Engineering judgment in applying geotechnical solutions for primary crusher tip wall in mining operations: Case studies

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ABSTRACT:

Mining clients demand and expect to get professional engineering judgment when they appoint a geotechnical engineer, to propose, solve or execute a geotechnical or structural problem on a new or existing site. To correctly evaluate, the Engineering Judgment (EJ) of the appointed Engineers, can be confirmed, by an interview, presentation, past acquaintance, work relationship, recommendation or own analysis, which will define the start of this working relationship. This decision determines whether the judgment applied to the geotechnical solution, (which in these described case studies, for primary crusher mining operations), will be successful and or satisfy the client's requirements. The cases studies represent some new points of departure of Engineering Judgment (EJ) for mining operations in Africa and Turkey using Mechanically Stabilized Earth Technology (MSEW). Soil reinforcement materials, its associated backfill and choice of solution are discussed as a means to transfer knowledge gained from experience with the specific projects.

1 THE NATURE OF SOME MINING PROJECTS

Mining projects are commercially driven, often; in remote locations, with limited choice of position, with complex geology, on a fast track schedule, where the civil engineering component is part of a multi disciplinary programme. Mine tip walls must be integrated with the process plant and their position is a function of the efficient layout, required by the materials processing geometry. The mine would prefer the discarded spoil or lower graded materials, to be used for backfill behind tip walls and their respective approach ramps. With the above listed background the Geotechnical Engineer has to dig deep and consult across a range of disciplines, to satisfy the clients' requirements within his own disciplinary code of conduct. The traditional tip wall design uses a reinforced concrete design approach. This solution is heavy, expensive, requires a highly skilled workforce and requires a robust design, if the backfill and foundation soil is of poor quality. During the past 10 years many tip walls in Africa and some in Turkey have been built with MSEW technology instead of the traditional concrete structure.

It has however required particular attention to sound EJ to accommodate the varied problems and circumstances, which were presented. EJ according to RB Peck (1996) can be acquired and is a particularly useful skill for the Geotechnical Engineer, because the earth sourced materials are so varied and the development of manufactured materials requires sensitive application. A keen interest and understanding of geology, soil mechanics, material science and hydrology is needed, which are all part of distinct engineering and natural science fields. To determine the level of EJ, cognizance of a reasonable period and quality of training and experience forms the base criteria.

2 CASE STUDIES

2.1 *Klipspruit coal mine, South Africa*

The mine is positioned between a national highway and agricultural land north east of Johannesburg. The expansion programme had limited choice of locating the tip wall and process plant. The final position and design, was greeted with a high water table and poor insitu foundation conditions.
The Geotechnical Engineer, who conducted the feasibility investigation, recommended excavation of poor quality insitu soil, to a depth (approximately

2m below ground level) where a more competent laterite layer was found, and to fill this volume with rock spoil, well compacted. The available two types of backfill material, although having poor characteristics individually, when blended in a 50/50 ratio, complemented each other, to offer a well-graded material with a high angle of friction, as measured in triaxial tests (ø = 38°). The tip wall consisted of two wing walls (Figure 1), on either side of the crusher building, supported on the left hand side of the ramp with a natural earth slope and a retaining wall on the right hand side, when facing the structure. The walls reached 21.5m high and the surface of retaining and wing walls totaled 4000m². Consequently the platform surface area was found to be large, which would catch a large volume of rainwater on its surface that would need management. The main Consulting Engineers solved this problem with a central slot, which assisted in channeling water off the ramp and consequently considerably reduced the amount of backfill required for the ramp. This project represents a close cooperation between main Consultant, Specialist Geotechnical Engineers and MSEW solution providers, each contributing their best EJ to dove tail into the clients final solution.

Figure 1. MSEW Macforce retaining wall

2.2 *Iduapriem gold mine, Ghana*

The rainfall of this area of Ghana is relatively high in the order of 1500mm per year. In assesment of the most efficient position to locate the process plant, the required tip wall made use of an existing ramp embankment. The process plant design necessitated a crusher building 30 m high (Figure 2). To economise on the excavation, an external Consultant devised a split wall, where by the first 11.5m would create a platform, thereby reducing the amount of excavation and then start the 17m high wing walls, at ground level. The use of a completely porous MSEW, of gabion baskets and geosynthetic soil reinforcement, raised the functionality and improved the drainage and reduced the pore water pressure, risk, over the whole surface of the structures.

Figure 2. Terramesh gabion MSEW with geosynthetic soil reinforcement (Iduapriem Ghana)

To establish and secure strict construction compliance and preserve the maximum advantage of the drainage design, careful attention was given, to the training of labour in packing the rocks in the gabion baskets and placing the geosynthetic seperation fabric, which creates an efficient drainage system behind the the wall (Figure 2). In comaparison with a reinforced concrete designed retaining wall, this MSEW technology was cost effective, more flexible to cope with differential settlement and creates a much better drainage capacity for the structure as a whole.

Figure 3. Drainage behind the concrete panels

By accomodating the clients needs, with the available conditions and ensuring safer long term performance, with respect to surface water and water migration, promotes the concept of applying good engineering judgment rather than standard problem solving.

