Project Case Study
Tengmieshan Highway Tunnel
Xishuang Banna, Yunnan PR China

Prepared by:
Hydrotech Asia Limited
20/F Queens Centre
58-64 Queens Road East
Tel (852) 2865 6600 Fax (852) 2865 6606
www.hydro-usl.com

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Hydrotech

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1.0 Introduction

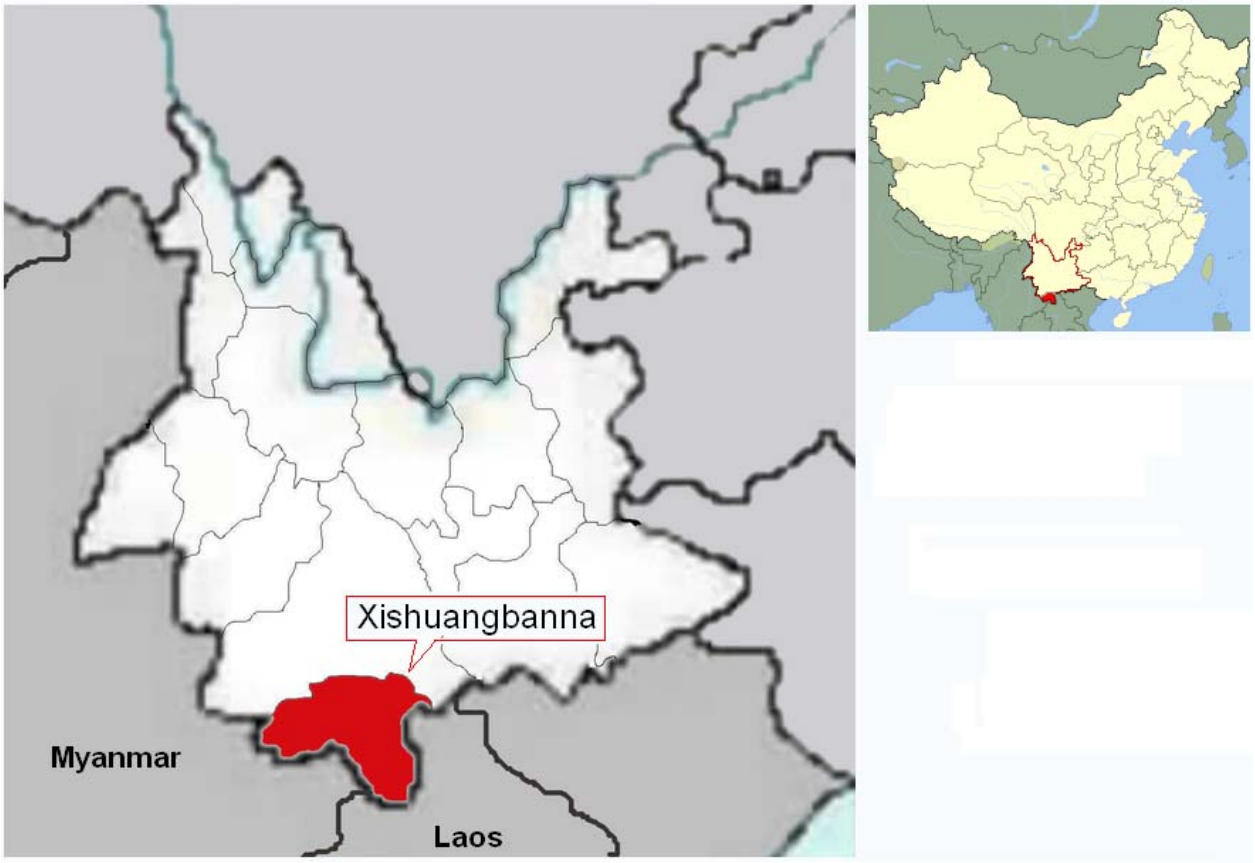
Hydrotech Asia Limited and Hydrotech China Company Limited, herein referred to as “Hydrotech”, were appointed by the Kunming Municipal Government under the Highway Maintenance Department to install the MPS System in their existing highway tunnel located at Tengmieshan, Xishuang Banna, Yunnan Province, PR China.

Hydrotech was given 15 days to mobilise and install the MPS System during the period 5 to 22 January 2009. The client’s instruction was to complete the MPS installation before the Chinese Lunar holidays which started on 25 January 2009.

2.0 Project Location

Tengmieshan Tunnel is 1 hour drive south from Jing Hong, the capital city of Xishuang Banna.

Xishuang Banna 西双版纳 is an autonomous region in Yunnan Province. It has an area of 19,700 sq km and is the home of the Dai people. Jing Hong is the largest settlement in the area and one that straddles the Lancang River (or Mekong River).



3.0 General Description of Tengmieshan Highway Tunnel

Tengmieshan Highway Tunnel is 3km long and has been constructed with a cast in-situ reinforced concrete lining. The height of the tunnel is 7.7metres and the width is 13.7metres. Maintenance lay-by bays of 3.1 metres width are provided at intervals along the tunnel. The typical section of the tunnel and lay-bys is shown in Figure 1.

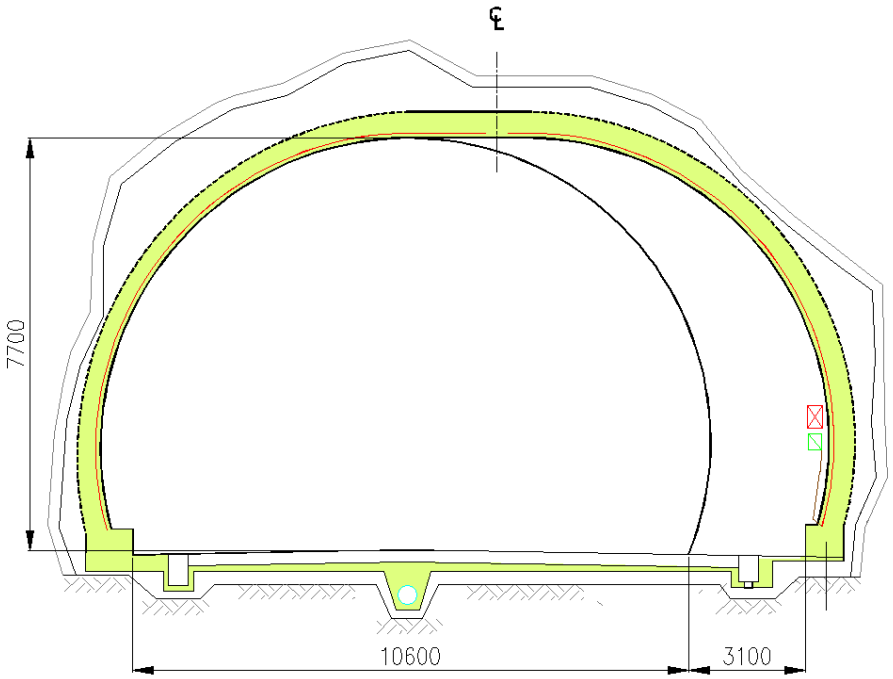


Figure 1

Tunnel Technical Details:

1. Thickness of tunnel lining: 400 to 450mm
2. Spacing between construction joints: 6000mm
3. Concrete compressive strength: C25
4. Concrete cover: 50mm

4.0 Problem Statement

Tengmieshan Tunnel was completed in 2007 and already has a water ingress problem from the body of the concrete lining and from the construction joints in the lay-by area at the mid-section of the tunnel.

Various measures have been used to try to control the water ingress, such as drilling holes in the lining and providing drainage pipes. The installed remedial drain pipes were eventually clogged with debris less than 6 months after they were installed and the ingress of water has continued despite these measures.

During the initial site visit, it was observed that water ingress is originating from the following locations:

1) Through the gaps between the construction joints;
2) Through the body of the concrete structure by capillary action;
3) Through the hairline cracks in the concrete lining.

A typical construction joint shows the flow of water through the 400mm thick concrete tunnel lining, refer to Figure A.

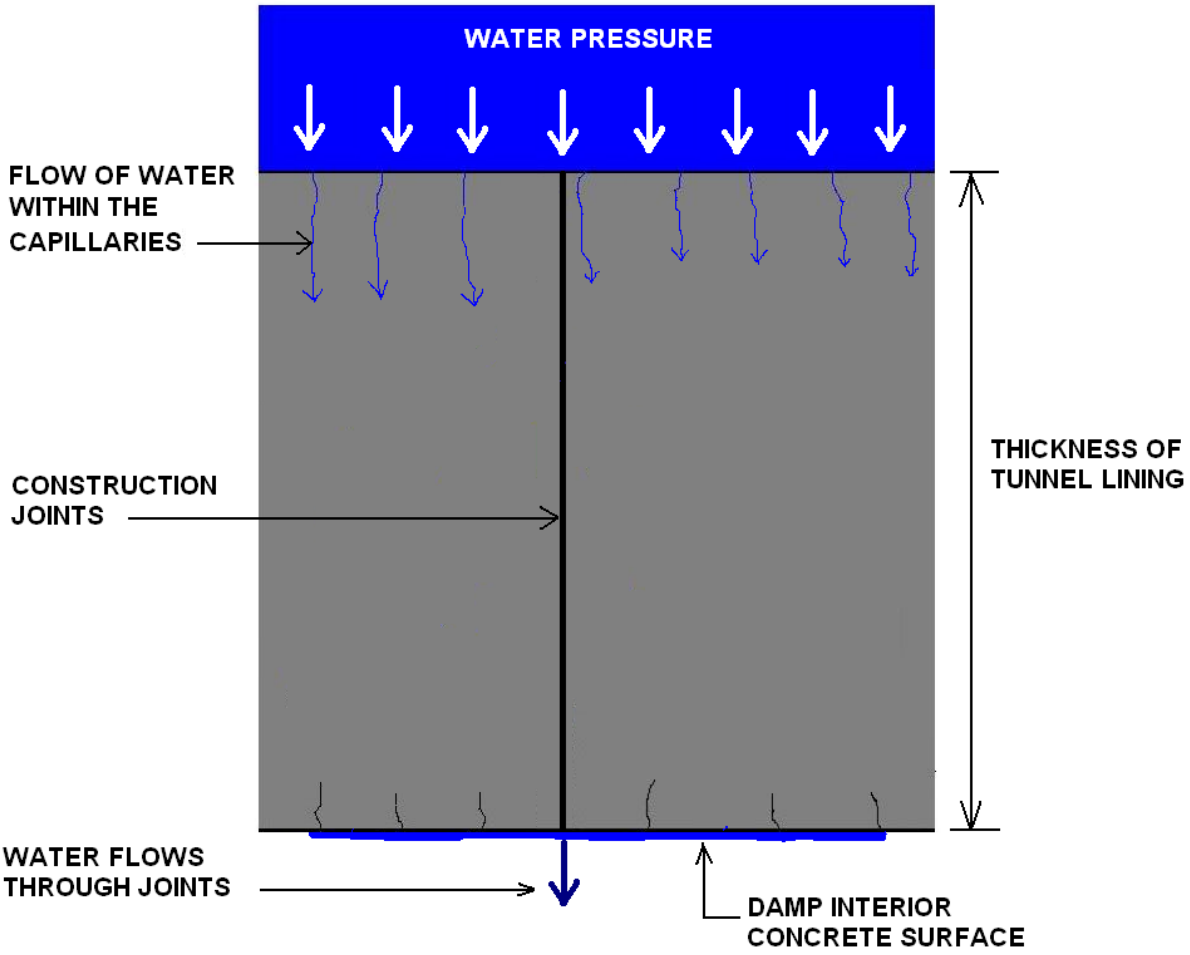


Figure A

Condition of Tengmieshan Tunnel prior to MPS Installation

Existing drainage pipes have failed to prevent water ingress at the joints

Possible corrosion of existing reinforcement embedded inside the tunnel lining

Condition of Tengmieshan Tunnel prior to MPS Installation

Signs of concrete degradation and failure of sheet membrane

Signs of high water pressure behind the tunnel lining

Condition of Tengmieshan Tunnel prior to MPS Installation

Signs of dilapidation of tiles and efflorescence

5.0 Hydrotech's Scope of Works

The scope of works by Hydrotech for Tengmieshan Tunnel was as follows:

- Provide a comprehensive MPS System design to cater for the existing tunnel condition over the trial MPS area of 720 square metres.
- Supply all materials for the MPS System including control unit, junction box, titanium wire, cathodes, feeder wires and connectors necessary to complete the installation.
- Provide all the necessary tools for the installation.
- Provide technical training to the workers with regards to the extent of works to be carried out on site.
- Supervise the installation of the MPS System.
- Determine the extent and supervise the injection works for cracks and construction joints.
- Test, commission and provide final results report for the MPS System.

