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SEEPAGE ANALYSIS FOR SUNGUN HIGH CENTERLINE TAILINGS DAM

S. SOLEYMANI
Expert of Engineering Seismology, Toossab Consultant Engineering Co., Iran

M. NAEINI
Supervisor, Mahab Ghodss Consulting Engineering Co., Iran

ABSTRACT

The important results obtained from seepage analysis are to control boiling potential of the foundation material in concrete spillway and earth dyke toe. Also determining the actual distribution of pore pressures (uplift pressures for controlling structures against slipping or overturning) is possible. Although the aim of construction of tailings dam is not storage of water, it is necessary to distinguish the amount of discharge from foundation and body to prevent the environmental pollutions and its reduction if necessary. Seepage analysis is based on a residual flow scheme involving saturated and unsaturated zones in which the hydraulic properties remain invariant during transient flow. With available software, the solution of any seepage problem is reduced to a simple routine requiring negligible engineering time. Seepage control is necessary to prevent excessive uplift pressures, sloughing of the downstream slope, piping through the embankment and foundation, and erosion of material by loss into open joints in the foundation and abutments. A two dimensional seepage analysis was conducted using Geoslope package, Seep/W to determine seepage quantities. Results are shown for earth dyke body and foundation.

1. INTRODUCTION

Seepage control is a critically important aspect in the design, construction, and operation of tailings dams as it directly affects: the stability of the downstream slope; internal erosion due to piping; and pollution of ground and surface waters downstream of the dam. Accurate calculation of seepage amount from the body and foundation in dams is very important for economical and technical considerations. Water escape from the body and foundation of earth dams can lead to unacceptable water losses in arid climates, cause problems during construction and can have destabilizing effects on the earth dam. Seepage analysis in earth dam designs is very important for dam safety, because the water flow in the body and foundation in dam cause creation of pore pressure and seepage forces, that if not within tolerable limits, the dam stability may be in jeopardy, which may lead to dam failure.

Methods for controlling seepage through embankments, abutments, and foundations have been extensively studied and developed over a period of many years in the field of conventional water storage dams. These procedures, which are considered standard practice in the conventional water storage dam field, are well documented in the published engineering literature. Moreover, these conventional seepage control procedures are directly applicable to the control of seepage flows in the embankments, abutments, and foundations of tailings dams. However, they must be suitably modified to account for the fact that a tailings slurry, rather than water is being stored behind the dam.

The statistics show that more than 30 percent of earth dam failures are resulted from a wrong estimation of seepage. Furthermore seepage during earthquake occurrence can create additional problems for dam stability. So seepage control is a management before crisis. Seepage control from dams that are located on foundations with higher permeability is one of the important problems for dam stability and it is necessary for sure and acceptable servicing in water maintenance.

The aim of this study is seepage analysis of Sungun tailings dam and determination of the water discharge content that will leak from foundation and body of the dam and estimation of maximum of gradients due to seepage water in body and foundation of the tailings dam.

Sungun porphyry copper mine is located 125 km northeast of Tabriz, in north-western Iran (43° 46′ E and 38° 42′ N) (Figure 1). The Sungun high centerline tailings dam is a rockfill dam with a clay core and final crest level is 2275 meters.

Figure 1 : Location of Sungun copper mine in Iran.

In order to identify the dam geometry, the typical cross section of Sungun tailings dam along the two different sections has presented in the Figures 2 and 3. According to the geological surveys, alluvial foundation of Sungun tailings dam concluded from coarse-grain (GC, SC and partial SM-SC) and fine-grain materials (CL and partial CL-ML). The dam reservoir (tailings) has concluded from slimes and silicone sands.

Dam crest width is 16-23 and the core width is 5.2 meter.

Modified foundation and abutments (banks) drainage system layout has been shown in Figure (4).

