Planning Interventions

13 June 2008

Guy Bridges
Aecom Asia

Planning Interventions

AECOM

- TBM Cutterhead
- Cutter Wear
- Compressed air working
- Cutterhead Intervention
- Summary

TBM Cutterhead

AECOM

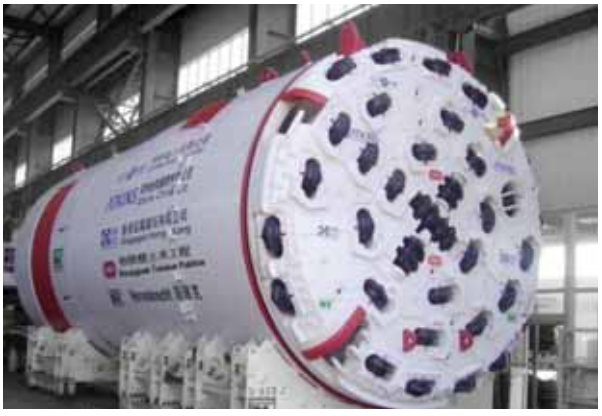
- **Slurry TBM / EPB TBM**
  - Closed face, cutterhead is pressurised
  - Typically disc cutters and picks
  - Stone crusher to break large rocks
  - Screw to remove spoil on EPB



TBM Cutterhead

AECOM

- **Double Shield TBM / Open Beam TBM**
  - Open face is not pressurised
  - Disc cutters only
  - Scrapers to remove spoil from face
  - Stone crusher




TBM Cutterhead

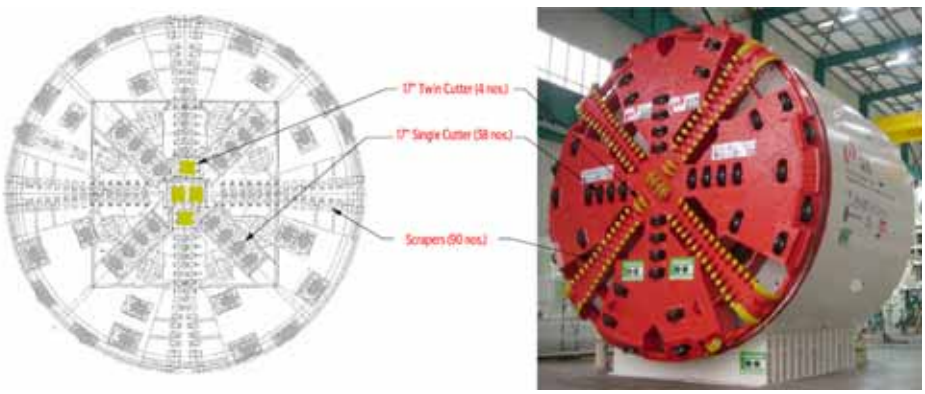
AECOM

- Slurry and EPB TBM's pressurise the cutterhead in soft and mixed ground conditions
- Double shield and Open Beam TBM's do not have pressurised cutterheads
- During interventions in soft and mixed ground, air pressure in the excavation chamber must balance the groundwater pressure in the ground
- Slurry TBM uses filter cake on the face to prevent air losses
- EPB TBM relies on cohesiveness of ground to prevent air losses

TBM Cutterhead

AECOM

- Cutter discs spaced at regular intervals to cut rock
- Twin cutters required in the centre
- Picks/scrapers if soft ground anticipated



TBM Cutterhead

- Disc cutters apply point load to the rockmass in a rolling action
- Create tensile forces that chip off rock fragments between each rolling track
- Cutters designed for back-loading

TBM Cutterhead

- Scrapers used to excavate soft ground
- Can wear or break off
- Replaced at routine interventions
- Cutterhead can wear
- Cutterhead repaired at major intervention
- Exposed surfaces must be armoured to prevent cutterhead wear

Cutter Wear

AECOM

Four main rock parameters affect cutter wear

- Unconfined Compressive Strength
- Tensile Strength
- Cerchar Abrasivity Index
- Mineral Content / hard and abrasive minerals