6.0 MPS System Design

The MPS System is an electro-osmosis system that uses low voltage and low current levels to ionise water within the capillaries of concrete and actively repel water out of the structure.

The MPS Control Unit generates a repeating cycle of positive and negative pulses of DC current at a voltage not exceeding 40 volts, with specific rest periods. The pattern of timing of the pulses is selected to generate an electro osmotic effect to expel water from the capillaries in the concrete efficiently and without any significant loss of functionality over a term of at least 10 years. Each MPS Control Unit is capable of providing an efficient water expulsion effect over a total concrete surface area of up to1,500 square metres.

The MPS System design for Tengmieshan Tunnel was to cater for its submerged condition, deteriorating concrete structure and uninterrupted traffic flow. The MPS System was installed one traffic lane at a time.

The five major components of the MPS System are:

a. Titanium wires referred to as Anodes
b. Copper rods referred to as Cathodes
c. Junction box
d. MPS Control Unit
e. Anode and Cathode feeder wires

A typical MPS System layout diagram indicating the location of each major component is shown in Figure B.

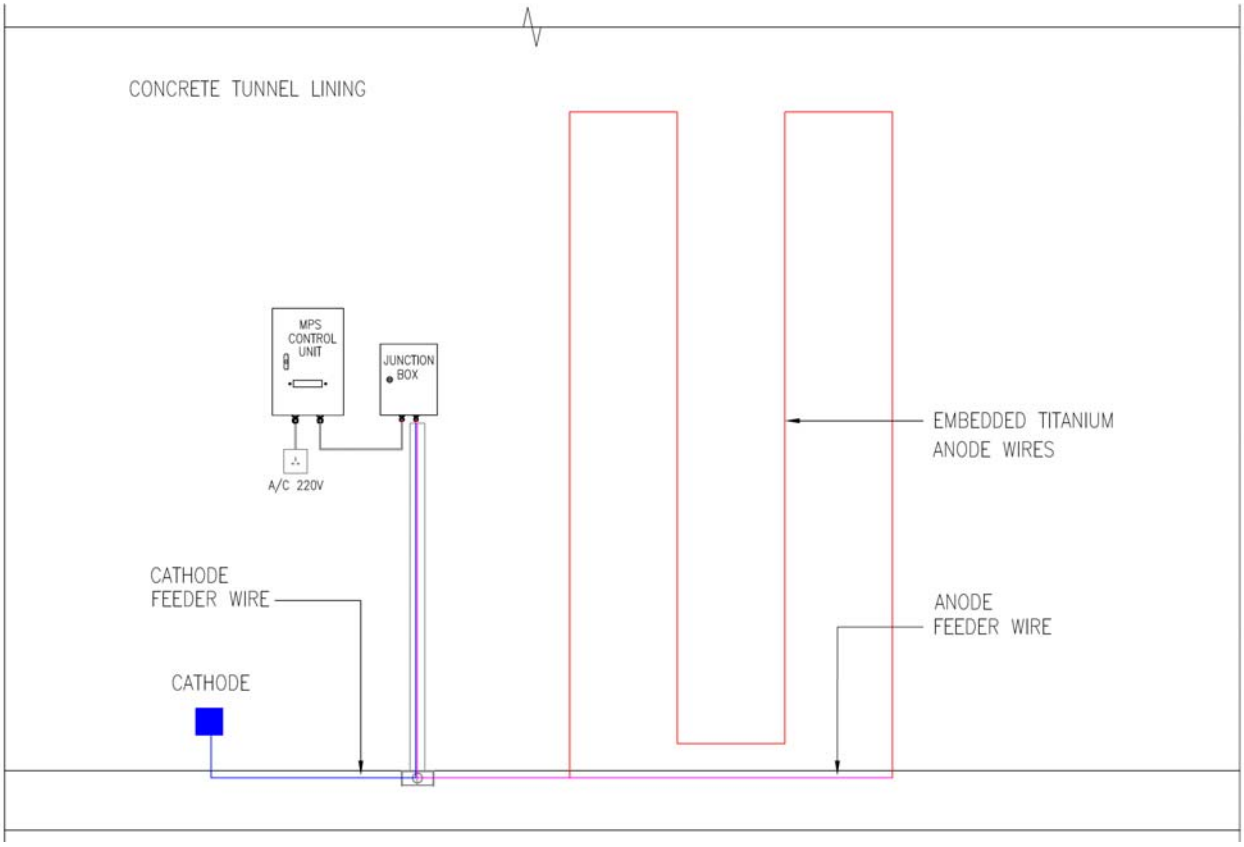


Figure B

To counter the serious water ingress within the body of the concrete and construction joints. Hydrotech designed the anodes to be located at both sides of the joints at approximately 100mm distance from the construction joint. A force field barrier is created by the MPS System and repels the water back to the opposite side of the tunnel lining, refer to Figure C.

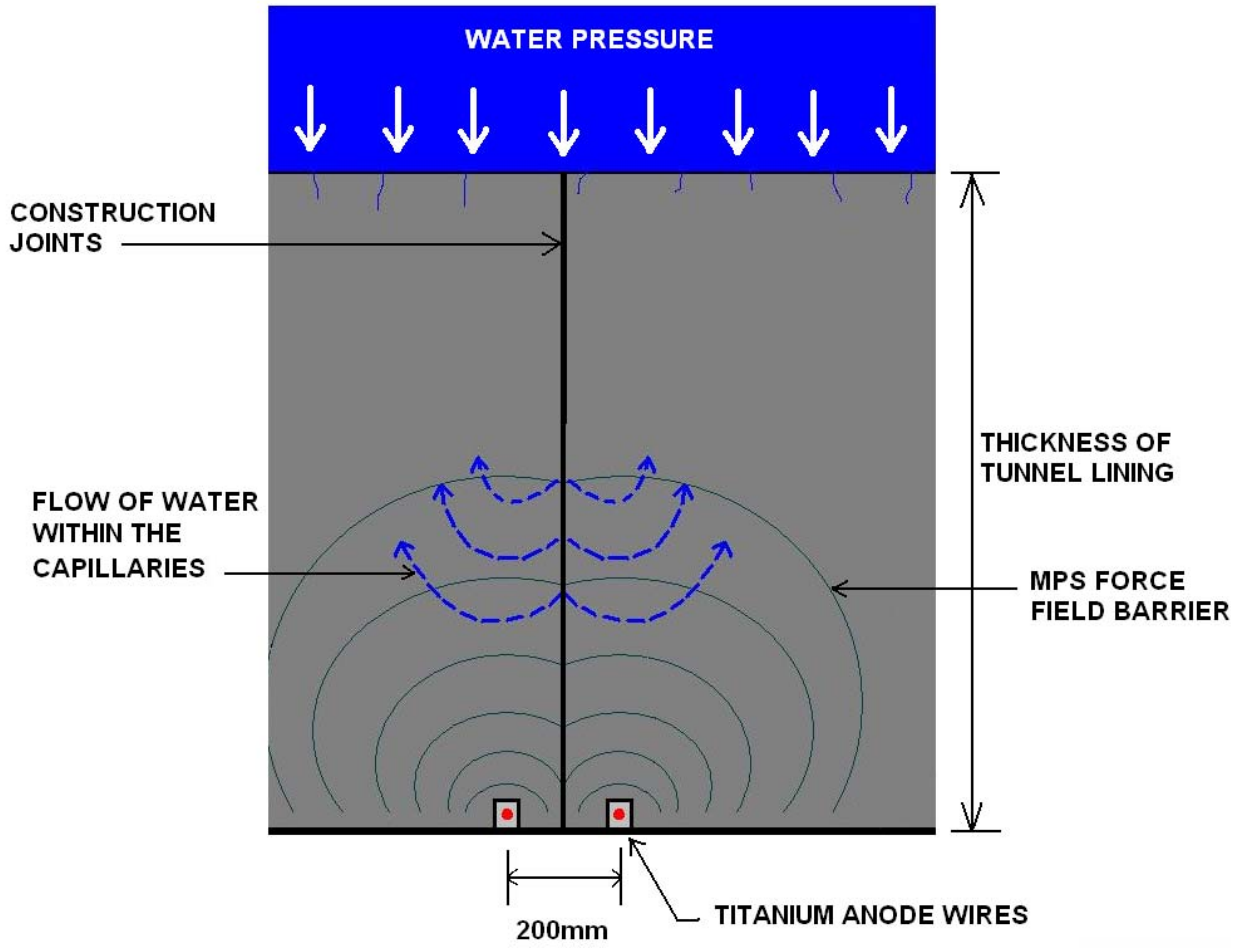
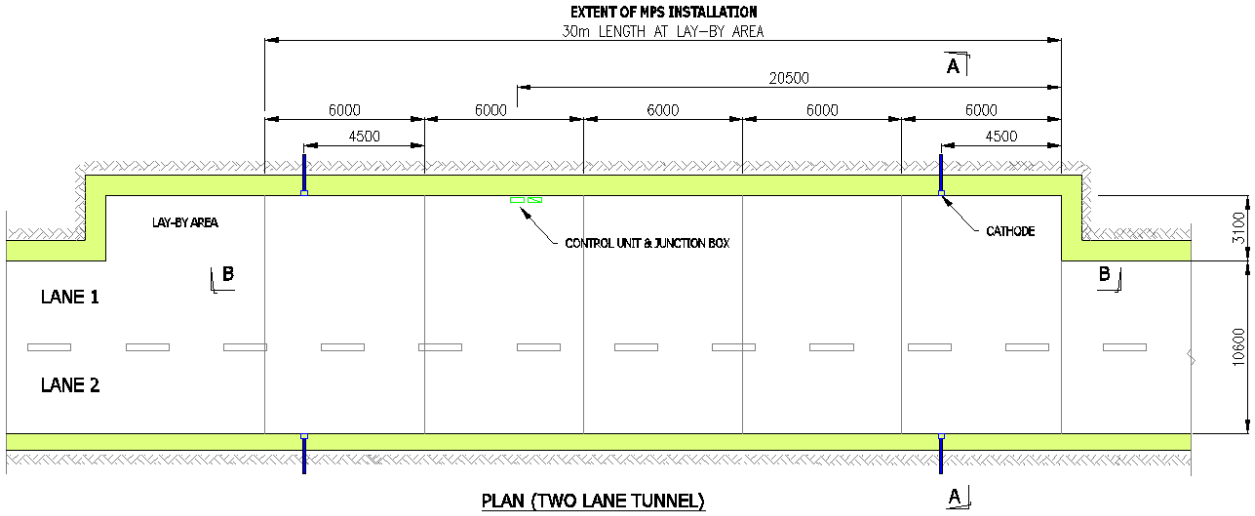


Figure C

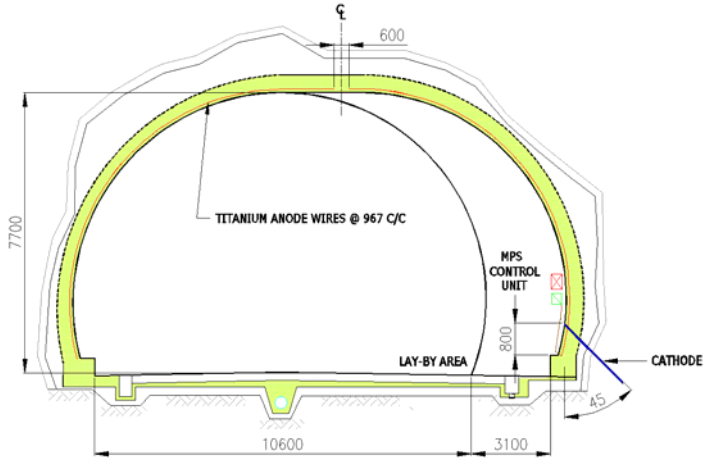
Summary of MPS System Design:

Total length of titanium anodes: 1,100m
Anode spacing: 967mm c/c and in-between joints
Total number of cathodes: 4
Total length of feeder wires: 1,400m
Total length of trunking system: 50m
Total Area = 720sqm

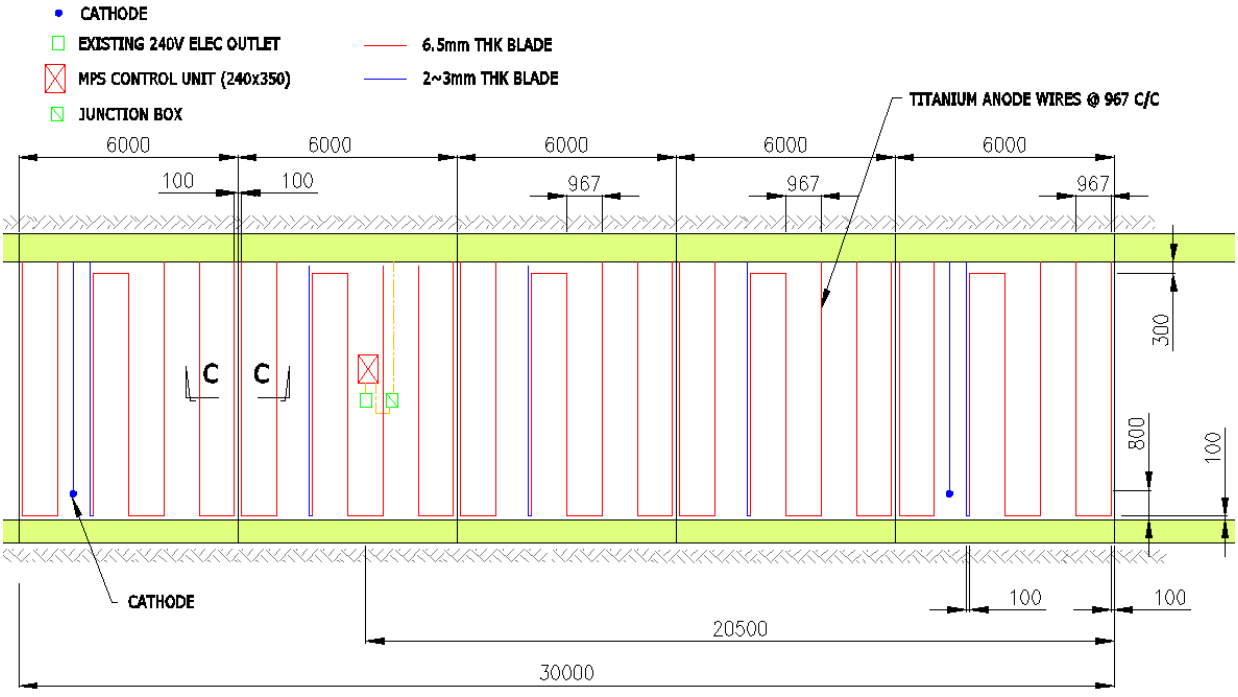
General Layout of MPS System



PLAN (TWO LANE TUNNEL)



SECTION A-A



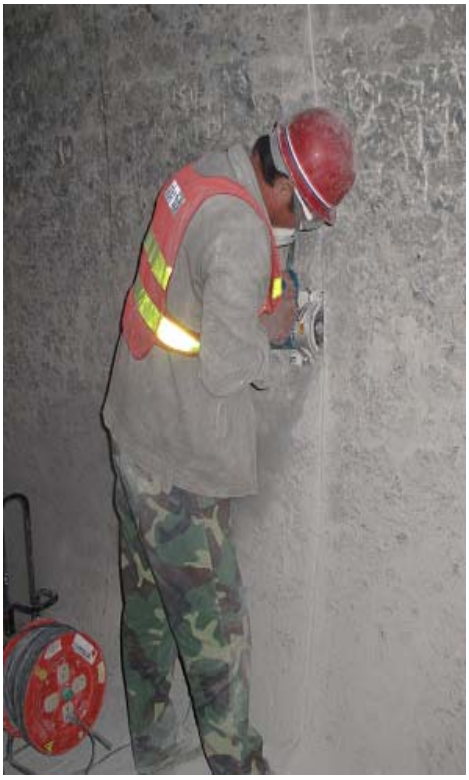
SECTION B-B

7.0 MPS System Site Installation

Rebar Locator

Relative Humidity Test

pH Testing



Saw Cutting

Titanium Wire Installation

Grouting

Cathode Installation

Trunking System Installation

Feeder Wire Connection

MPS Control Unit Installation

Control Unit to Junction Box Wiring Connection

Hydrotech provides technical support for site engineers and foreman

Completed Tunnel Installation

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8.0 Electrical Current Readings and Relative Humidity readings at the Concrete Surface

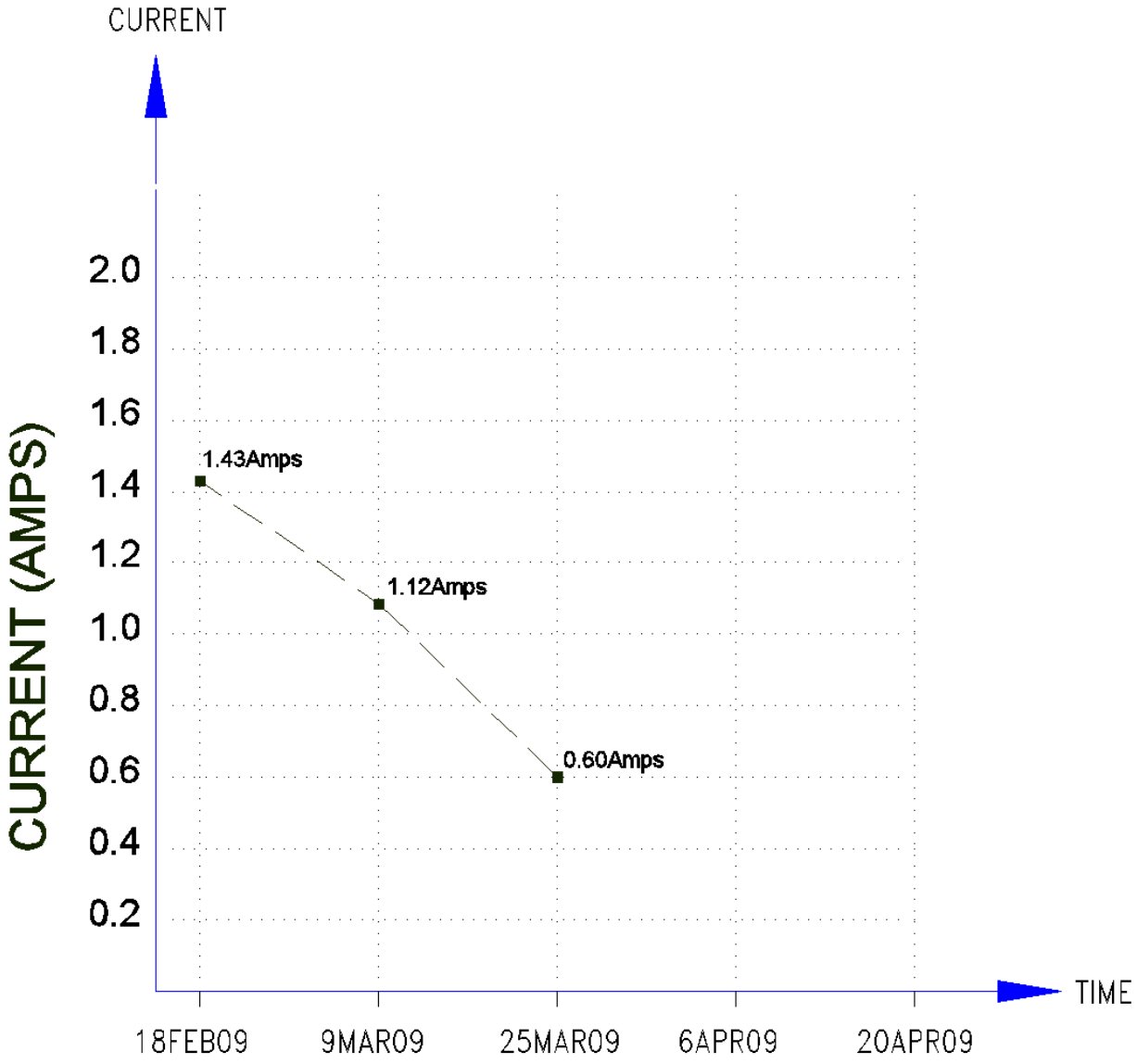
Date of site visit:	18-Feb-09	9-Mar-09	25-Mar-09	
Weather:	Sunny	Sunny	Sunny	
Temperature:	25°C	28°C	29°C	
LCD Reading:	71-73%	54-57%	16%	
Anode	Amps	Amps	Amps	Remark
Circuit 1	2.47	2.66	2.84	▲
Circuit 2	2.04	2.70	2.52	▼
Circuit 3	1.94	1.18	2.71	▲
Circuit 4	1.66	2.89	3.89	▲
Circuit 5	1.30	1.12	0.25	▼
Circuit 6	1.69	0.82	0.39	▼
Circuit 7	1.12	1.06	0.32	▼
Circuit 8	0.89	0.82	0.19	▼
Circuit 9	1.38	1.28	0.15	▼
Circuit 10	1.27	1.47	0.33	▼
Circuit 11	1.19	1.02	0.22	▼
Circuit 12	1.94	1.67	0.45	▼
Circuit 13	1.66	0.86	0.30	▼
Circuit 14	0.89	0.62	0.21	▼
Circuit 15	1.35	1.19	0.13	▼
Circuit 16	2.34	1.42	0.39	▼
Circuit 17	1.61	0.96	0.29	▼
Circuit 18	1.96	0.94	0.30	▼
Circuit 19	1.43	1.36	0.25	▼
Circuit 20	1.35	1.15	0.29	▼
Circuit 21	1.06	0.71	0.25	▼
Circuit 22	0.78	0.68	0.11	▼
Circuit 23	0.89	0.43	0.10	▼
Circuit 24	1.09	0.49	0.17	▼
Circuit 25	1.08	0.90	0.19	▼
Circuit 26	0.87	0.47	0.07	▼
Circuit 27	1.51	0.72	0.26	▼
Circuit 28	1.37	0.82	0.15	▼
Circuit 29	1.37	0.67	0.16	▼
Circuit 30	1.48	0.65	0.22	▼
AVERAGE	**1.43**	**1.12**	**0.60**	▼
All (1-15)	2.38	2.64	2.09	▼
All (16-30)	2.38	2.23	1.75	▼
All (1-30)	5.24	5.80	3.67	▼
Cathode				
Circuit C1	1.04	1.18	0.67	▼
Circuit C2	1.65	0.66	0.35	▼
Circuit C3	3.93	4.60	2.47	▼
Circuit C4	3.43	3.47	2.31	▼
All (C1-C4)	5.23	4.26	3.74	▼

