Assessment of seismic interaction between a crusher and a MSE wall in Peru

Évaluation de l'interaction sismique entre un concasseur et un mur de terre stabilisée mécaniquement au Pérou

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ABSTRACT: A crusher box in a copper mine in central Peru is located adjacent to a 35m-high MSE wall, which supports a large 2500MN stockpile on its crest. Seismic-induced lateral deformation of the MSE wall is larger when the stockpile comes closer to the edge of the wall. The objective of this study was to minimize the stockpile-crusher distance while keeping the design safe. The problem was assessed by 2D numerical models developed in Plaxis since the MSE wall deforms mainly in plane-strain mode. Being a soil dynamics problem, the HS-Small constitutive model was selected, as it is able to reproduce hysteretic dissipation and small-strain stiffness of geomaterials. Results show that the MSE wall stability is of no concern; that the wall experiences a distortion of 2%-3% for the design earthquake; and that the wall contacts the crusher structure so that contact pressures were computed for configurations analyzed. As a result, a simplified earth-pressure diagram for seismic conditions was given to design engineers. It was concluded that geotechnical safety is adequate, that the crusher station is not significantly affected by the position of the stockpile and that the seismic-induced displacements of the MSE wall face are tolerable, only requiring operational maintenance after a large seismic event.

1 INTRODUCTION

This paper reports a challenging problem in a mine located in the central part of Peru: a crusher station has an ore stockpile located on the surface behind the MSE wall which is so close to the crusher that the static and dynamic interaction between these components must be considered. The problem was addressed by numerical models performed in the finite element program Plaxis 2D AE. The objective was to evaluate: i) the contact pressure between the MSE wall and the primary crusher for different positions of the stockpile; ii) the concrete structure's displacements due to the static and seismic loading; and iii) the safety factor for each scenario by the strength reduction method available in Plaxis.

2 MODEL GEOMETRY

The problem of the interaction between crusher and reinforced earth wall surrounding it is three-dimensional in nature, as shown in Figure 1, and therefore it cannot be reduced to a single 2D problem without a serious compromise of predictive capacity. However, for the accuracy required for this study, the authors considered that the evaluation of the interaction could be achieved through the analysis of two representative sections, those shown in Figure 2.

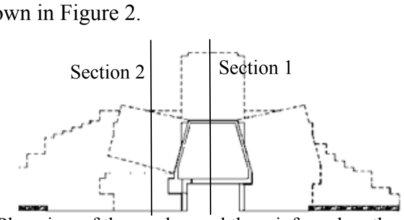

Figure 1. Plan view of the crusher and the reinforced earth wall.

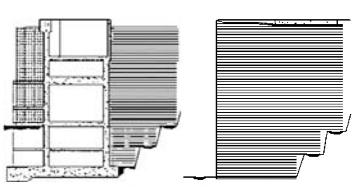

Figure 2. (left) Section 1 (crusher), (right) Section 2 (MSE wall).

The model dimensions are 350m x 80m for Section 1, and 350m x 100m for Section 2. Furthermore, the primary crusher, the MSE wall and the stockpile rest on quartz-monzonite rock, which was modeled as a linear elastic material. The concrete building was modeled as a linear elastic cluster with axial and bending stiffness equivalent to the real structure. Figure 3 shows the model geometry for Section 1 and Figure 4 shows the geometry for Section 2. The crusher has a maximum height of 39.5m and the loads of heavy trucks were considered.

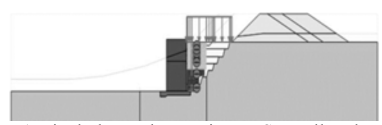

Figure 3. Section 1 – include crusher station, MSE wall and stockpile.

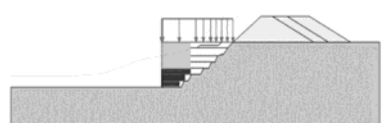

Figure 4. Section 2 – include MSE wall and stockpile.

3 MESH AND BOUNDARY CONDITIONS

The mesh is standard for ground-interaction problems with the following features: i) horizontal reinforcing geogrids have a vertical separation of 0.60m but were modeled with a separation of 1.20m as a compromise between predictive capacity of the model and numerical quality of the mesh; ii) one polystyrene layer installed between the concrete structure of the crusher and the backfill was modeled as an interface element of equivalent thickness and mechanical properties; iii) the geogrids are not connected to the concrete structure and, consequently, are not connected to the concrete block in the numerical model; iv) the stockpile was modeled as a material for dynamic analyses and as a load for static analysis.

Boundary conditions were conventional for static analysis, with horizontal full restraint at the base and vertical restraints on both sides of the mesh. For the dynamic analyses, absorbent lateral borders were employed and the "compliant base" option was used in the base of the model (Brinkgreve et al 2016).

