Technical Memorandum

To: Joel Carrasco

Company: Tetra Tech

Re: Rosemont Heap Leach Pad Anchor Trench Stability

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1.0 Introduction

This Technical Memorandum provides a summary of Tetra Tech’s anchor trench stability analysis related to the Heap Leach Facility (HLF) at the proposed Rosemont Copper Project (Project) in Pima County, Arizona. This information is in response to the April 14, 2010 Comprehensive Request for Additional Information from the Arizona Department of Environmental Quality (ADEQ) to Rosemont Copper Company (Rosemont). Specifically, this Technical Memorandum answers item no. 6 on page 7 of 18.

- Anchor Trench – Please submit stability calculations supporting the design for the anchor trench within the perimeter containment berm. This feature is a critical component with respect to pad stability.

The results of our calculations indicate that the anchor trench will be stable and will provide sufficient resistance to the forces developed in the geomembrane due to the differential settlement.

2.0 Anchor Trench Stability

2.1 Tensile Strength Capacity of Anchor Trench

The tensile strength capacity of the anchor trench was evaluated using the methodology presented by Koerner (1999). The methodology is based on a static equilibrium analysis of the problem. Illustration 1 shows the free body diagram for the geomembrane considered to develop the analytical equations.

The proposed analytical equation for determination of the allowable geomembrane tension from the anchor trench is:

\[ \sum F_x = 0 \quad (1) \]

\[ T_{allow} \cos \beta = F_{U0} + F_{L0} + F_{LT} - P_a + P_p \quad (2) \]
where:

\[ T_{allow} = \text{allowable force in geomembrane stress} = \sigma_{allow} t; \]
\[ \sigma_{allow} = \text{allowable stress in geomembrane}; \]
\[ t = \text{thickness of geomembrane}; \]
\[ \beta = \text{side slope angle}; \]
\[ F_{U\sigma} = \text{shear force above geomembrane due to cover soil (negligible for thin cover soils)}; \]
\[ F_{L\sigma} = \text{shear force below geomembrane due to cover soil}; \]
\[ F_{LT} = \text{shear force below geomembrane due to vertical component of } T_{allow}; \]
\[ P_a = \text{active earth pressure against the backfill side of the anchor trench}; \]
\[ P_p = \text{passive earth pressure against the in-situ side of the anchor trench}. \]

Illustration 1: Cross Section of Geomembrane with Anchor Trench and Related Stresses and Forces Involved (modified from Koerner, 1999).
The shear forces above and below the geomembrane are defined as:

\[
F_{U\sigma} = \sigma_n \tan \delta_U (L_{RO}) \quad (3)
\]
\[
F_{L\sigma} = \sigma_n \tan \delta_L (L_{RO}) \quad (4)
\]
\[
F_{LT} = 0.5 \left( \frac{2T_{allow}\sin \beta}{L_{RO}} \right) (L_{RO}) \tan \delta_L \quad (5)
\]

where:
- \( \sigma_n \) = applied normal stress from cover soil;
- \( \delta_U \) = angle of shearing resistance between geomembrane (LLDPE) and cover soil (upper material);
- \( \delta_L \) = angle of shearing resistance between geomembrane (LLDPE) and GCL (lower material); and
- \( L_{RO} \) = length of geomembrane runout.

The active and passive earth pressures are defined as:

\[
P_a = \frac{1}{2} (Y_{AT} d_{AT}) K_a d_{AT} + (\sigma_n) K_a d_{AT} \quad (6)
\]
\[
P_a = (0.5 Y_{AT} d_{AT} + \sigma_n) K_a d_{AT} \quad (7)
\]
\[
P_p = (0.5 Y_{AT} d_{AT} + \sigma_n) K_p d_{AT} \quad (8)
\]

Where:
- \( Y_{AT} \) = unit weight of soil in anchor trench;
- \( d_{AT} \) = depth of anchor trench;
- \( K_a \) = coefficient of active earth pressure = \( \tan^2 (45 - \phi/2) \);
- \( K_p \) = coefficient of passive earth pressure = \( \tan^2 (45 + \phi/2) \); and
- \( \phi \) = angle of shearing resistance of respective soil.

Combining equations (2) and (5), the tensile strength capacity of the anchor trench (\( T_{allow} \)) is:

\[
T_{allow} = \frac{(F_{U\sigma} + F_{L\sigma} - P_a + P_p)}{\cos \beta \sin \beta \tan \delta_L} \quad (9)
\]
2.2 Calculations and Results

Illustration 2 shows the geometry of the anchor trench and soil parameters used to calculate the capacity of the proposed anchor trench.

**Illustration 2  Geometry of Anchor Trench and Related Soil Parameters**

The following conservative assumptions were considered in the calculation of the anchor trench capacity:

- The soil cover above the geomembrane was neglected, therefore $\sigma_n = 0$, $F_{uo} = 0$, and $F_{lo} = 0$;
- The weakest interface friction was used in the calculation. This is the friction between the LLDPE liner and the GCL ($\delta_L = 20.3^\circ$);
- The geomembrane runout length within the anchor trench was neglected.

Based on the above assumptions, the calculated anchor trench capacity is

$$ T_{allow} = \frac{(F_{uo} + F_{lo} - P_a + P_p)}{\cos \beta - \sin \beta \tan \delta_L} = \frac{-P_a + P_p}{\cos \beta - \sin \beta \tan \delta_L} $$

and:

$$ P_a = 0.5K_a Y_{AT} d_{AT}^2 = 6.19 \text{ lb/in} $$

$$ P_p = 0.5K_p Y_{AT} d_{AT}^2 = 55.69 \text{ lb/in} $$
\[ T_{\text{allow}} = 59.49 \text{ lb in} \]

According to the settlement calculations presented in a separate Technical Memorandum titled *Rosemont Heap Leach Pad Settlement Analysis* dated August 11, 2010 (Tetra Tech, 2010), the maximum strain in the liner system will be 0.0012 percent. Using the tensile elongation at yield of 12 percent and the tensile strength at yield of 100 lb/in for the proposed LLDPE liner, the maximum tensile stress in the geomembrane due to differential settlement will be:

\[ T_{\text{max}} = \frac{100 \text{ lb in}}{12\%} \cdot 0.0012\% = 0.01 \text{ lb in} \]

According to these analyses the anchor trench will provide sufficient resistance to the forces developed in the geomembrane due to the differential settlement. The maximum force to be experienced by the geomembrane was calculated to be 0.01 lb/in, while the anchor trench provides an allowable resistance force equal to 59.49 lb/in.

3.0 Conclusions

The calculations show that the anchor trench will provide sufficient resistance to the forces developed in the geomembrane due to the differential settlement.
REFERENCES