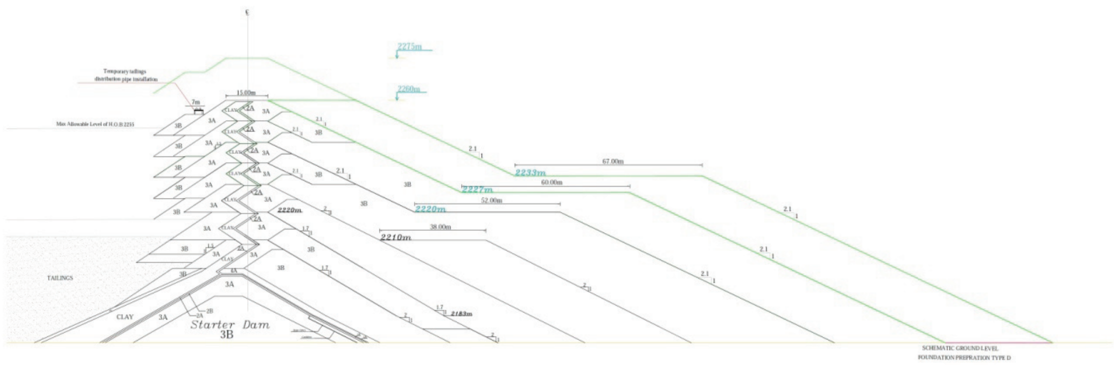

Figure 2 : Sungun tailings dam typical cross section along the section A-A

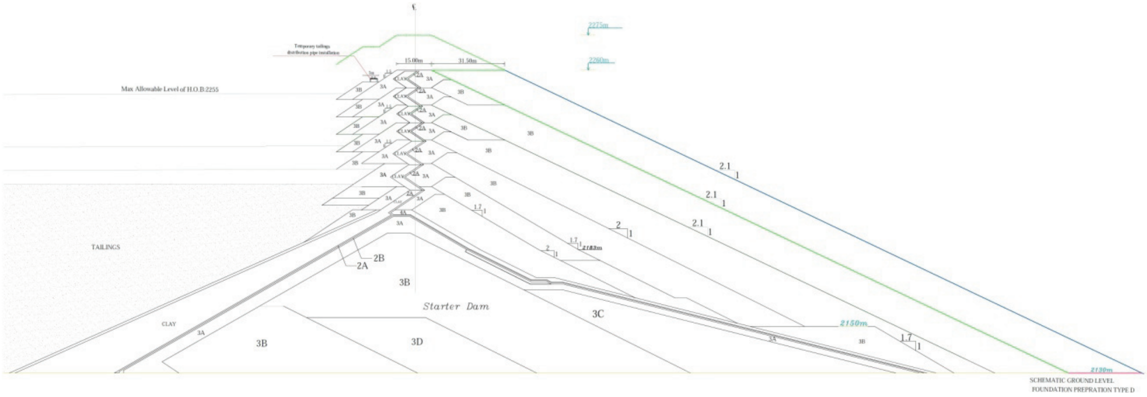

Figure 3 : Sungun tailings dam typical cross section along the section B-B

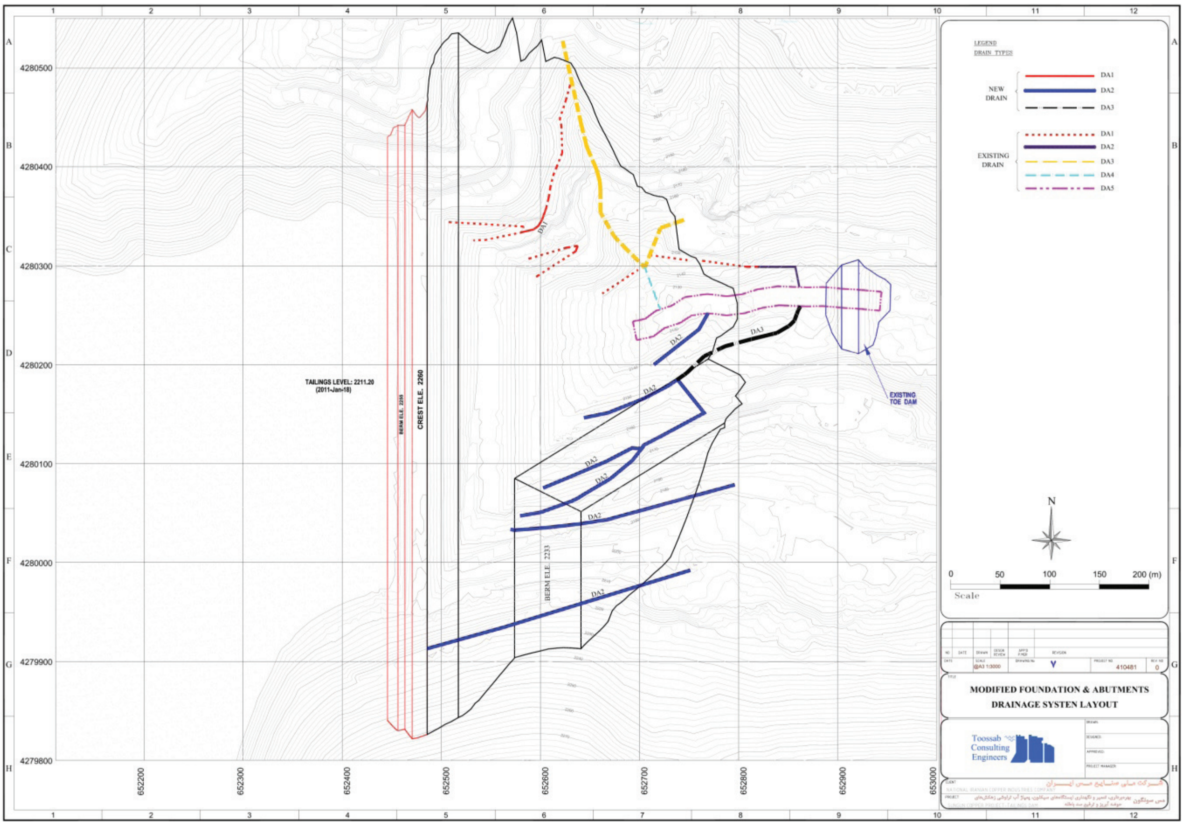

Figure 4 : Modified foundation and abutments (banks) drainage system layout.

