Talk on 'Permanent Works Shotcrete in Hong Kong Tunnels'

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The talk on 'Permanent Works Shotcrete in Hong Kong Tunnels' was delivered by David Salisbury, an Associate Director of Ove Arup & Partners, Hong Kong with 20 years' experience in tunnel design and construction, on 19 October 2007 at the IEM lecture hall in Petaling Jaya at 5.30 p.m.

The past ten years has seen rapid advances in sprayed concrete technology for use in underground construction works. In Hong Kong, the recent development of a number of large underground infrastructure projects has led to increasingly imaginative uses of sprayed concrete technology and in particular its use for permanent works.

Spray concrete has made great advances in recent years and is increasingly used in permanent works. In fact, sprayed concrete is better than cast concrete in terms of strength and quality. Salisbury started the lecture by introducing the tunnelling activities in Hong Kong.

At present, there are over 380km of bored tunnels in Hong Kong, 59km in the next seven years and at least another 50km has been planned by 2015. Traditionally tunnels are constructed in hard rock but there is an increasing demand for large diameter soft ground tunnelling.

The presentation started with the review of tunnelling case studies on several projects in Hong Kong where alternative and innovative proposals for using sprayed concrete in the permanent works have been adopted. These include:

- one pass shaft lining;
- caverns in excess of 20m span;
- complex junctions and irregular shapes;
- formed surface finishing to provide smooth hydraulic flow;
- fully reinforced shotcrete;
- application of shotcrete directly onto waterproofing membranes and;
- drainage relining works.

Both dry and wet mix spray concrete (shotcrete) are used in permanent shotcrete applications in

i) Caverns and tunnels
ii) Shafts and
iii) Other applications

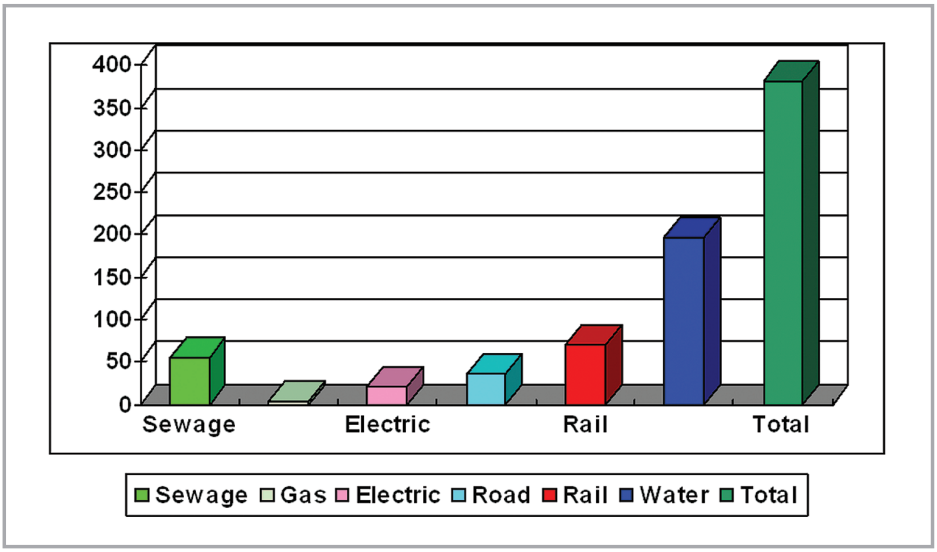


Figure 1: Use of shotcrete in engineering

Figure 2: Use of dry mix shotcrete in slope protection

Figure 3: Use of dry mix shotcrete in tunnel in Hong Kong

DRY MIX SHOTCRETE

Figures 2 and 3 show the examples of dry mix shotcrete used in Hong Kong.