9.0 Relative Humidity readings at the Concrete Surface

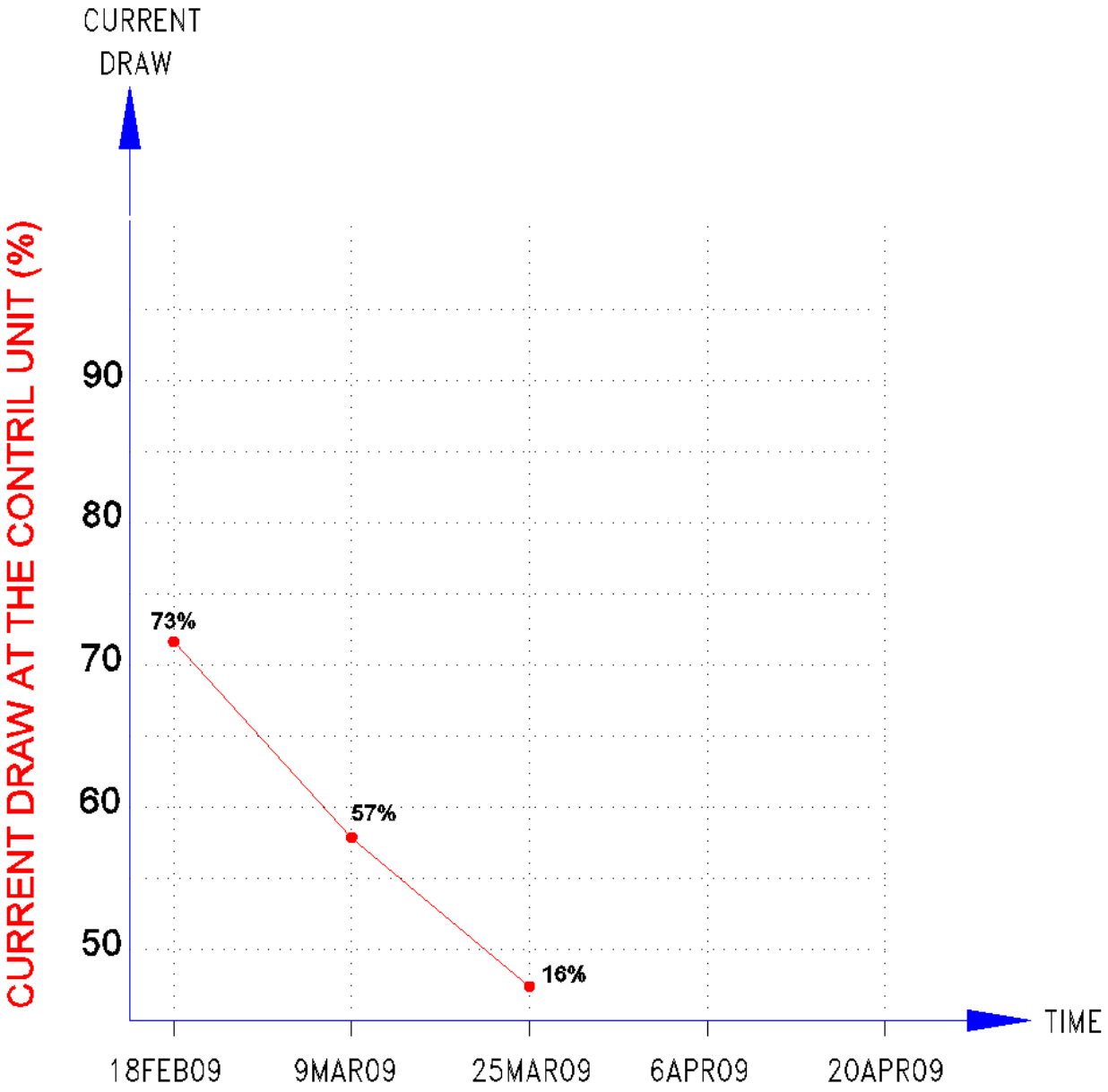
Date of site visit:	18-Feb-09	9-Mar-09	25-Mar-09		
Relative Humidity	%WME	%WME	%WME	%WME	%WME
RH1	21.60	20.50	28.10	▲	
RH2	93.60	24.00	21.40	▼	
RH3	21.00	27.60	19.70	▼	
RH4	20.50	18.40	13.50	▼	
RH5	30.50	28.60	25.70	▼	
RH6	59.00	52.00	42.80	▼	
RH7	82.00	61.40	52.90	▼	
RH8	96.10	25.00	22.30	▼	
RH9	96.10	18.90	16.10	▼	
RH10	49.00	33.40	25.70	▼	
RH11	96.10	60.20	58.40	▼	
RH12	96.10	51.40	42.60	▼	
RH13	50.00	71.20	61.40	▼	
RH14	20.60	20.40	16.60	▼	
RH15	27.20	17.50	18.60	▲	
RH16	35.40	18.40	12.50	▼	
Average	55.93	34.31	29.89	▼	
Note: Refer to attached drawing for the location of RH's.					

10.0 Graphical Performance Data Plots

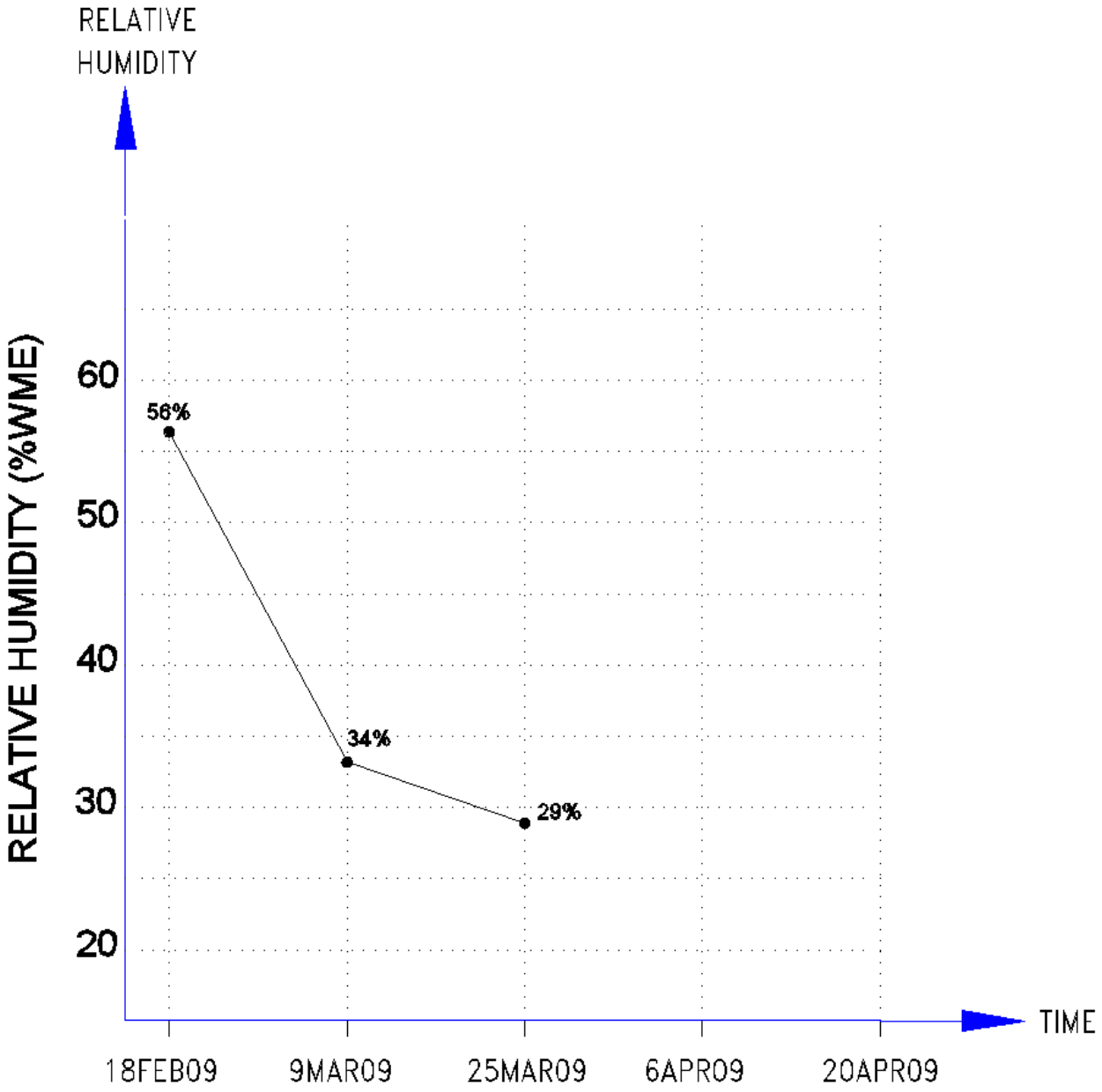
a. Average Current Readings



b. Current Draw of the Control Unit
(LCD Reading)



c. Average Relative Humidity Readings



11.0 MPS System Performance at the Concrete Lining

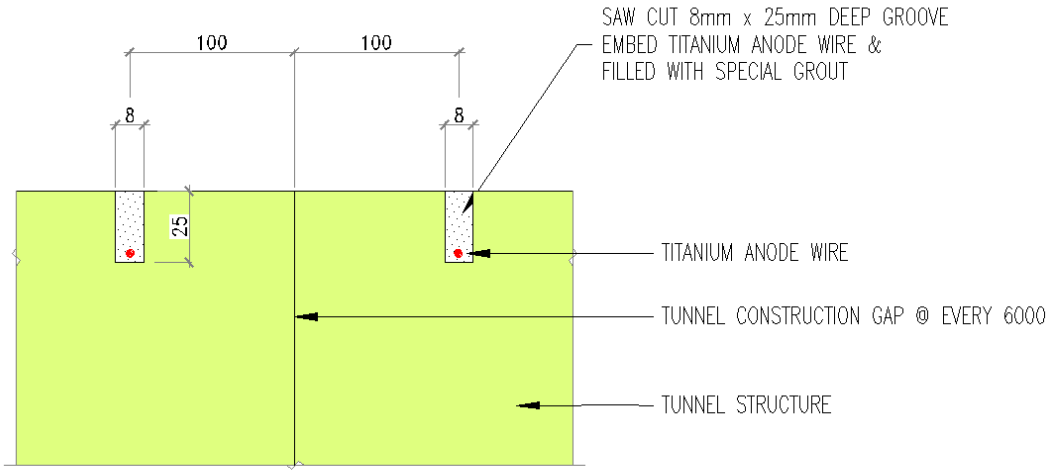
Based on the results of the current readings submitted by the maintenance engineer; the average current readings for all 30 circuits was reduced from 1.43Amps, 1.12Amps & 0.60Amps. The current draw from the Control Unit also dropped from 73%, 57% & 16% from 18 February 2009 to 25 March 2009, respectively.

The reduction in current flow between the anodes and cathodes is due to the fact that dry concrete has a lower conductivity than wet concrete. Thus these reducing current flows are a positive proof that MPS system is operating properly and drying-out the concrete.

These readings had shown consistency with the average Relative Humidity Readings on the concrete surface of the tunnel lining which significantly dropped from 56% to 29%.

