrum was calculated based on probabilistic methods (having a 2% probability of exceedance in 50 years).

Figure presents results of the matching procedure application using EZ-Frisk (2011).
Spectral Matching

**Graph 1:**
- **x-axis:** Period (s)
- **y-axis:** Spectral Acceleration (g)
- **Legend:**
  - Original Earthquake Spectrum
  - Design Spectrum (Target Spectrum)
  - Matched Spectrum

**Graph 2:**
- **x-axis:** Dynamic time
- **y-axis:** Acceleration

**Legend:**
- step: 963270
- Dynamic Time: 2.8210E+01
- 1-Mar-15 16:08
Profile FLAC finite differences model (control points).

ORE STACK h=80 meters

ROCK MASS FOUNDATION
Distribution of $G_{\text{max}}$ (Pa) in function of $\sigma'_m$.

Distribution of effective internal friction angle ($^\circ$) in function of $\sigma'_3$.
Acceleration time history at the base of FLAC model $a_x$ (m/s$^2$) vs $t$ (s).

Acceleration time history at the top of FLAC model $a_x$ (m/s$^2$) vs $t$ (s).
ANALYSIS RESULTS

Maximum Permanent Displacements

Horizontal displacements in meters

Vertical displacements in meters
Horizontal time history displacements relative to the model base of control points located at the interface region 2, 7 and 8 are presented in Figure.

The maximum deformation computed in this area reached values below 0.03 m in control points 7 and 8.
CONCLUSIONS

- From the results of the dynamic analysis it can be concluded that the heap leach facility will remain safely during an OBE design occurrence.
- The maximum permanent deformations in the slope is about 0.5 m in horizontal and 0.25 m in vertical.
- The acceleration time history obtained shows an amplification of about 2 times considering the control points located at the top and at the base of the model.
- The ore stack material of quartz-sandstone has the following properties:

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<td>$K_{2,\text{max}}$</td>
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¡¡¡MUCHAS GRACIAS!!!

Visiten Perú............

ANY QUESTION?

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