SHOTCRETE APPLICATIONS IN THE MATSOKU TUNNEL.
LESSONS LEARNT

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Introduction

- Background Information
- Shotcrete Specifications
- Shotcrete Application
- Experiences (Sweet & Sour)
- Conclusions & Recommendations
Background
Matsoku Diversion Tunnel and Weir
WEIR FROM EAST BANK

Intake Portal
Specifications

❖ Material and Mix
  • Wet mix shotcrete process was mandatory
  • Steel fibre content between 30-60kg/m^3 was specified.
  • Accelerators non-caustic with dosing limited to 3% of cementitious material
  • Quality control for material (cement, extenders, etc) to comply with SABS 1491 Part 3
  • Water/cement ratios of 0.35 -0.45 to achieve strength of 40MPa at 28 days

❖ Application
  • Application to good practice as detailed in ACI-506-R ‘Guide to Shotcrete’
  • Aggregates approved provided satisfactory results were obtained from site trials
  • 3-day curing period when shotcrete surface had to be kept damp was specified
  • Contractor was to provide reasonably smooth a natural gun surface finish
  • Nozzlemen had to undergo trials prior to spraying to the permanent works

❖ Support and Lining
  • 50mm Plain shotcrete, was applied as initial support to the tunnel roof
  • 75mm Steel fibre reinforced shotcrete to sidewalls to water flow levels
<table>
<thead>
<tr>
<th>Sprayed Concrete Class</th>
<th>Test Method</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td><strong>Cube Strength</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8 hours</td>
<td>ASTM-C42</td>
<td>-</td>
<td>-</td>
<td>5</td>
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<tr>
<td>24 hours</td>
<td>ASTM-C42</td>
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<td>-</td>
<td>9</td>
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<tr>
<td>28 days</td>
<td>(BS1881)</td>
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<td><strong>Peak Flexural Strength at 28 days</strong></td>
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<tr>
<td>Peak</td>
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<td>Residual</td>
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<td><strong>Toughness Indices at 28 days</strong></td>
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<tr>
<td>I_{20}</td>
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<td>16</td>
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<td>I_{30}</td>
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<tr>
<td>I_{50}</td>
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<td>30</td>
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<td>Boiled Absorption, %</td>
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<tr>
<td>Volume of Permeable Voids, %</td>
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<td><strong>Setting Time (Minutes):</strong></td>
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<tr>
<td>Initial Set</td>
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<tr>
<td>Final Set</td>
<td>(BS EN 1963)</td>
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</table>
Shotcrete Applications

- **Crushed Aggregates**
  - Locally crushed aggregates had high water absorption (2.0 to 2.5%)
  - Rapid slump loss resulted in shotcrete being rejected
  - Intake drive, additives added at batching plant and slumps were under control while in the outlet, additives were added manually thus resulting in high slumps

- **Quality Control and Equipment**
  - Compressive strength and durability tests showed generally good quality shotcrete
  - Aggregate storage bins were roofed and continuously wetted to maintain moisture
  - Flexural strengths and toughness indices tests were conducted at accredited laboratories
  - Shotcrete equipment breakdown and often erratic compressed air supply.

- **Application**
  - Very wet shotcrete, 120 mm slump, resulted in very rough, pock-marked finishes
  - ½-moon craters - hydraulic roughness or reduction in the long term durability or both
CONCRETE BATCHING PLANT AT MATSOKU INTAKE
Shotcrete Lined portal
Experiences:
Sweet and Sour

- **Shotcrete Specifications**
  - Specification subjective in terms of shotcrete surface roughness
  - Training and approval of Nozzleman, with no clear guidelines
  - Trial Panels shot outside the tunnel prior to commencement

- **Quality Control**
  - Crushed aggregates caused harsh mix that required addition of super-plasticiser
  - Shotcrete workability (slump and segregation controls resulted in uncontrolled addition of water)
  - Introduction of additives (super-plasticiser, etc) resulting high slumps
  - Scheduled maintenance of equipment was often not adhered to, Shotcrete and compressed air equipment breakdowns
  - Insufficiently skilled nozzle operator leading to poor workmanship
Experiences: Sweet and Sour (Cont.)

- Shotcrete Surface Finish
  - ⅔ of tunnel achieved acceptable shotcrete surface finish
  - ½-moon craters caused by aggregate “splashing” experienced in the rest
  - Application of smoothening flash coat shotcrete proposed by contractor
  - Benchmark panels with satisfactory finish marked for Contractor’s reference

- Claims and Disputes
  - Below standards nozzle operator proficiency and equipment poor state of repair - contributor to quality of work
  - Hydraulic considerations were not great concern
  - Tunnel Lining - long term durability of lining was Engineer’s concern
  - Contractor argued he had achieved reasonably smooth, natural gun finish

- DRB Recommendations
  - Interpretation of Specifications “reasonably smooth finish”
  - ACI 506R-85 and ‘good practices’ recommendations totally ignored
  - Views of Client’s Panel of Experts not considered
  - DRB ruled in favour of Contractor. Amicable settlement was reached between Client and Contractor

M Lebitsa, Goba (Pty) Ltd
Fully Lined Tunnel

‘½-moon crater’ surface finish
Acceptable finish – reference panel
Close-up shot of shotcrete – 2005 (after 5 years in operation)
Conclusions & Recommendations

• The importance of concise and precise specification clearly defining Owner’s requirements can never be over-emphasised.

• In the case of hydraulic tunnels, it is recommended that the roughness depression and waviness be limited to ±5mm’, which would result in a Mannings ‘n’ values in the order of 0.015 to 0.018.

• Means of quantifying the quality of works including, the surface finish (roughness) should be prescribed in the contract specifications (use of measuring templates, etc).

• The shotcrete panels shooting trials to be mandatory as part of approval. Trial panels to be shot, cured, sawn and visually examined prior to commencement of application to permanent works in order to demonstrate each nozzleman’s ability to execute work of expected quality.
Conclusions & Recommendations (Cont.)

• Flash coat as remedial where satisfactory finish not achieved

• In the absence of nozzle operator certification/accreditation legislation in the region, Contractor should undertake an approved, structured nozzlemen training programme, with demonstrable potential competency levels

• the contractor should prepare a detailed quality control plan which addresses shotcrete application methods and processes, nozzlemen training programme and procedures for carrying out remedial works where the specific requirements for quality (mix and/or surface finish) are not being achieved
Finally there’s light at end of the tunnel (some 6km away)

Accreditation might be coming soon!
I THANK YOU