12.0 MPS System Performance at the Construction Joints

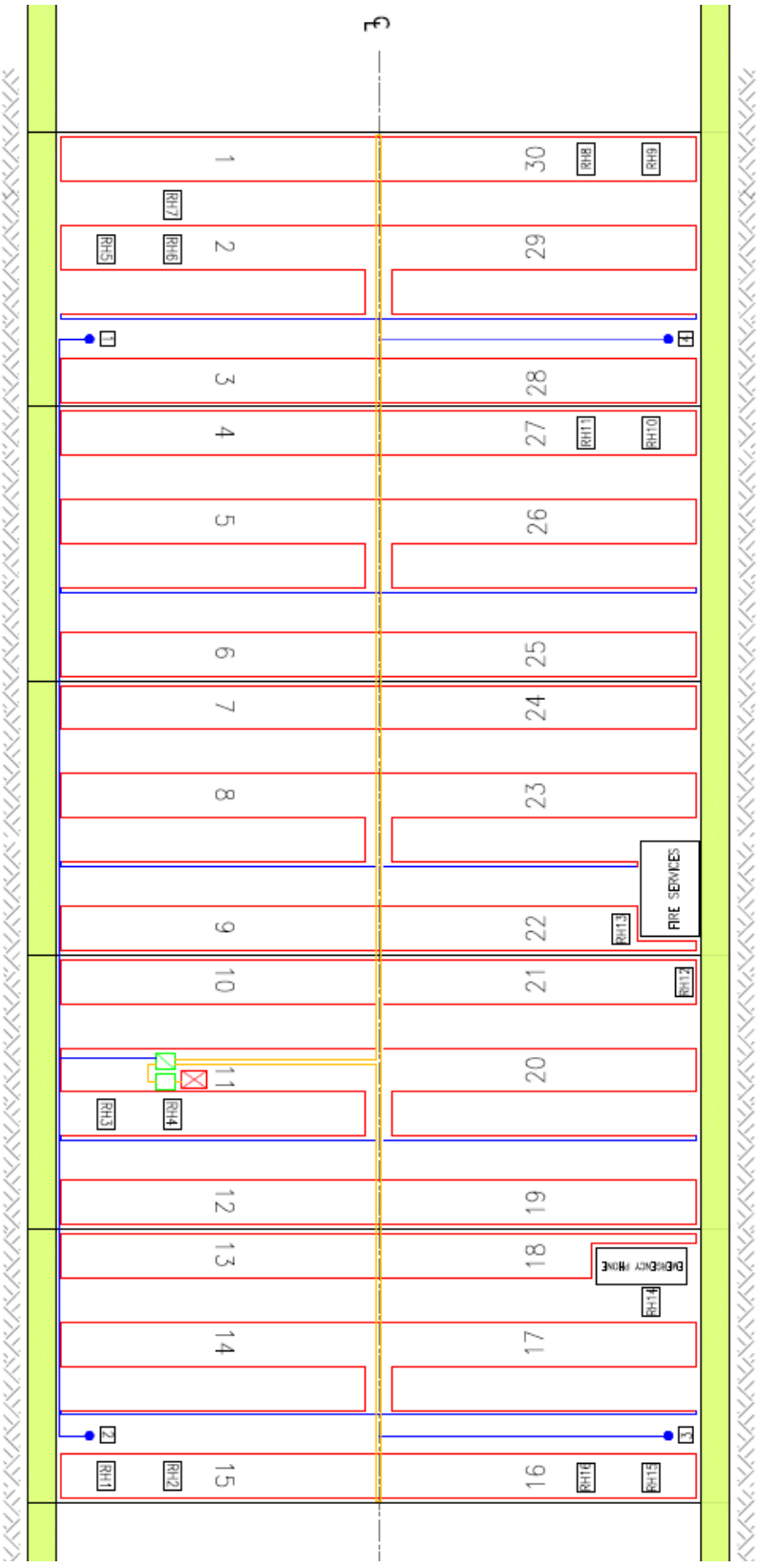
The moisture reading located at the construction joints was also significantly reduced. The MPS installation details for construction joints are shown in the Figure D below.



TUNNEL CONSTRUCTION JOINT DETAIL

Figure D

13.0 MPS Design Drawing



Final MPS System Design for Tengmieshan Tunnel

14.0 Electrical Power Consumption of MPS Control Unit

LCD Reading (25 March 2009) = 16%

Max capacity of MPS Control Unit = 10Amperes

Voltage output = 40volts

Power = (Current)(Voltage)

Units: Power = Watts
Current = Amperes
Voltage = Volts

Current = 16% of 10Ampere = 1.60Amps

Power = (1.60Amps)(40volts) = 64watts = 0.064kilowatts (kW)

Therefore, the electrical power consumption of 1 MPS Control unit for one year is:

(0.064kW)(24hours)(365days/year) = 560kilowatt-hour/year

15.0 Conclusions from the trial

15.1 MPS is an efficient and proven technology for preventing water ingress in concrete structures including tunnels.

15.2 MPS is effective in stopping water inflow through construction joints and large cracks when the MPS application is combined with conventional crack injection methods.

15.3 MPS keeps concrete in a dry condition which prevents corrosion of reinforcing steel, achieves large savings in maintenance costs and extends the design life of the structure.

15.4 MPS is relatively simple to install and can be applied in repair works or in new tunnel construction.

15.5 MPS is an environmentally friendly system with low running costs and no negative impacts.

15.6 Conventional systems which drain water from the tunnel will draw down the ground water in the mountain and can have severe effects on growth of trees, vegetation and soil erosion. MPS repels ground water back into the mountain and maintains the ground water levels.

15.7 MPS is reasonably economical to install, particularly if it replaces the plastic membrane in new tunnels. Savings in maintenance and extended tunnel life will achieve overall costs benefits.

15.8 This trial has been successful in a severely leaking tunnel which indicates that MPS can be applied to treat all cases of water ingress in tunnels.

15.9 While the tunnel was leaking severely, this trial has been conducted in the “dry” season. Monitoring of the trial will continue during the “wet” season to confirm the performance when the water table rises.

APPENDICES

- Tengmieshan Site Photos
- Works Programme
- Work Rates
- Installation Equipments
- Material Specifications
- Compliance Certificate for Railway Environment
- Qualification Certificate
- Testimonial Letters
- Frequently Asked Questions

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Tengmieshan Site Photos

Existing Site Condition – Existing drain pipes was clogged, tiles are in dilapidated condition

Existing Site Condition at the opposite side of the tunnel

Setting-out of anodes, 100mm distance from the construction joints

Saw Cutting Works – Lower Tunnel Lining

Saw Cutting Works – Upper Tunnel Lining

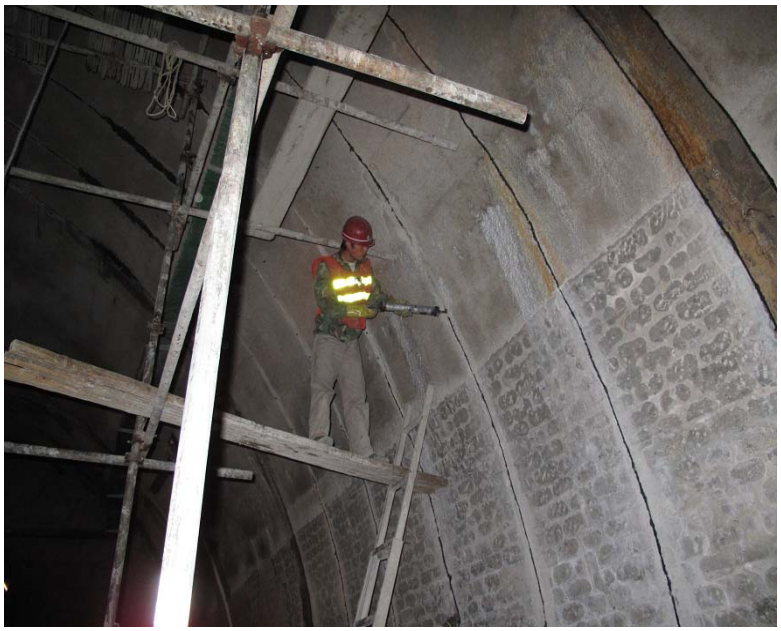

Checking of grooved depth and cleaning of grooves



Cathode drilling and installation

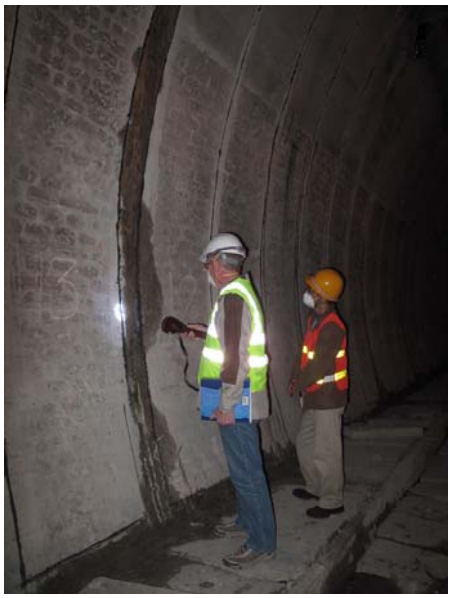


Titanium Wire Installation and grout preparation

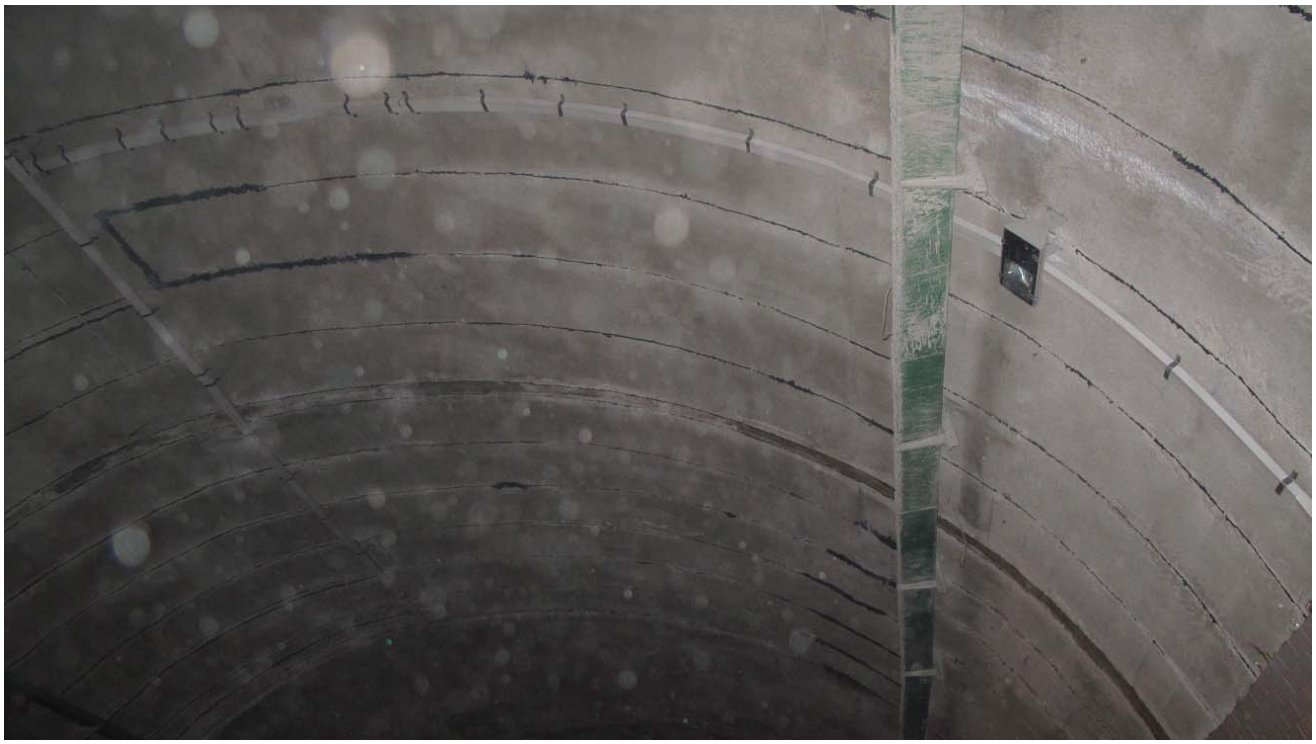
Grouting works at lower and upper level of the tunnel lining

