Shaft Sinking with Electronic detonators at the Gautrain Rapid Rail Link Project

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Gautrain Project Overview

- One of the largest civil engineering projects in South Africa’s history
- Construction is being carried out by the Bombela consortium of Bouygues, Murray and Roberts, Bombardier and Strategic Partners Group
- Phase 1 is planned for completion in time for the 2010 FIFA Soccer World Cup
Gautrain Blasting Project Requirements

- A Blasting system that maximises advance and optimises blasting cycles

- An explosives services provider that was able to manage all the requirements associated with transporting, handling, storing and using explosives

- An initiation system and blast design that would minimize air blast and ground vibrations due to environmental constraints
Gautrain Geology

• The underground line encounters two different geological formations namely;
  – Witwatersand formation  
    (from Park to E2 shaft)  
    heterogeneous ground composed alternatively of quartzite, siltstone, shales in various degrees of weathering, with water circulation
  – Granite formation  
    (from E2 shaft to Marlboro Portal)  
    Granite with all degrees of weathering from soft to sound rock, with some intrusion of diorite (diabase)
Shaft Sinking

AEL’s products for Shaft Sinking.

Products Used:

• Explosives – Pumpable Underground Bulk Emulsion – R100G
• Explosives – Magnum 365 Cartridges (32 x 200mm)
• Initiation System – QuickShot™ Electronic detonators
Explosives

AEL Underground Bulk Systems (UBS)

- State of the art pumpable emulsion formulation
- The system consists of a non explosive base emulsion, which is only sensitised whilst charging
- The ability to store non-explosive base emulsion
- The system optimises safety and security, while dramatically speeding up the charging process
Explosives

AEL Underground Bulk Systems

- Critical diameter - 22mm
- The emulsion is cap sensitive and no booster is required.
- Water resistant
- High VOD - 4500 m/s in 45mm diameter
- Shelf life - 6 to 8 weeks
- Repumpability - 6 stages
Explosives

- R100G – Gassed Emulsion
Explosives

- UBS – UV 80 Bulk Charging unit with palfinger crane
- Two charging hoses for efficient charging
Initiating System

QuickShot™ Features:

- Pre programmed (125ms)
- Full functionality testing
- Daisy chain connection, connected in order of firing
- Can fire up to 1200 detonators
- Millisecond accurate delays
- Inherently safe
- Fast to connect up
- Automatic delay allocation
Robust, watertight, easy to connect connectors
QuickShot

• Easy daisy chain connection
QuickShot splitter

QuickShot pause marker

QuickShot delay marker
• Shaft E6 being constructed using the raise boring method. (Shaft diameter of 6.1m)

• Six circular emergency shafts and rectangular station-access shafts employed the traditional top-down (blind sink) shaft sinking method
Rectangular Shafts – Sandton Station

AERIAL VIEW OVER SANDTON STATION
Drilling

• The hole diameters used are either 45 or 48 mm in size.
• Drilling was closely monitored and was identified as one of the critical factors to determine whether a blast has been successful in achieving the required results.
Sleeving for Hole Lining
Sandton South Shaft
Using Cut to Create Free Face
Connecting up a round – Rectangular Shaft

Fly lead one to control box on surface

Fly lead two to control box on surface
- 28ms Delay Marker
- Splitter
- 14ms Pause Marker

Fly lead three to control box on surface
Sandton North Shaft - Connecting up detonators
Sandton North Shaft – Covering the Blast
Emergency Shafts - Circular
E5 Emergency Shaft

- Magnum Explosives Cartridges often used due to space constraints
Connecting up a round – Circular Shaft

Fly lead to control box on surface

First Detonator
Delay Marker
First detonator
Delay marker
Results

• An average advance of 95% - 100% of drilled length was achieved
• Increased speed of charging and timing operations allowed two blasts per day
• Vibration and Airblast levels within USBM limits
## Vibration Limits

<table>
<thead>
<tr>
<th>Blasting Situation</th>
<th>Recommended Maximum Level (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavily reinforced concrete structures</td>
<td>120</td>
</tr>
<tr>
<td>Property owned by the concern performing blasting operations where minor plaster</td>
<td>84</td>
</tr>
<tr>
<td>cracks are acceptable</td>
<td></td>
</tr>
<tr>
<td>Commercial property in reasonable repair where public concern is not an important</td>
<td>25</td>
</tr>
<tr>
<td>consideration</td>
<td></td>
</tr>
<tr>
<td>Private property if public concern is to be taken into account or if blasting is</td>
<td>10</td>
</tr>
<tr>
<td>conducted on a regular and frequent basis</td>
<td></td>
</tr>
</tbody>
</table>
Vibration Control – an example

• In one case, a sensitive structure was measured at 60m from blasting activity at the base of a construction shaft.

• Using the empirical formula:

\[
\frac{D}{\sqrt{E}} \geq 31
\]

• And solving for $E$ (mass per delay), the maximum safe mass was calculated to be 3.7kg/delay.

• This was achieved using shorter holes and electronic timing to ensure not only single hole firing but also to ensure a minimum of 9ms between each hole.

• No limits were exceeded.
AEL Guide for Airblast control

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 dB (2.0 Pa)</td>
<td>Barely noticeable</td>
</tr>
<tr>
<td>110 dB (6.3 Pa)</td>
<td>Readily acceptable</td>
</tr>
<tr>
<td>128 dB (50.2 Pa)</td>
<td>Currently accepted by South African authorities as being a reasonable level for public concern. (No more than 10% of measurements should exceed this value.)</td>
</tr>
<tr>
<td>134 dB (100.2 Pa)</td>
<td>Currently accepted by South African authorities that damage will not occur below this level. (No measurements should exceed this value outside of the mining boundaries.)</td>
</tr>
</tbody>
</table>

95% confidence could be given that adoption of the recommended measures, in the absence of unforeseen events, e.g. failure along a geological feature, would result in the required control of the airblast i.e. < 134 db.
Recommended measures to limit Environmental Impact

- Adequate stemming
- Sequential firing
- Charge per delay
- Avoid adverse environmental conditions
- Time blasts to coincide with peak ambient noise levels.
- Use a blast cover. e.g. sand and/or blasting mats
- Larger, less frequent blasting
Conclusions

• Shafts completed within 33 months and on schedule

• The success of the project was due to a combination of knowledge, application and the use of the correct products to match the robust and challenging conditions.
Thank you
Questions?