2.3 *Aflease gold mine, Springs South Africa*

An existing gold mine, using an inclined shaft to access the workings and transport, the 'run of mine', materials to the surface, proposed to expand its operation. It was faced with the problem of poor insitu foundation material, which had a very low bearing capacity. The solution chosen was, 14m deep piles, constructed with auger holes, filled with dynamically compacted rock. On top of the stone piles, a further 4m layer was made, with dynamically compacted rock spoil, to create a platform with a bearing capacity of 500KPa. In deciding the preference, of which tip wall technology to use, the criteria of a minimum amount of movement/displacement, adjacent to the crusher, promoted the use of a MSEW concrete panel system for the main wall and a MSEW- Terramesh / gabion rock filled system for the wingwalls (Figure 4).

Figure 4. Combination of Macforce and Terramesh Aflease Gold mine South Africa

This combination of concrete cladding and rock filled baskets, offered a cost saving, a rapid construction programme and an overall functional solution that satisfied the clients requirements. Use of very competent rockspoil as backfill, created a well drained system, that also gave the best friction on the soil reinforcement.

The foundation conditions of this location was problematic, with expected settlement and consequent distortion of structures. Applying a combination of MSEW technologies and a novel foundation improvement, the combined solutions helped overcome and generate a very suitable total end result.

Sufficiently so that a national competition recognized the merits of the project for recommendation in a best project competition.

2.4 *Efemcukuru - Izmir gold mine, Turkey*

A retaining wall was required to be built on the boundary of a mining property with a total area, of 3430m² (360m long and reaching a maximum height of 13.6m). This would create a platform for the mine offices and process plant. Additonally a bridge was required to create access to this platform as the mine is situated in a mountainous forest area with neighbouring vineyards (Figure 5).

Figure 5. East and west bridge abutments leading on to retaining walls for mine process plant and offices

This ecological and environmentally sensitive area would not allow site batching of concrete and by virtue of its restricted access, varied foundation conditions, (strong and weathered hornsfelt rock to adjacent alluvial deposits next to the river), all contributed to the exercise of ingenuity by the Geotechnical Engineer. Using the French standard NF P94-220-0(1998) for the static design and FHWA(1997) for the seismic design, a MSEW, with concrete panels and geosynthetic (polymer) reinforcement of similar technology to one that survived the 1999 Kocaeli earthquake, (Kempton et al. 2008) was designed. To reduce the amount of pre-split blasting, that was essential in certain locations, a trapezoidal block width method of MSEW design was used. This allowed the soil reinforcement strip length to be shorter at bottom levels, to accommodate very strong rock conditions were it was preferred not to blast. Both abutments of the bridge also used the MSEW technology of concrete panels and the geosynthetic Paraweb® soil reinforcement. The availability of competent rock aggregate, for backfill not only improved the soil reinforcement friction characteristics, but solved a removal to spoil of excavated rock. Additonally this arrangement assisted greatly to reduce the tight soil compaction control, normally needed and assisted in the placing of backfill. By close coperation of the, client, geotechnical engineer and consultant engineers, the combined EJ of each participant, concluded with an equitable solution. All aspects of ecology, environmental, varied insitu conditions and restricted access was solved.

2.5 *Kisladag gold mine, Turkey*

A mine crusher plant of 22.5m in height, required wing walls (Figure 6), adjacent to the reinforced concrete structure. To accommodate the height requirement, to allow for 1st degree earthquake zone where horizontal ground accelaration, (a/g) is 0.4 and a live load for haul trucks of 250 tonnes, the turnkey Contractor choose a MSEW system to cope with these varied requirements. Additionally a staircase was required to give access from an area midway up the crusher, to the control room at the top of the crusher. The design was modified by splitting the wing walls on two levels. Thus the first section consisted of a 12m wall with an offset of 6m before the next section of a 10.5m wall started to the top of the crusher. To reduce and control the settlements during construction and after completion, a coarse granular fill with little fines was used that was well compacted, Özçelik (2008). The EJ to choose this MSEW system allowed compliance with a tight tolerance of plumbness adjacent to the structure for verticality and using a coarse granular fill avaialable on site.

Figure 6. Retaining walls for the primary crusher of Kisladag gold mine Usak, Turkey (22.5m)

3 CONCLUSION

• Mining clients that require the expertise of geotechnical engineers to solve site engineering problems, in innovative, cost effective, sensitive to ecology and the environment, would do well to establish their track record that confirms training, experience and sound engineering judgement.

• There may be a sense of safety or comfort in traditional solutions and provided the ecology, environment and financial capacity of the client is not overly cost restricted, old established methods will be adequate.

• A new generation of entrepreneurs and conscience minded public and share holders are demanding higher levels of problem solving, that requires innovation, minimal damage to environment and the most cost effective and code compliant design that is available.

• The case studies presented demonstrate a section of the current trend towards seeking to apply proven technology and sets a point of departure to traditional systems, demanding experienced and competent functional solutions.

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