Completed grouting and injection works



Inspection of works

Preparation of feeder wires and installation



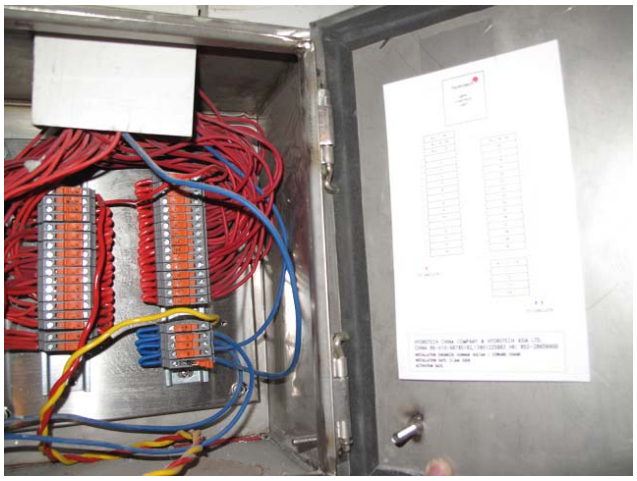
Installation of PVC trunking system

Connecting the feeder wires to the junction box

Installation of Junction Box and MPS Control Unit

Completed MPS installation works


Testing and Commissioning of MPS System witnessed by Client Representatives

MPS Control Unit was activated in 18 Feb 2009 with an initial LCD Reading of 74%

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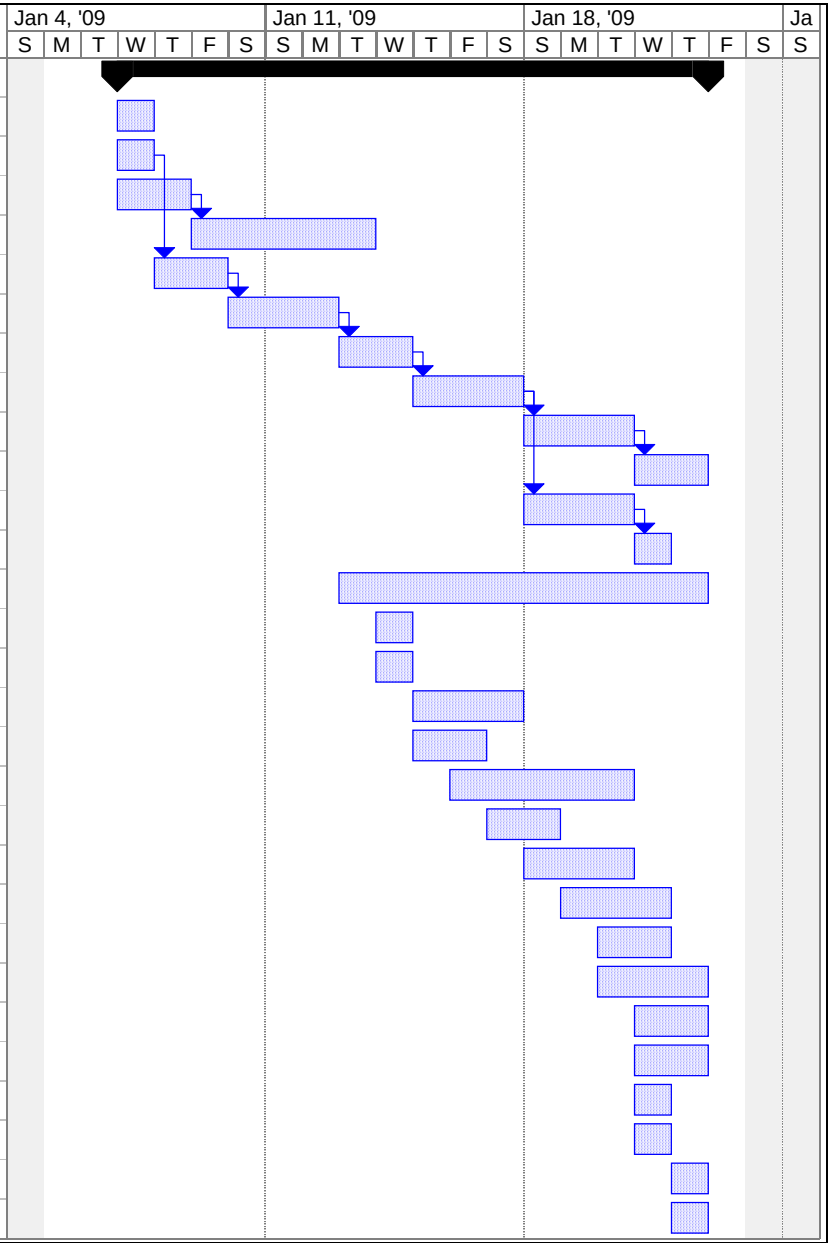
Works Programme

ID	Task Name	Duration	Start	Finish
1	**MPS Installation - Yunnan Highway Tunnel**	**16 days**	**Jan 7 '09**	**Jan 22 '09**
2	Briefing of site workers	1 day	Jan 7 '09	Jan 7 '09
3	Removal of tile finished (half-side of tunnel)	1 day	Jan 7 '09	Jan 7 '09
4	Installation of scaffoldings	2 days	Jan 7 '09	Jan 8 '09
5	Setting out of anodes	5 days	Jan 9 '09	Jan 13 '09
6	Setting out of cathodes	2 days	Jan 8 '09	Jan 9 '09
7	Saw cutting works (half-side of tunnel)	3 days	Jan 10 '09	Jan 12 '09
8	Drilling of cathode 1	2 days	Jan 13 '09	Jan 14 '09
9	Cleaning of groove	3 days	Jan 15 '09	Jan 17 '09
10	Installation of titanium wire	3 days	Jan 18 '09	Jan 20 '09
11	Drilling of cathode 2	2 days	Jan 21 '09	Jan 22 '09
12	Grouting works	3 days	Jan 18 '09	Jan 20 '09
13	Dismantle of scaffolding	1 day	Jan 21 '09	Jan 21 '09
14	Injection works	10 days	Jan 13 '09	Jan 22 '09
15	Removal of tile finished (opposite side of tunnel)	1 day	Jan 14 '09	Jan 14 '09
16	Installation of scaffoldings	1 day	Jan 14 '09	Jan 14 '09
17	Setting out of anodes	3 days	Jan 15 '09	Jan 17 '09
18	Setting out of cathodes	2 days	Jan 15 '09	Jan 16 '09
19	Saw cutting works	5 days	Jan 16 '09	Jan 20 '09
20	Drilling of cathode 3	2 days	Jan 17 '09	Jan 18 '09
21	Cleaning of grooves	3 days	Jan 18 '09	Jan 20 '09
22	Installation of titanium wire	3 days	Jan 19 '09	Jan 21 '09
23	Drilling of cathode 4	2 days	Jan 20 '09	Jan 21 '09
24	Grouting works	3 days	Jan 20 '09	Jan 22 '09
25	Installation of trunking system	2 days	Jan 21 '09	Jan 22 '09
26	Preparation of feeder wires	2 days	Jan 21 '09	Jan 22 '09
27	Installation of Junction box	1 day	Jan 21 '09	Jan 21 '09
28	Installation of Control unit	1 day	Jan 21 '09	Jan 21 '09
29	Wiring Connection	1 day	Jan 22 '09	Jan 22 '09
30	Testing and Commissioning	1 day	Jan 22 '09	Jan 22 '09



Project: Yunnan Works programme
Date: Apr 13 '09

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

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Work Rates

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Work Rates

1.0 Stripping-off of wall tiles using hand chisel:

1 sqm per 45 minutes per 1 worker

2.0 Replacing of wall tiles including mixing of grout:

1 sqm per 25 minutes per 1 worker

3.0 Erection of scaffolding:

Dimension: 12m length, 6m wide, 4m high
Area: 12x6=72 sqm
72 sqm per 3 hours per 4 workers

4.0 Dismantling of scaffolding:

Dimension: 12m length, 6m wide, 4m high
Area: 12x6=72 sqm
72 sqm per 1 hour per 4 workers

5.0 Saw cutting (Anode) using 6.5mm thick concrete blade:

Less than 2.0m high;
18m per day per 1 worker

More than 2.0m high;
15m per day per 1 worker

6.0 Saw cutting (Feeder wire) using 2.0mm thick concrete blade:

Less than 2.0m high;
25m per day per 1 worker

More than 2.0m high;
20m per day per 1 worker

7.0 Grouting (Anode) using applicator gun including mixing and refilling:

Less than 2.0m high;
1m per 8 minutes per 1 worker

More than 2.0m high;
1m per 15 minutes per 1 worker

8.0 Grouting (Feeder wire) patch-up method:

Less than 2.0m high;
1m per 5 minutes per 1 worker

More than 2.0m high;
1m per 8 minutes per 1 worker

9.0 Trunking system installation:

2.5m per hour per 2 workers

10.0 Feeder wire installation:

5m per hour per 1 worker

11.0 Mounting of Control Unit (more than 2.0m height):

1 control unit per 3 hours per 2 workers

12.0 Mounting of Junction Box (less than 2.0m height):

1 Junction Box per 2 hours per worker

13.0 Wiring connection (Feeder wires to Junction Box):

For 30 circuits, 3.5 hours

14.0 Cathode installation including drilling & preparation:

From 1 Cathode per day per 2 workers to
1 Cathode per 1.5 days per 2 workers

15.0 Crack injection including drilling and packers installation:

1 meter per 15mins per 2 workers

Notes:

1) 1 day = 8 hours
2) Indicated rates are assumed that materials are readily available on site.

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Installation Equipments

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List of Equipments
设备清单

1.0 Cover Meter 面层测厚仪器

2.0 Concrete Cutter with spare blades 混泥土切割机刀片备件

3.0 Heavy Duty Vacuum Cleaner 重型吸尘器

4.0 Grout Applicator 灌浆器

5.0 Concrete Drill with Bits 混泥土钻与钻头

6.0 Other tools: 其它工具：

- 6.1 Crimp tools 卷曲工具
- 6.2 Hot Air Gun 热气枪
- 6.3 Silicone Sealant Gun 硅酮密封胶枪
- 6.4 Stainless steel spatula 不锈钢刮铲
- 6.5 Sledgehammer 大锤
- 6.6 Industrial Markers 工业标记笔
- 6.7 Industrial Brush 工业刷
- 6.8 Heavy duty Electrical Extension Cord 重型电拖板
- 6.9 Plastic bucket 塑料桶
- 6.10 Water spray 喷水罐

1.0 Cover Meter 面层测厚仪器

Electronic Metal Finder

Measurement of Concrete Cover

The exact position and orientation of rebars can be measured quickly and accurately. Rebar-free areas can be identified for coring, grinding, resurfacing, or insertion of new machinery mountings.

The instrument can be used to inspect new structures for compliance with specifications as well as old structures under modification.

混泥土保护层的测量仪器

可以快速和准确的测量钢筋确切的位置和方向。可以确定无钢筋区域便于取芯，研磨， 重铺或插入新的机器装置。

该仪器可用于检查新结构是否符合规格， 以及正在改装的旧结构。

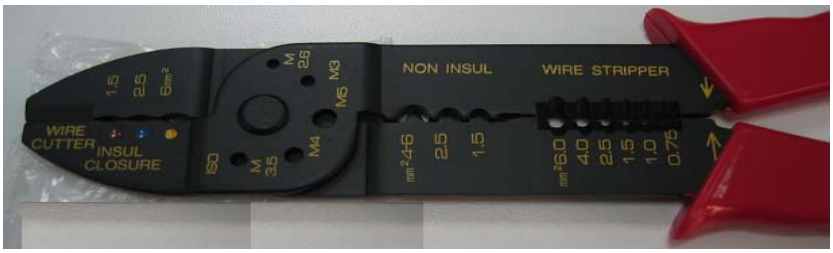
2.0 Concrete Cutter with spare 6.5mm to 8mm thick Blades
混泥土切割器及 6.5mm 至 8mm 厚刀片

3.0 Heavy-Duty Vacuum Cleaner for Industrial Use
重型工业用吸尘器

4.0 Grout Applicator 灌浆器

5.0 Concrete Drill with Bits ranging from 20mm to 25mm (300 to 600mm length) 混泥土钻与 20 毫米到 25 毫米（300 毫米到 600 毫米长）的钻头

6.0 Other tools:
其它工具：



6.1 Crimp Tools 卷曲工具

6.2 Hot Air Gun 热气枪

6.3 Silicone Sealant Gun 硅酮密封胶枪

6.4 Stainless Steel Spatula 不锈钢刮铲

6.5 Sledgehammer 大锤

6.6 Industrial Markers – Pencil, String Marker or Chalk
工业标记 - 铅笔，标记绳或粉笔

6.7 Industrial Brush with strong bristles 强硬毛的工业刷

6.8 Electrical Extension Cords 电拖板

6.9 Plastic Bucket for Mixing Grout 调灌浆用的塑料桶

6.10 Water Spray 喷水罐

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Materials Specifications

MPS System – Materials Specification

1) Titanium Wire
Titanium Grade 1 wire dia 2.030mm,tol +/- 0.0203

2) Water stop
Sika 4A waterstop or Rapid 1

3) Non-Shrink Mortar Cement
Non-Shrink Cementitious Mortar, 5 Star Grout or equivalent

4) Cathode rod
14 to 16mm diameter copper coated rod or equivalent earth rod

5) Splice Connectors with adhesive
Duraseal blue sealed splice terminals, RS Components order number 533-667

6) Ring Terminals with adhesive
Duraseal blue sealed terminals; RS Components order number 465-687

7) Isolating Terminals
Short blade isolating terminals 4mm, RS Components order number 627-3440

8) Jumper bars
EB10-6 From Phoenix Action UK, or Electroskandia, Norway

9) Heat Shrink Tubing with adhesive
HTAT Adhesive lined Heatshrink tubing, RS Components order number 344-0619

10) Din Rail
Top hat din rail 1.0 plain RS ORDER no 424-131

11) Graphite Powder
10micron, 99% pure Graphite Powder

12) General Cable
For Anode; 1.5mm^2 (or 1.38mm diameter) Brown or Red
For Cathode; 2.5mm^2 or 4.00mm^2 (or 1.78mm diameter) Blue

13) Containment or Trunking System
50mm x 50mm Galvanized mild steel rectangular trunking

Hydrotech

UK & EU Compliance Certificate For Railway Environment

York EMC Services Limited · The University of York · Heslington · York YO10 5DD · Tel +44 (0) 1904 434440 · Fax +44 (0) 1904 434434

York EMC Services Ltd

Competent Body Certificate

Name and address of client:	Equipment included in TCF
Underground Solutions International Ltd., 2101 Asian House 1 Hennessy Road Hong Kong	Manufacturer: Underground Solutions International Ltd.
	Type or model No: EPS/MPS System (prototype)
	Client Ref: 2152TCF1 dated 20 November 2006

Competent Body Statement

From the information presented by Underground Solutions International Ltd. in Technical Construction File 2152TCF1, dated 20 November 2006 and the supporting documentation, it is our view that Underground Solutions International Ltd. have reasonably demonstrated that the 'as built' EPS/MPS System (prototype), build state as at 21 September 2006, meets the protection requirements Article 4 of the EMC Directive 89/336/EEC when used in a railway environment as defined in the EN50121-X series of standards.