Cutter Wear

AECOM

- Rock properties
- Force on cutters
- Size of cutter

- Allow prediction of ‘average’ wear in uniform ground conditions

- May also need to tighten disc cutter mountings

Cutter Wear

AECOM

17 inch cutters – 50 to 90m^3 per cutter

Rock Type	Penetration Rate (mm/rev)	Wear Rate (m^3/cutter) ϕ 5.00 m	Wear Rate (m^3/cutter) ϕ 6.00 m	Wear Rate (m^3/cutter) ϕ 7.00 m
Granite	3.0 - 4.0	82 - 91	87 - 96	93 - 102
Granite	4.0 - 5.0	98 - 107	104 - 113	111 - 120
Meta Tuff	1.5 – 2.5	46 - 63	49 - 67	82 - 112
Meta Tuff	2.5 - 3.5	58 - 60	62 - 63	66 - 67

Higher penetration rate gives more rock per cutter

Larger diameter TBM gives higher average rock per cutter

Cutter Wear

AECOM

19 inch cutters – 80 to 130m^3 per cutter

Rock Type	Penetration Rate (mm/rev)	Wear Rate (m^3/cutter) ϕ 5.00 m	Wear Rate (m^3/cutter) ϕ 6.00 m	Wear Rate (m^3/cutter) ϕ 7.00 m
Granite	3.5 - 4.5	133 - 147	142 - 157	150 - 166
Granite	4.5 - 5.5	159 - 164	169 - 175	180 - 185
Meta Tuff	2.0 - 3.0	73 - 99	77 - 106	82 - 112
Meta Tuff	3.0 - 4.0	97 - 99	104 - 106	110 - 112

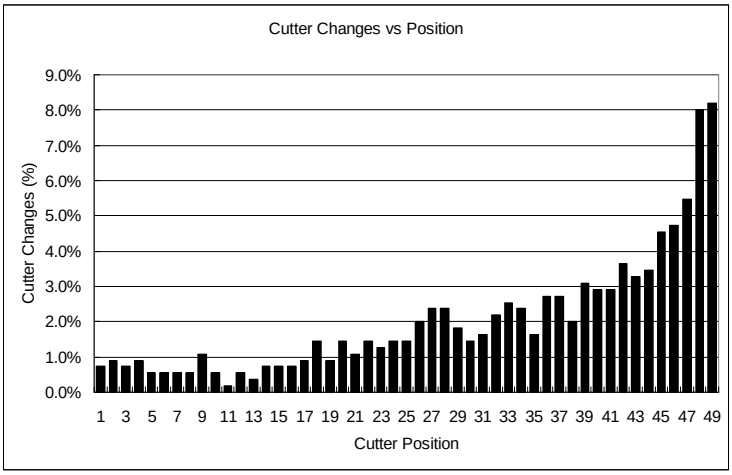
But at 200kg each are 50kg heavier than 17 inch cutters

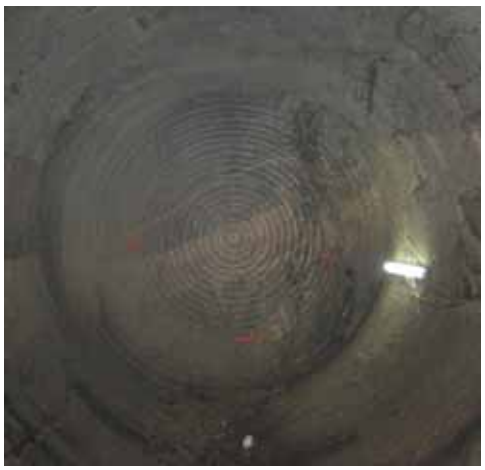
Twin cutter can weigh 335kg

Harder to handle in confined space

Cutter Wear

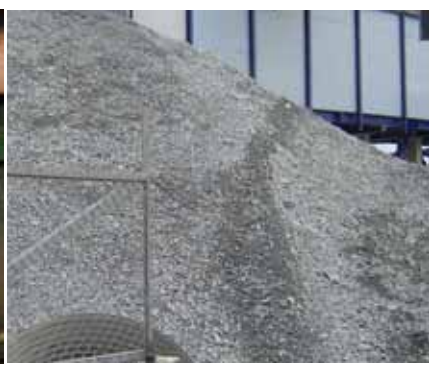
- Inner cutters travel a shorter distance
- More frequent changes of outer cutters
- Can move part worn cutters to centre locations
- Frequent Gauge cutter changes to ensure tunnel diameter





Cutter Wear

- Massive rock is cut as rock chips
- In mixed ground conditions large rocks may fall from the face
- Highly fractured rockmass allows easy cutting (ripping)