2. ANALYSIS METHOD

Analysis of seepage through the dam was performed by finite element method using Seep/W software (Geoslope, 2012). Amount of water discharge, extension of pore water pressures, water flow and velocity and extension of hydraulic gradients can be estimated by this software. Seepage calculation principles in soil environments, is based on Darcy's relations and continuity equations.

Since earth dyke of Sungun tailings dam is rather long, Darcy's law is dominant on two dimensions. Consequently, two dimensional analyses are adequate to meet design criteria. Estimation of maximum gradients consequences the safety factor against materials washing out from dam foundation. This coefficient is obtained through Equation (1).

$$F.S = \frac{i_{cr}}{i_{ex}} \tag{1}$$

In which, icr is critical gradient, and iex is hydraulic gradient at exit boundaries. iex is obtained according to material permeability at given point and water exit velocity at that point. Critical hydraulic gradient (icr) is estimated about 1.0 based on material type.

Seepage analyses were performed assuming "steady state seepage" conditions. According to experiences, the ratio of horizontal permeability (Kx) to vertical permeability (Ky) in compacted materials is greater than or equal to one (Kx/Ky≥1). Above ratio is greater for compacted and well-graded materials, and smaller for poor-graded materials.

The permeability characterizes of the various parts of the body, foundation and reservoir (tailings) of the Sungun Dam has been shown in Table (1). The variety range of permeability coefficients of the dam body materials was determined based on the results of laboratory permeability tests and the values of the dam foundation permeability coefficients were determined on the basis of field permeability tests.

In addition to permeability, water content curve is also one of the important parameters in the seepage analysis. This curve shows that in a given suction, how many percent of the soil pores are filled with the water. Naturally, with increasing of the amount of suction in a given soil layer, the percentage of water in the particle void decreases and is filled by air. In Figure (5) the proposed water content curve for the various materials of the Sungun tailings dam has been presented.

Table 1 : Permeability characterizes of body, reservoir and foundation material of Sungun tailings dam

Dam Part	Material Type	Max Kh (cm/s)		
		Minimum	Moderate	Maximum
Foundation	Fine-grain & Coarse-grain	9.5E-05	1.2E-03	1.3E-02
	Bedrock	6.0E-06	4.8E-04	2.2E-03
	Fine-grain	1.3E-06	2.2E-04	2.3E-03
	Coarse-grain	1.1E-05	1.4E-03	1.4E-02
	Bedrock	2.1E-05	1.3E-04	1.1E-03
Reservoir (Tailings)	Sand	1.3E-04	-	3.2E-04
	Slimes	1.0E-07	-	1.0E-06
	All-in tailings	1.1E-06	2.6E-05	8.9E-05
Body	Core	-	1.2E-05	-
	Rockfill (As-sumed)	-	5.0E-02	-

The modified Kovács (1981) model was used to estimate the slimes content curve. This model was first proposed for tailings from mineral hard rock (Aubertin et al., 1999). Then examined and reviewed for other soils (Aubertin et al., 2003). The MK model is one of the pre-defined functions in the GeoStudio software (2012) and draws the material content curve function using basic geotechnical properties (including D10, D60 and LL). It should be noted that the modified Kovacs model is not a good model for high plasticity soils (PH). But for tailings from mineral hard rock, it is in good agreement with the results of laboratory tests. For tailings, on average, based on the results of soil gradation tests, D10 = 0.0035 and D60 = 0.03 mm. The soil liquid limit (LL) is also based on the atterburg test results on the slimes tailings considerer as 29 percent.