WET MIX SHOTCRETE

Advantages:

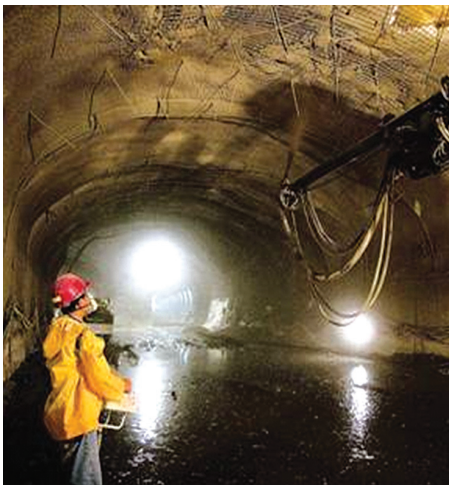
- Higher output (30m^3/hr)
- Quality control
- Pump over long distances
- Less rebound (5-10%)
- Steel & polymer fibres
- More advanced equipment
- Advanced mix design
- Another method of concrete placement

Figures 4 and 5 show the application of wet mix shotcrete.

MIX DESIGN

Dry Mix

OPCement…….....….480kg
10mm Aggregate.....…...600kg
Crushed rock.…….....1200kg



Figures 4 & 5: Applications of Wet Mix Shotcrete

Accelerator…….....…….15kg
Water (added at nozzle)

HIGH PERFORMANCE WET MIX

OPCement…….....……...400kg
PFA…….....…….60kg
Silica fume…….....…...40kg
10mm Aggregate…….....……450kg
Crushed rock.…….....……..1230kg
Water……...…….....…….200ltrs
RB561 (Superplasticiser)….....6ltrs
Steel fibres RL45/35…….....…30kg
Fibermesh 150…….....…0.9kg

PERMANENT SHOTCRETE APPLICATIONS

Caverns

- Island West Transfer Station - EPD
- Pak Shing Kok Tunnels – MTRC
- Disneyland Resort line – MTRC
- Queensway Subway – Swire/MTRC

Shafts

- Kai Tak Transfer Scheme – DSD

Non-Standard Tunnel Sections

- Corners - Kwai Chung Cable Tunnel – CLP
- Cross Passages – Lok Ma Chau Spur Line – KCRC

Other Applications

- Hydraulic profiling - Kai Tak Transfer Scheme – DSD
- Relining of Nullah - Kai Tak Transfer Scheme – DSD

Caverns – Island West Transfer Station

Environmental Protection Department (EPD)

- Waste transfer station on HK Island located within a hillside waterfront cavern
- Excavation in rock
- Primary shotcrete and permanent rockdowels
- Concrete lining only at portals
- Engineer's design 175,000m3
- Shotcrete Final design 30,000m3
- HK$ 200 million saving

Caverns – Pak Shing Kok Crossover

MTR Tseung Kwan O Extension

- 6.1km of running tunnels
- Standard tunnel lining by moving form
- Unreinforced cast in-situ concrete
- Not suitable for Crossings, Junctions, Fan Niches.

Caverns – Pak Shing Kok Crossover

- One 24m wide crossover Cavern
- Seven 12m wide fan niches
- Five bifurcations
- Two 'T' junctions
- All permanent shotcrete lined

Caverns – Tai Yam Teng Tunnel Niches

MTR Disneyland Resort Line

- 3km long shuttle connection to the new Disney theme park
- 850m long tunnel section, 5.4m internal diameter
- two fan niche caverns
- six other non-standard sections
- Sheet and sprayed membrane

Caverns – Queensway Subway

- 300m long pedestrian subway
- Linking developers properties and MTR station
- Cavern enlargement for escalator connection
- Excavated in rock with low cover below major road
- 15m wide x 33m long rock cavern
- Constantly varying section
- Constant access required
- Fully tanked
- Sprayed membrane (Masterseal 345)
- Steel and polymer fibres
- Primary sprayed concrete
- Gunite smoothing layer

Figure 6: Queensway Subway

- Reinforced concrete invert
- Main tunnel unreinforced cast in-situ
- Leaks diverted to temporary invert drain
- Masterseal spray applied
- Several layers used
- Rough substrate
- 5-6mm thick
- Sprayed over sheet membrane at intersections
- Construction joints prepared with waterbar and sealant (Masterflex 900)
- Final inspection for leaks
- Permanent sprayed concrete applied directly onto Masterseal
- 600mm thick applied in 2-3 layers
- Minimal rebound (<10%)
- Survey check then final layer, no fibres
- Escalator adit fully reinforced sprayed concrete

Figure 6 shows the completed subway at Queensway.

