SBM
SINGLE BORE MULTIPLE ANCHOR

CASE HISTORY OF SATISFACTORY PERFORMANCE, SHORTCOMINGS AND FAILURES IN SERVICES - FREEPORT MINE SOIL ANCHORS

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1. Introduction

The Freeport Mine in West Papua, Indonesia is the largest copper mine in the world and has been operating since the early 1970's. Located in the highlands of Papua the mine site is found at 2400m above sea level whilst the crusher plants were found at approximately 3760m above sea level. Crusher plant no 6 was installed in 1997 and crusher no 7 in 2001. The plant was designed around 27m high vertical retained earth walls, and 36m high operating mine dump structures, allowing 200 tonne dump trucks to tip the mined ore load into the crushers located at the wall base.

2. Reinforced Earth Wall Condition

Inspection of the walls in 2002 revealed that the fill material used (mine cuttings and tailings) in the *Reinforced Earth* wall construction, combined with acid water percolating into the backfill, had led to severe deterioration of the steel facing panel and of the buried tensile members essential to the sound structural behaviour of the wall. Continual monitoring of the walls by means of inclinometers and surveys indicated substantial wall displacement and therefore determined that the overall stability of the wall was compromised.

Photo 1 Freeport Mine anchored piled wall to crusher 6 dump slab

The risks related to potential failure were high (the 200 tonne trucks working as closely as 3m from the edge of the wall) and therefore the decision was taken to stop all activities around the concerned perimeter and to install a new *Reinforced Earth* wall around the crusher plant.