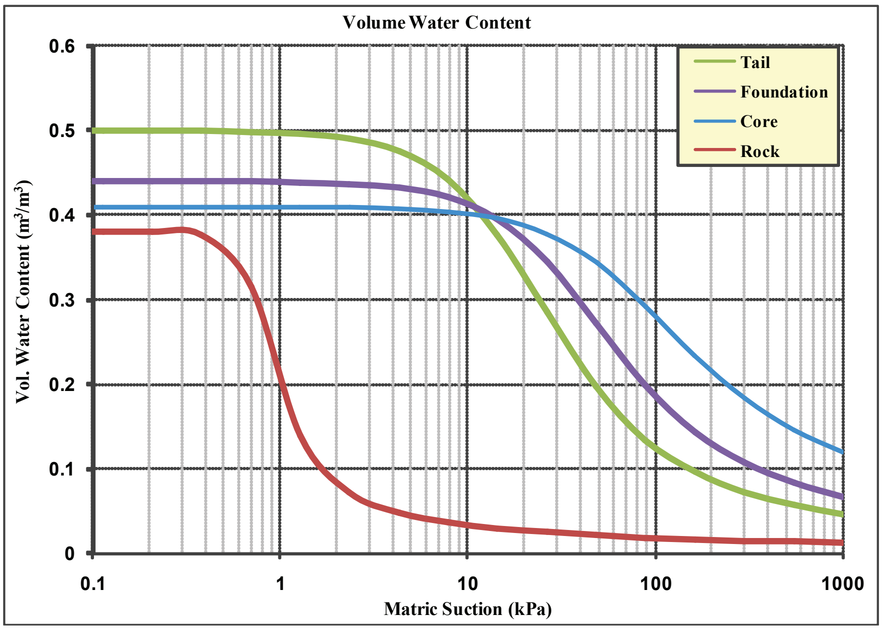

Figure 5 : The proposed water content curve for the various materials of the Sungun tailings dam.

Van Genuchten model (1980) is used for core materials. In summary, this model uses three fitting parameters a, n and m to estimate the soil content curve. It is advisable to replace the parameter m = 1-1 / n (Van Genuchten, 1991). To calculate "a" and "n" parameters also used from the Tinjum et al. relations (1997). These relations are provided by testing on dense clay specimens. For using these equations, plasticity index (PI), optimum moisture and soil compaction moisture are required, which are averaging 18, 17, and 15, respectively. GeoStudio software curves for fine-grain soils containing coarse-grain and sand have also been used for foundation materials. The rockfill content curve is also typical based on Williams (2015). It should be noted that if using the MK model the results are very close to the presented content curve by Williams (2015).

3. SEEPAGE ANALYSIS CALCULATIONS

Due to a rather high permeability of the alluvial foundation, it was anticipated that it would be necessary that a cut-off be extended to the rock foundation for seepage and gradient control. The seepage analysis consists of seepage analysis through the earth dyke body and foundation along the B-B section in Figure (3).

The aims of performing these analyses are, controlling the boiling potential at the toe of earth dyke, determination of seepage amount from body and foundation and considering cut-off wall influence. Figure (6) and Figure (7) Show the total head and water pore pressure at the steady state seepage.

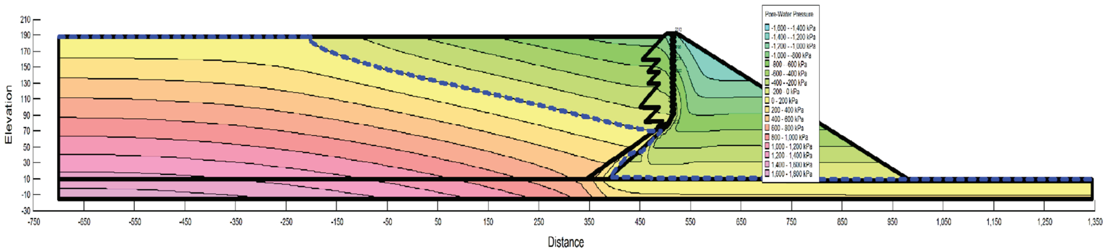

Figure 6 : The total head at the steady state seepage

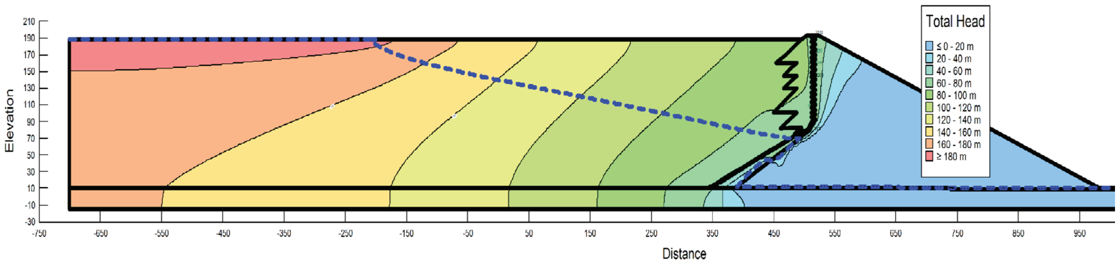

Figure 7 : The water pore pressure at the steady state seepage

4. CONCLUSION

In this paper Analysis of seepage through the dam performed by finite element method using Seep/W software (Geoslope, 2012). Finally and due to the results, about the leakage rate through the Sungun tailings dam dam body can be said due to the dam type and the low amount of tailings permeability, the seepage rate is not worrying. In fact, the starter dam core has a good seal against the seepage.

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