Shafts – Kai Tak Transfer Drainage Scheme

Drainage Services Department

- 1.9km long storm water transfer tunnel
- Six shafts
- Four shafts by the one-pass shotcrete method
- Circular: 7.0-8.5m I.D.
- Depth: Max. 21.0m
- Shotcrete One Pass Temporary and Permanent lining
- Foam Concrete Backfill for TBM Entry
- R.C. Base Slab & Roof Slab
- Pipe piles installed
- Excavate 2.0m
- Steel ring beam installed
- Excavate 2.0m and shotcrete Primary layer 200mm x 1.5m
- Shotcrete Permanent layer 100mm x 1.0m
- Float finish Permanent layer
- Pipe piles installed
- Excavate 2.0m
- Steel ring beam installed
- Excavate 2.0m and shotcrete primary layer 200mm x 1.5m
- Shotcrete permanent layer 100mm x 1.0m
- Float finish Permanent layer
- Early Strength 16MPa at 12 hours
- Excavate 1.5m
- Fix hydrophilic and grout tube strips
- Shotcrete primary layer 200mm x 1.5m
- Shotcrete permanent layer 100mm x 1.5m
- Float finish permanent layer
- Repeat three-day cycle
- Detail of shotcrete overlap showing grout tube hydrophilic strips
- Construction joint 1.3m long
- No membrane, no leaks
- Float finish as good as cast in-situ lining form

Figure 7

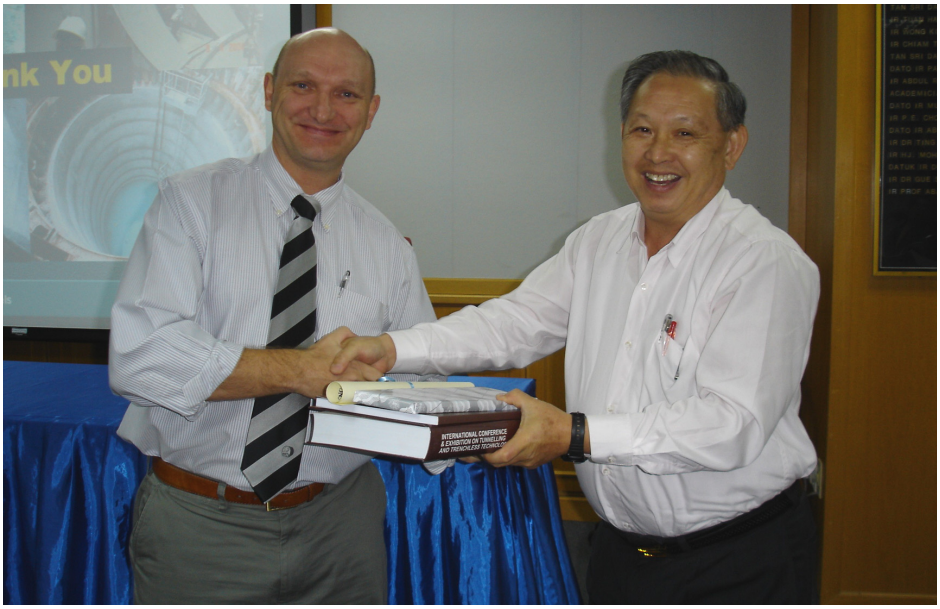


Figure 8

The talk on permanent work spray concrete was indeed very informative and it attracted some 90 participants.

Figure 7 shows a section of the participants in the IEM hall.

The talk ended at 7.30 p.m. with numerous interesting questions from the floor. Dr Ooi, on behalf of the Tunnelling and Underground Space Technical Division presented Salisbury with a memento as a token of appreciation (see Figure 8). ■