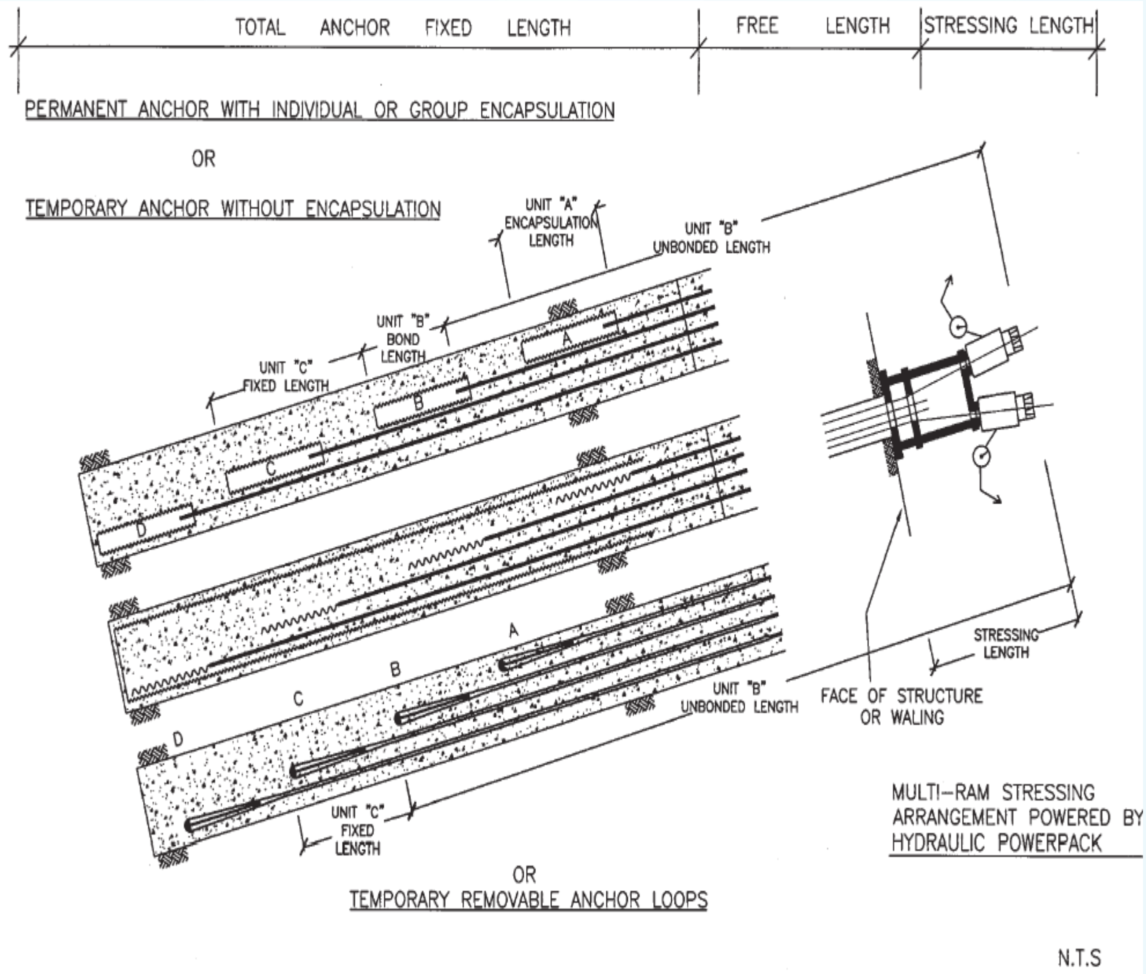
3. Remedial Solution

a. Anchored Wall Concept

An anchored piled wall 23m high was designed to allow the demolition and rebuilding of the *Reinforced Earth* walls 2 to 4 that support the crusher 6 dump slabs. The anchored piled wall consisted of 273mm dia grouted steel piles spaced at 750mm distance and included 7 rows of soil anchors inclined at alternative angles of 10 and 15 degrees to the horizontal. The anchors were connected to the wall by means of concrete and steel walers. Whilst the top row of anchors had a design working load of 600kN at 3 meters spacing, the remaining 6 rows of anchors were designed to provide working loads of 1200kN at 1.5m spacing. Altogether, a total of 130 anchors were included in the design. The anchors were provided with a free length to ensure that the bond length was located outside a line drawn up at 45 degrees from the toe of the wall, finally a minimum free length of 12m was respected. Total anchor lengths ranged from 18 to 27m. Bond length of the anchors were to be installed in a mixture of granular fill and mine tailings with assumed friction angle of 40 degrees.

b. Multiple Anchor Concept

Due to the variable nature of the fill material and the relatively high anchor capacities of the required the soil anchor system, Single Bore Multiple Anchor (SBMA) technology was proposed. This soil anchor system relies on the succession of small successive bond lengths rather than one unique longer bond length and has proven its efficacy in numerous projects worldwide. Refer to figure below for illustration of typical multiple anchor system arrangements (Barley and Windsor 2000).



SINGLE BORE MULTIPLE ANCHOR TERMINOLOGY

To accommodate project requirements SBMA anchors made of 4 to 6 units and able to mobilise working loads of 200kN each were proposed with two 15.7mm strands per unit. Design guidance for multiple anchors was obtained from “Ground Anchors” by Ostermeyer and Barley (2003).

Design of the production anchors was substantiated by a test anchor program which allowed an accurate estimate of the available bond shear stress in the in-situ wall material. Consistent with established practice an adjustment in unit anchor fixed length was carried out based on ultimate bond stresses proven.

The use of post-grouting system (tube-a-manchette) and end of casing grouting techniques to make provision for likely grout ”flow-away” situations as were experienced during the initial grouting trials were carried out. These techniques increase the available shear stress that can be mobilized in a mixed backfill material.

c. Realisation
The anchors were installed in successive rows with maximum excavation steps to be respected of 3.5m. At each stage the complete rows of anchors of a given level was installed, stressed and lift off tested before successive excavation could occur. Austress Menard realized the complete installation of all anchors within an extremely limited time frame of 4 months.

4. Results and performance

A maximum allowable wall deflection of 50mm was to be respected allowing for maximum anchor loads of 1200kN to 1420kN and maximum bending moments in the wall of 70 to 142KNm whilst the maximum axial force was 750 to 980 kN.

During the installation and excavation phases, monitoring was performed and showed that the above requirements were satisfactorily met thus proving the sound behavior of the SBMA anchors installed.

5. Conclusions and Recommendations

Although the initial system of wall support did not use ground anchors, the degradation of the unprotected steel tensile members within an aggressive soil environment supports the world wide consideration that permanent works anchor tendons should be isolated from the environment by the use of a proven corrosion protection system.

Only the requirement of a particularly short working period for the temporary works anchors allowed the omission of a complete anchor protection system. The short period of anchor usage in turn demanded an extremely rapid installation and stressing period so as not to delay the main mining works.

The ability to install a reduced number of extremely high load multiple anchors in fill material contributed to the accelerated program. Both the anchors and the wall were, throughout their lifespan, subjected to extremely severe and fluctuating load conditions from the repeated passage of 200T dump trucks. Failure in service would have been catastrophic.

The performance criteria of the anchors and the anchored structure in service during the limited life span were fully satisfied in that face movement did not exceed the specified limits and the multiple anchors satisfactorily maintained their load capacities even when founded in an unusual back fill material of mine cuttings and tailings.

The remote location, the project environment and the site conditions provided demanding logistical and engineering challenges. These demanded the use of established anchoring methods and some innovative practices to be adopted in this unique location.

6. Acknowledgments

Austress Menard, the specialist anchor contractor wish to thank the Indonesia Mining Company for their provision of all necessary documents and site service at the remote location and A.D. Barley of Single Bore Multiple Anchor Ltd for continual guidance in the use of the multiple anchor system.

7. References

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