Reference should be made to the Competent Body if significant changes, likely to affect the EMC performance, are made to the system during production and use and also for subsequent installations.

Issued by:	York EMC Services Ltd., University of York, Heslington, York, YO10 5DD, UK.	
Certificate number:	2285CBC1	**Page 1 of 1**
Date of issue	09 January 2007	

Prepared by	Approved by
Graham Whyte, HND	**Chris Marshman, BEng, MPhil, CEng, MIET, MIEEE, MIoD**

York EMC Services
A DTI appointed Competent Body

Hydrotech

Qualification Certificate

Qualification Certificate

Product Origin: Norway			Product Inspector: John Sagen	
Hydrotech R&D Ltd Sognshøy Næringspark Postboks 73 Sognshøy N-1641 Råde Norway			John Sagen Test and Development Engineer	
Product	**Batch ID**		**Count**	**Remarks**
MPS v2	Order date 2007-11-05		30	Serial 0101 to 0130
Control unit specific	**Prod. date**	**Test date**	**Status**	**Test standards**
Serial number: 0127	2007-14-05	2007-18-06	OK	EN50121-X / EN61558

All final assembly and testing is conducted at Hydrotech Research & Development facility in Norway.

Sub contractor production:

Norteam Electronics as is an ISO 9001-2000 certified electronics manufacturer and all products from Norteam is manufactured according to ISO standards

Norteam Electronics as
Industriveien 3
Box 26
N-2020 Skedsmokorset

NORTEAM ELECTRONICS AS

Hydrotech

Testimonial Letters

Transport for London
London Underground

Department: Technical Assurance
Ext/Direct: 0207 027 9596
Fax: 0207 027 9607
Our ref: BCV06020-COM-C002
Your ref: PBE00043-LUL-COP-01
Date: 14th May 2008

RECEIVED
16 MAY 2008
PBE00043

BCV CONT
NAME | ACTION
M·Henn ✓

AO-15389

Mr R. Peake
Professional Head Civils, Stations and Facilities
Metronet Rail BCV Ltd
Templar House
81-87 High Holborn
London
WC1V 6NU

London Underground
Engineering Directorate (ED)
Southside
105 Victoria Street
London SW1E 6AD
Phone 020 7222 5600
www.tfl.gov.uk/tube

Dear Bob,

PBE00043: Walthamstow Central Subway EPS Installation and Trial - Completion

Thank you for the above Completion submission, received 17th April 2008 under cover of letter PBE00043-LUL-COP-01.

Please be advised that ED have no objection with respect to the above submission and therefore give our approval.

Please distribute this letter within your organisation as necessary. If you require any further information please do not hesitate to contact, in the first instance, Garry Gilby; to whom any future submissions/correspondence related to this project should be sent.

Yours sincerely,

Andy Guest
Head of Station, Civils and Power Engineering

Copy to: D. Wilson, DC BCV(CPO), F. Blanchard (MRBCV), File

Q:\A06.0 COMPLIANCE\A06.01 COMPLIANCE PROJECTS\A06.01.01 IBCV\BCV06020_T492_Walthamstow Central Subway EPS Installation and Trial\C003 Completion lono _lw_20080514.doc

MTR Corporation Limited
香港鐵路有限公司
www.mtr.com.hk

11 April 2008

TO WHOM IT MAY CONCERN

This is to certify that the performance to date of the Multi-Pulse Sequencing System installed in 2000 (under Contract No. R4206.A-00C) behind the artwork at the Central Subway in Hong Kong Station has been acceptable.

Yours faithfully

Teresa Tang
Procurement & Contracts Manager – Operations

MTR Headquarters Building, Telford Plaza, 33 Wai Yip Street,
Kowloon Bay, Hong Kong. GPO Box 9916, Hong Kong.
Tel (852) 2993 2111 Fax (852) 2798 8822

香港九龍灣偉業街33號德福廣場港鐵總部大樓
香港郵政總局信箱9916號
電話 (852) 2993 2111 傳真 (852) 2798 8822

MTR Corporation Limited
香港鐵路有限公司
www.mtr.com.hk

Our Ref: LCD/MCB/009

11 April 2008

Hydrotech Asia Ltd.
20/F Queen's Centre
58-64 Queen's Road East
Hong Kong

Attn: Mr Peter Arbon, General Manager Asia

Dear Sirs

Contract No. R4206.A-00C
Artwork Repair II – HOK Central Subway

Following review of your request as stated in your letter J002/0052/PA/WC dated 9 April 2008, please find attached our reference letter for your record.

Yours faithfully

Teresa Tang
Procurement & Contracts Manager – Operations

TT/cf

P&CD-MCB/MCB009/Hydrotech-I1.doc

MTR Headquarters Building, Telford Plaza, 33 Wai Yip Street,
Kowloon Bay, Hong Kong. GPO Box 9916, Hong Kong.
Tel (852) 2993 2111 Fax (852) 2798 8822

香港九龍灣偉業街33號德福廣場港鐵總部大樓
香港郵政總局信箱9916號
電話 (852) 2993 2111 傳真 (852) 2798 8822

SWIRE PROPERTIES

Our Ref: DLC/cc/L-003/2008
Please use this reference in your reply

21st January 2008

Hydrotech International Limited
20th Floor, Queen's Centre
58-64 Queen's Road East
Hong Kong

Attn: Mr Ian Dallas

Dear Mr Dallas,

Cityplaza Four Basement

We are pleased to confirm that three bays of basement wall at Cityplaza Four had been treated with EPS (currently known as MPS) Waterproofing System in 1999 and 2001.

The basement walls suffered from water seepage during the rainfall days. After the EPS application, the water seepage problem was resolved and the basement walls are now maintained in good condition.

To this end, we are of opinion that the EPS Waterproofing System is a practical solution to address water seepage problem at basement.

Yours sincerely,
For and on behalf of
SWIRE PROPERTIES MANAGEMENT LIMITED

Daniel Chang
Chief Building Surveyor

cc: CPMO – Malvin Lam / Sam Ko

Swire Properties Management Limited
21/F Cityplaza Three 14 Taikoo Wan Road Taikoo Shing Island East Hong Kong
Tel (852) 2844 4988 Fax (852) 2590 7502 www.swireproperties.com

恒基兆業地產有限公司
HENDERSON LAND DEVELOPMENT COMPANY LIMITED

28 December 2007

Hydrotech Asia Ltd.
20/F Queen's Centre
58-64 Queen's Road East
Hong Kong

Dear Sirs,

One International Finance Centre
Lift Motor Room for Lifts L4 and L5
MPS Waterproofing System

We are pleased to acknowledge the services that have been provided by Hydrotech Asia Ltd to provide a long-term remedy for water ingress problems in the Lift Motor Room (LMR) for Lifts L4 and L5, which is situated below Basement B4 at a level of -16.25mPD.

Despite treatment by traditional methods such as grouting and crack injection, the ingress of water through the walls of the LMR had persisted since the structure was taken over from MTRC. Early in the year 2000, a failure of the drainage sump pumps resulted in the LMR being flooded to a depth of 1.8metres, with consequent damage to some items of the M&E plant.

Hydrotech's MPS electro-osmotic system was installed in the walls of the LMR in July 2000 and within 3 months the ingress of water had effectively ceased and the relative humidity of the walls had been reduced from 98% to around 85%.

The MPS system has continued to operate satisfactorily over the 7 years since it was installed with minimal maintenance and a low level of power consumption.

Based on the performance of the MPS system in this instance, we have no hesitation in recommending it as an effective long-term means of preventing water ingress, reducing humidity levels and preserving the condition of concrete in new-build or existing underground structures.

Yours faithfully,
For and on behalf of
Henderson Land Development Co. Ltd.

David F. Dumigan
General Manager
Project Management (1) Department

香港中環金融街八號國際金融中心二期七十二至七十六樓
72-76/F, Two International Finance Centre, 8 Finance Street, Central, Hong Kong
電話 Tel (852) 2908 8888 傳真 Fax (852) 2908 8838 網址 Website: www.hld.com

Hydrotech

Frequently Asked Questions

Hydrotech

Frequently Asked Questions about the MPS System

Q1. What is the most common and probably the most difficult problem to solve in an underground structure such as a highway tunnel?

Water ingress is the most common and the most difficult problem to solve permanently. It can be a result of design issues, workmanship or maintenance. Water ingress can still occur even in very dense concrete, in fact, the denser the concrete the stronger are the suction forces within the capillaries.

Q2. How does water ingress occur?

Water penetrates the concrete fabric by three primary mechanisms: Capillary action, temperature differentials and hydraulic pressure. Capillary action is much more powerful than the force of gravity, as demonstrated by "rising damp" in buildings.

Q3. What is Capillary action?

Capillary action is the tendency of a liquid to rise in a narrow tube. It is a result of the cohesion[1] force between water molecules and the adhesion[2] force between those molecules and the solid material forming the walls of the tube. The more narrow the tube, the greater the rise of the liquid.

[1] Cohesion, the mutual attractive force that exist between the like molecules of a particular liquid.
[2] Adhesion, is the attractive force between two unlike materials, such as liquid and a solid container,

Q4. What is Electro-osmosis?

Electro-osmosis or Electro-osmotic flow is the motion of ions in a solvent environment through very narrow channels, or capillaries, where an applied potential across the channels cause the ion migration.

Q5. What is the MPS System?

The Multi-Pulse Sequencing (MPS) System is a highly advanced form of electro-osmosis technology that uses low voltage and low current to ionise water within the capillaries of the concrete or masonry lining and actively repels water out of the structure.

Q6. What is the history of the MPS Technology?

- In1807, the German professor Russ discovered the theory and principles behind the movement of liquids in capillary structures.
- In 1930, the Ernst brothers in Switzerland discovered how to move fluids in capillary structures through applying an electrical charge between positive and negative electrodes.

- In 1962, the theory behind the effect was established by E Franke. Subsequent experiments by Prof. Andreas Fourie at Newcastle University over a 10 year period failed to move water through concrete effectively, because there was no efficient control system.

- In 1987, the Norwegian inventor Kjell Aage Utklev discovered that a pulsating current would continue to transport water in concrete for as long as the current was applied.

Q7. What are the basic components of the MPS System?

The basic components are anode circuits (Titanium wire), cathodes (copper rods or stainless steel plates), a junction box and a Control Unit.

Q8. How does the MPS System work?

The Control Units of the MPS system produce a low voltage electric current which is passed through the anode circuits which are installed on the internal faces of the concrete tunnel lining.

Water within the capillaries in these concrete linings will be ionized and the water molecules will travel towards the cathodes which are placed in the ground outside the concrete lining. Thus an electro-osmotic force field will be created around the anodes that will prevent water and moisture from intruding back into the tunnel.

Q9. Why do MPS Systems use Titanium wires?