4 MATERIALS

A geotechnical exploration program was performed to characterize and identify the materials involved in the model and as a result, the following geotechnical units were identified: U1) reinforced ground and structural backfill, classified as (GC-GM) with 66% of gravels, 20% of sands and 14% of fines; U2) stockpile, classified as (GP-GM) with 77% of gravels, 17% of sands and 6% of fines; U3) rock mass composed of hard quartz-monzonite. In order to represent the behavior of soils (Units 1 y 2) the HS-Small model was used whereas for the rock (Unit 3) the linear elastic model was considered.

On the other hand, the structural elements: foundation (E1) and crusher structure (E2) were modeled as linear elastic materials. The geogrids of the MSE wall were represented as flat elements without bending stiffness. Moreover, the vertical face of the wall does not have rigid elements, so it was not subjected to a special analysis in the models. The material parameters are shown in Table 1. For a complete description of the material models and parameters see (Brinkgreve et al 2016).

Table 1. Strength for geotechnical units

Parameter			U1	U2	U3	E1	E2
γ	[kN/m^2]	unit weight	24	23	26	24	10.7
c	[kN/m^2]	cohesion	1	1	-	-	-
ϕ	[°]	friction angle	42	41	-	-	-
ψ	[°]	dilatancy angle	4	0	-	-	-
E	[GPa]	Young's modulus	-	-	9.5	21.7	12.7
υ	[-]	Void ratio	-	-	0.20	0.17	0.17

5 SEISMIC RECORDS

According to the level of project, a simplified procedure was used to obtain the seimic records for dynamic analyses. Therefore, regional seismic catalogs (CISMID) and (PEER) were analyzed; a set of seismic records compatible with the seismic demand of the project in terms of magnitude (M), hipocentral distance (R) and with a PGA value were selected and scaled to the design seismic parameters of the site. The preselected records were grouped and ordered in terms of Arias intensity and duration for a PGA similar to the design PGA, which was calculated based on a probabilistic study of seismic demand, where a return period of 2475 years for the design earthquake was established, due to the importance of the structure in the production process of the mine. Finally, the two seismic records that showed the maximum duration and maximum Arias intensity were chosen to perform 2D dynamic analyses.

6 RESULTS

6 .1 *Static analysis*

On one hand, wall-crusher contact pressures were evaluated for different positions of the stockpile under static and seismic conditions. For the static case, the pressure distribution was calculated from numerical model and was reproduced with sufficient accuracy by adopting the Rankine earth pressure theory with horizontal pressure coefficient K = 0.25|0.27. The results indicated that the translation of the stockpile from its original position to a closer distance increases the total thrust on the crusher by 70% (Figure 5).

On the other hand, the numerical factor of safety (FoS) was calculated using the strength reduction method (Brinkgreve et al 2016). For Section 1, the potential failure surface is restricted by the structure of the crusher, so the numerical analysis of the safety factor has little interest. The safety factor calculated for Section 2 is larger than 2.0 for all positions of the stockpile (Figure 6).

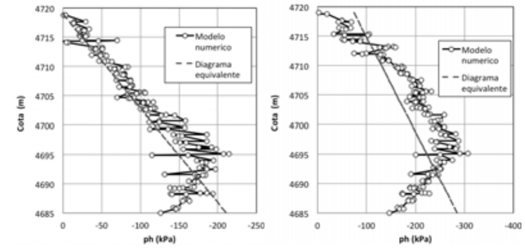

Figure 5. Stockpile - original position (left), closer distance to crusher (right).

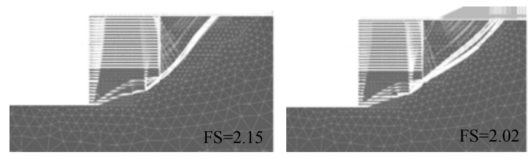

Figure 6. FoS - original position (left), closer distance to crusher (right).

Furthermore, approaching the stockpile to the front of the MSE wall caused horizontal and vertical displacements in the crown of the wall to increase in 40 and 65 mm, respectively, which represents a distortion in the front of the wall of 1%. Finally, the vertical and horizontal displacements in the highest part of the crusher were not affected by the stockpile's change of position due to its stiffness.

6 .2 *Seismic analysis*

In this case, a simplified triangular distribution similar to the method of Mononobe-Okabe was considered as the contact pressure for a seismic event. Therefore, the total thrust capable of reproducing the residual horizontal displacement recorded on the crusher by dynamic analysis was calculated.

In addition, horizontal movements were recorded at the crown of the crusher up to 12mm. On the front of the reinforced wall, the displacements reached maximum residual values up to 1270mm and 480mm in horizontal and vertical direction respectively. These displacements represent a distortion in the front of the MSE wall of 3.1%. It was noted that the approach of the stockpile to the front of the wall increased the horizontal displacement in 300mm.

7 CONCLUSION

It was concluded that the geotechnical safety of the construction is adequate and is not affected by the position of the stockpile. From the operational point of view, the structure of the crusher is practically indifferent to the approach of the stockpile in static conditions. The calculated displacements in the front of the reinforced earth wall are tolerable because the front of the wall has no structural covering.

For the seismic case, the displacements reported by the model are important, although consistent with the selected method of calculation and the return period of the adopted earthquake for the design.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

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