Cutter Wear

AECOM

- Mixed ground may create more or less wear

Compressed air working

AECOM

- Compressed air working controlled by Labour Department
- Emergency procedures approved by FSD
- Higher working pressures lead to shorter working times and longer decompression times
- Normal limit of compressed air working in Hong Kong is 3.45 Bar

Compressed air working

- Use of mixed gases (trimix) can extend working time
- Use of oxygen can reduce decompression times
- Very high working pressures require specialist techniques
  - Saturation diving
  - Slurry diving

Compressed air working

- Use of specialist techniques must be planned from the design stage
- TBM must be designed to accommodate necessary equipment
- Pre-planned major intervention locations may be included in the design
- First stage of planning interventions is to optimise the tunnel alignment to minimise the frequency and depth of interventions

Cutterhead Intervention

AECOM

These can be divided in to 3 types:

- Planned
- For total head inspection and re-building

- Routine
- For inspection and regular maintenance

- Unplanned
- Emergency inspection and maintenance

Cutterhead Intervention

AECOM

- In hard rock, can use free air if no significant groundwater inflow

- In soft ground and water bearing ground need compressed air

- Can plan Interventions based on prediction of ground conditions, and prediction of cutter wear and risk profile

Cutterhead Intervention

AECOM

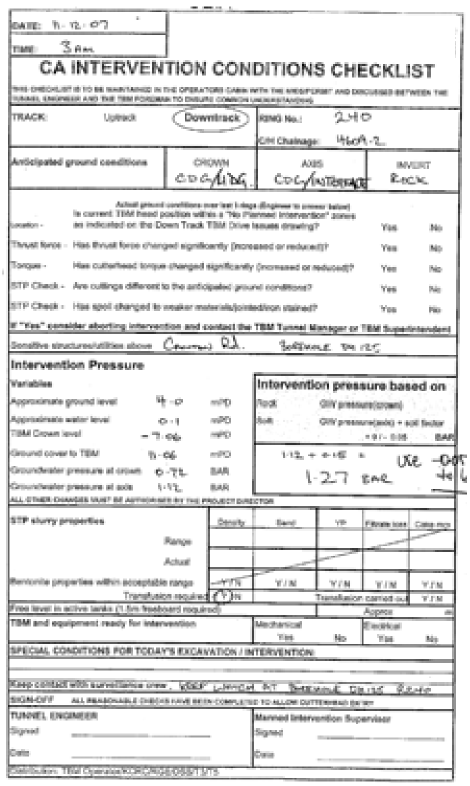
- Intervention will halt TBM excavation, so may programme them during night shift when there are noise restrictions
- Intervention removes normal face support – avoid areas at high risk in the event of ground settlement if possible
- May have designated ‘no planned intervention zones’
- If major interventions known to be essential, can prepare stable zones in advance

Cutterhead Intervention

AECOM

Planning the Intervention:

- Completion of checklist to confirm parameters
- Review spoil to confirm ground conditions
- Check groundwater level for required CA pressure
- Circulate fresh slurry


DATE: 11-12-07
TIME: 3 am

CA INTERVENTION CONDITIONS CHECKLIST

TRACK: Uptrack / Downtrack — RING No.: 240 — C/H Chainage: 4609.2

Anticipated ground conditions — CROWN: CDG/HDG — AXIS: CDG/INTERFACE — INVERT: ROCK

Location -	Is current TBM head position within a "No Planned Intervention" zones as indicated on the Down Track TBM Drive issues drawing?	Yes	No
Thrust force -	Has thrust force changed significantly (increased or reduced)?	Yes	No
Torque -	Has cutterhead torque changed significantly (increased or reduced)?	Yes	No
STP Check -	Are cuttings different to the anticipated ground conditions?	Yes	No
STP Check -	Has spoil changed to weaker materials/jointed/iron stained?	Yes	No

If "Yes" consider aborting intervention and contact the TBM Tunnel Manager or TBM Superintendent

Intervention Pressure

Variables		
Approximate ground level	4.0	mPD
Approximate water level	0.1	mPD
TBM Crown level	-7.06	mPD
Ground cover to TBM	11.06	mPD
Groundwater pressure at crown	0.72	BAR
Groundwater pressure at axis	1.12	BAR

Intervention pressure based on
Rock: GW pressure(crown)
Soft: GW pressure(axis) + soil factor
1.12 + 0.15 = 1.27 BAR