Based on research carried out by our development team in Norway, Titanium wire has been selected due to its high strength, high resistance to corrosion and good electrical conductivity.

The spacing of the Titanium wires will be selected by our designers depending on the site conditions, grade and thickness of concrete tunnel lining being treated, and other factors such as age and alkalinity.

Q10. Where is the best location for the cathodes?

The cathodes should be placed at locations where the ground behind the tunnel lining is expected to be most wet. Site testing is required to determine the appropriate locations for the cathodes.

Q11. How much water pressure can the MPS System repel from the concrete capillaries?

The electro-osmotic force acting on the ionised water in the capillaries is stronger than both gravity and capillary action. The MPS System has proven successful in preventing the penetration of water in the turbine chamber of a dam structure against a pressure of 600 metres head (60bar).

Q12. Can MPS Systems be installed in both existing and new-build structures?

Yes, MPS Systems can be installed in existing structures by saw-cutting small grooves in the interior surfaces of the walls, floors and ceilings as required. For new-build structures, the titanium wires can be installed in grooves which can be pre-formed in the concrete, or by saw-cutting grooves as for existing structures. Installation in new-build structures will generally cost significantly less due to better accessibility.

Q13. What is the scope of MPS applications?

MPS Systems can be installed in the following structures:

- Underground projects such as railway stations, car parks and all other basement structures.
- Tunnels such as road and rail, pedestrian subways, cable and gas tunnels.
- Hydroelectric and dam projects.
- Marine structures, underwater foundations and embankments.
- Bridges and viaducts

Q14. What are the limitations of MPS Systems?

The system can only be applied to capillary structures such as concrete, blockwork, brickwork and masonry structures.

Q15. Is the MPS System effective in treating larger flows of water through construction joints (CJs) or wider cracks?

The problem of leakage of water through CJs and cracks can be difficult to treat. If such joints or cracks are treated with conventional crack injection, the leakage often occurs again within 1 to 3 years and re-treatment is needed. However, the MPS System has proven to be quite effective in these cases. Anode circuits are installed on each side about 100mm from the CJ. Then a fast-setting water-stop grout or injection is used to initially stop the larger flow of water. When the MPS System is activated, the whole body of concrete either side of the CJ is dried out. This reduces the source of water, and any flow of water entering into the joint will be drawn in to the dry concrete on each side, and drawn out again towards the cathode.

Q16. Can the MPS System be applied on roofs?

Yes, the MPS System can be applied on roofs without the need to cut chases on the ceiling below the roof deck level. For further information on green roof applications, please email us at info@hydro-usl.com

Q17. Can the MPS System be applied on reinforced concrete elevated water tanks?

Yes, the MPS System can be applied both on new build and existing corroded water tanks installed on roof deck levels. For further information on applications for water tanks, please email us at info@hydro-usl.com

Q18. What are the other benefits of MPS Systems?

MPS Systems reduce the corrosive environment for steel reinforcement thus reducing ongoing cracking of the structure.

MPS Systems reduce the relative humidity inside the tunnel, reducing the corrosive environment for mechanical equipment and other fixtures such as tiling and paint finishes.

Pumping out of water from the tunnel is not necessary, saving energy and maintenance costs.

MPS Systems prevent peeling of paint, mould, mildew, unpleasant odours and reduce the incidence of water and air-borne bacteria.

MPS Systems stop efflorescence, which is a whitish, powdery deposit on the surfaces of structures, formed when mineral-rich water rises to the surface through capillary action and then evaporates.

Q19. How long will the MPS System protect the structure?

For as long as the Control Unit is activated, the MPS System protects the structure 24 hours a day, 7 days a week for its design life which exceeds 50years.

Q20. Is there any maintenance required after installation?

The MPS System utilizes high grade materials, has no moving parts and is virtually maintenance free. Once installed, apart from periodic checking of current levels, there is no need for ongoing maintenance. The system is essentially self-regulating and will continue to operate for many years without requiring any intervention.

We can provide an on-going maintenance service, essentially to read and report on the current levels in the system, or alternatively, we can provide training for the client's staff to monitor the operation of the system.

Q21. What is the voltage and power consumption of the MPS System?

The Control Units of the MPS system produce 20 to 40 volts electric current at a maximum of 10 amperes. The MPS Control unit will be activated 24 hours per day (24/7) and the approximate power consumption will be 40 watts per 1,500 square metres of area treated.

Q22. What is the capacity of a single MPS Control Unit?

One MPS Control Unit will control the water ingress for an area of approximately 1,500 square metres.

Q23. How does the MPS System handle large areas?

For large areas, one Control Unit will be provided for each area of 1,500 square metres. Thus the technology is the same for large or small areas.

Q24. How long will the structure take to dry out after the MPS System is installed?

From the time that the MPS System is energised, it usually takes about 4 to 6 weeks on average to dry out the concrete. Once the concrete is dry, it will remain in a dry condition providing the power is not switched off. The time taken for drying out can vary with the thickness and condition of the concrete and its degree of saturation, porosity, pH level and other factors.

Q25. What if the electricity supply fails when the MPS System is in operation?

In the event of a power cut, it will take at least as long for the water to get back into the concrete, as it did to dry it out in the first instance, and since it is unlikely that the power will be off for more than a few hours under normal conditions, the concrete will therefore still be protected from the problems of water ingress.

The MPS System employs circuit breakers and the system will need to be turned on again if there is a sudden power surge causing the circuit breaker to trip.

Q26. What are some MPS reference projects?

Our previous projects include:

- Walthamstow Station Pedestrian Subway (London Underground)
- Central Station Pedestrian Subway (MTRC)
- One IFC Lift Motor Room (Henderson Land)
- Cityplaza 4 (Swire Properties)
- Kowloon Warehouse Basements
- Hang Seng Bank Headquarters
- Zhengzhou Electric Cable Tunnel (Zhengzhou Cable Authority, Henan PR China)
- Oslo Central Railway Station
- The Norwegian National Museum
- Oslo Housing Society
- Oslo Ullevall Hospital
- Tafjord Dam, Norway
- Tonstad Power Station, Sira Kvina, Norway
- The Norwegian Building Research Station
- The Norwegian National Hospital

Q27. Can you provide testimonial letters from reputable companies and developers?

Yes, we have testimonials from London Underground, Hong Kong Mass Transit Railway (MTR) and major Hong Kong property developers Henderson Land and Swire Properties. Copies of these testimonials are included in this report.

Q28. What are the advantages of MPS Technology over existing methods of water proofing?

Membranes require great care in installation to avoid failure. One tear during construction can be enough to compromise the essential continuous integrity of a membrane and render the system ineffective. Membranes are applied to the outside of a tunnel lining and it is not generally feasible to repair or replace them. The design life of a typical membrane will be typically be 5-10years, and this is not adequate for highway tunnels with a design life of 50years or more.

Q29. What is the cost of MPS Technology?

The cost of an MPS system can be considered in two parts, Hydrotech's Cost and the Installation Cost.

Hydrotech's Cost covers the site evaluation, testing, system design, supply and delivery of materials, site supervision, commissioning, and a license fee to cover the use of our MPS technology. Hydrotech's Cost to cover this scope will vary with the site location and the size of the installation.

The Installation Cost covers the cutting or forming of the grooves for the titanium wires (including supply of labour and cutting equipment), placing and grouting of the titanium wires, installation of cathodes, electrical wiring, etc. The Installation Cost also includes liaison with the client re approvals for the installation works, and compliance with all local safety, labour and working regulations, and insurance requirements.

The Installation Costs will vary widely depending on whether it is a new-build application with 24 hour unobstructed access for the work, to the other extreme such as installation in an operating railway tunnel with restricted working hours, difficult access, obstructions from other services and stringent safety requirements. The client is able to have good control over the Installation Costs by using his own contractor to carry out the Installation Works under Hydrotech's supervision.

The cost of installing an MPS system in a new-build application can be offset by savings in deleting the costs of a conventional membrane system, as this will not be required if an MPS system is installed.

Also the installation of an MPS system will result in permanent dry conditions in the structure, which will result in extensive savings in long term maintenance costs. Please contact Hydrotech for site visit and quotation.

In the case of highway tunnels such as the Tengmieshan Tunnel, the total cost of MPS would be in the range of RMB180 to RMB250 per square metre (Hydrotech's Cost plus Installation Costs). These costs could be offset by deducting the membrane, which could save RMB80 to RMB120 per square metre.

Q30. Does Hydrotech provide a guarantee for the MPS System performance?

Yes, we provide a guarantee against water ingress for 20 years. Conditions for our guarantee are stated in our Guarantee Certificate, a copy of which can be provided upon request.

Q31. Will the MPS System affect the existing rebars?

No, this has been confirmed by independent tests carried out for stray current levels in the steel reinforcement by CAPSIS Report, Reference no. AH5541 Rev. 3 dated May 2007.

Q32. Will the MPS System affect the signaling or other control systems for Highway Tunnels or Underground Railway installations?

No, this has been confirmed following extensive tests carried out for Electro-Magnetic Compliance (EMC) by York EMC Services Ltd, Document No. 2285CBR1 dated 9 January 2007. The MPS technology has been granted a full European EMC compliance certificate. It has also satisfied all the stringent requirements for London Underground and Metronet in the UK in connection with EMC compliance for railway systems.

Q33. How does the MPS System differ from Cathodic Protection?

The MPS System is completely different from Cathodic Protection for the following reasons:

- Cathodic protection has sacrificial mesh whilst MPS System does not.
- Cathodic protection connects directly to the existing rebars whilst the MPS System does not.
- Cathodic protection does not dry out the concrete structure.
- Cathodic protection is many times more expensive to operate than the MPS System due to the high current draws.

Q34. Can the MPS System be installed in combination with sheet membranes for tunnel projects?

Generally we would recommend that it is not necessary to install a sheet membrane in at tunnel if an MPS System in installed. Experience shows us that we cannot rely solely on a sheet membrane system. When the sheet membrane behind the concrete lining is punctured, torn or split, this will allow continuous ingress of ground water through these breaches under hydraulic pressure. The MPS System can either completely replace a sheet membrane system or can also be used as a back-up system to control water ingress due to breaches in the membrane system.

Q35. Can the MPS System be installed where the interior concrete lining was sprayed with shotcrete?

Normally yes, depending on the permeability and the porosity of the shotcrete material. Water ingress may be more rapid in the areas constructed of shotcrete than of insitu concrete. Hydrotech will conduct insitu and/or laboratory tests to determine the condition of the shotcrete lining prior to the determination of the required spacing of positive electrodes suited for these conditions.

Q37. What are the performance objectives of the MPS System? What values of relative humidity can be achieved? What is the corresponding electricity consumption?

The performance of the MPS System can be measured by monitoring the electrical current readings in each circuit and the insitu relative humidity levels at or just below the concrete surface.

As an example, our installation at Cityplaza 4, Taikoo Shing showed that the initial relative humidity reading in Nov 1998 was 100% and the current reading was 200 milliamps. On Dec 1998, the relative humidity had reduced to 95% and the current reduced to 40 milliamps. The reduction in current results from the increased resistivity of the concrete as the moisture level drops.

Q38. How can the MPS System intelligently monitor the structure against water ingress?

The MPS System is essentially self-regulating. Should there be any increase of moisture content in the concrete for any reason; the electrical current flowing through the MPS system automatically rises proportionally to counter-act the water ingress penetrating into the concrete structure. That means that more current is being drawn from the Control Unit to counter the increased rate of water ingress into the capillaries.

Q39. Can the MPS System provide a permanent solution to water ingress problems?

Yes, the MPS System provides a permanent solution to water ingress because the electro-osmotic force field generated from the Control Units actively repels the water within the concrete capillaries, dries out the concrete structure, and protects the existing rebars from corrosion.

Q40. How can we contact Hydrotech Asia Ltd?

Hong Kong Office:
Mr. Peter Arbon & Mr. Tony McKee
Tel no. +852-2865 6600
Fax no. +852- 2865 6606
Email: peter.arbon@hydro-usl.com
Email: tony.mckee@hydro-usl.com

Beijing Office:
Mr. Jiang Nan
Tel no. +86-13901225883
Fax no. +86-10-6878 5183
Email: jiang.nan@hydro-usl.com