Keep contact with surveillance crew

SIGN-OFF

TUNNEL ENGINEER — Signed — Date

Manned Intervention Supervisor — Signed — Date

Cutterhead Intervention

AECOM

Planning the Intervention:

- Completion of checklist to confirm intervention personnel
- Compressed Air Operations Supervisor (CAOS)
- Medical staff
- Intervention supervisor
- TBM lock attendant
- Intervention workers

MANNED INTERVENTION DATA SHEET and INTERVENTION PERMIT

DATE OF MANNED INTERVENTION	11-12-07 (11/5 13-12-07)
PROPOSED STARTING TIME	3 pm
PROPOSED RING NUMBER	240
PURPOSE (Inspection/Changes)	Cutter Change
PLANNED WORKING PRESSURE	1.2 Bar
PLANNED DURATION FOR INTERVENTION	4 hr
MAXIMUM DURATION PERMITTED FOR EACH INTERVENTION TEAM	4 hr
ANTICIPATED GROUND CONDITIONS	CDG, B Rock 5

MANNED INTERVENTION PERSONNEL

Atmospheric Pressure

Compressed Air Operations Supervisor (CAOS) or Tunnel Manager

Medical Lock Attendant

Appointed Medical Practitioner

Manned Intervention Supervisor

TBM Lock Attendant

Emergency Intervention Worker

Compressor House Attendant

Hyperbaric Environment Crew 1

Crew 2

Manned Intervention Team Chief

Manned Intervention Worker

Manned Intervention Worker

Manned Intervention Worker

Manned Intervention Team Chief

Manned Intervention Worker

Manned Intervention Worker

Manned Intervention Worker

Approved by:
Compressed Air Operations Supervisor (CAOS)*
Manned Intervention Supervisor (MIS)*

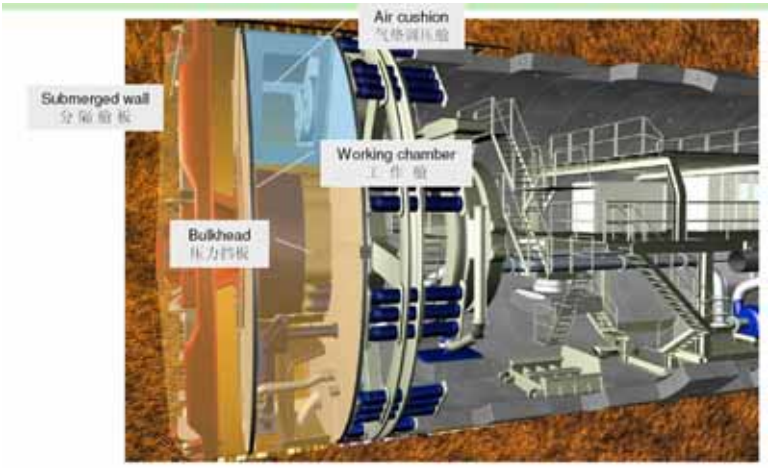
* delete as appropriate

Cutterhead Intervention

AECOM

Carrying out the Intervention:

- Circulate fresh slurry to ensure good filter ‘cake’
- Reduce slurry level in excavation chamber to expose top of cutterhead and tunnel face
- Monitor air leakage – abort if excessive air loss



Cutterhead Intervention

AECOM

Carrying out the Intervention:

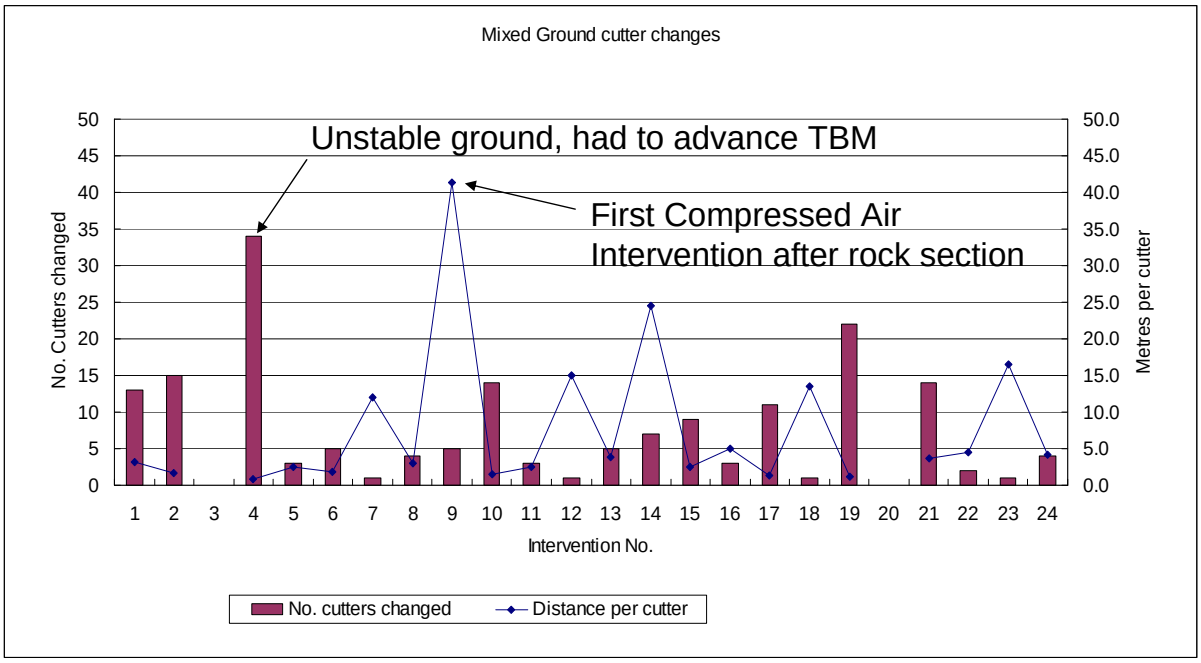
- Intervention team enter through manlock and inspect to ensure the face is stable
- Intervention aborted if face unstable or excessive groundwater inflow
- Aborted intervention requires advance of the TBM to a new face position, and new intervention attempted.

Cutterhead Intervention

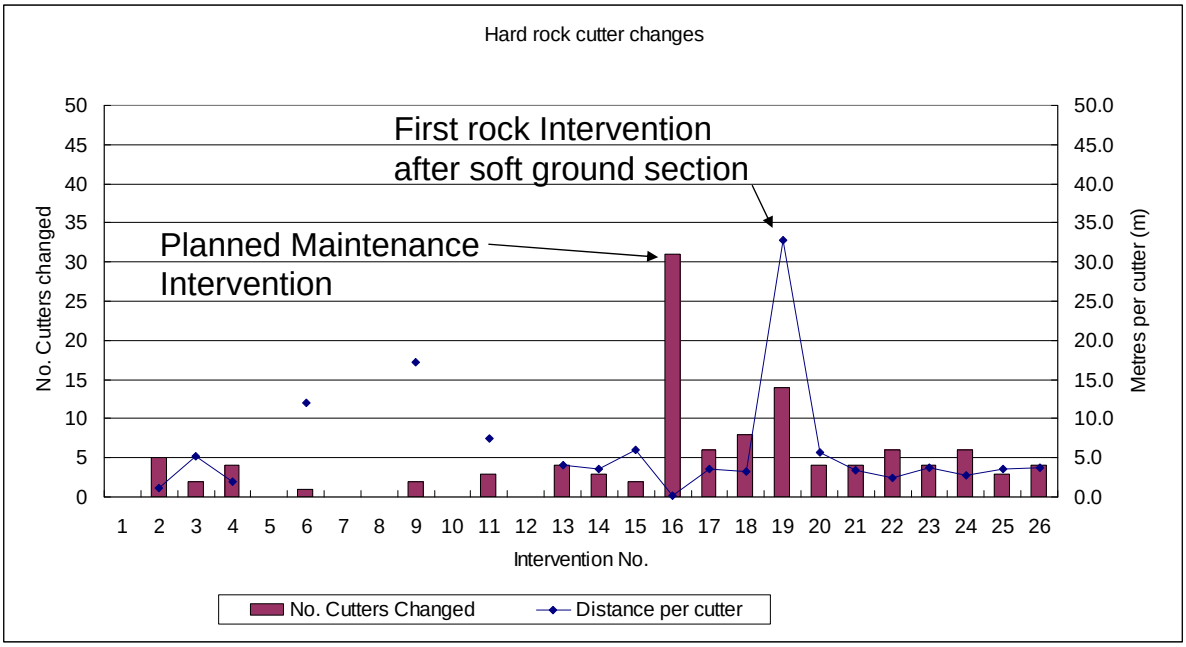
AECOM

Stratum	Length (m)	Cutterhead Interventions		
		Planned	Routine	Unplanned
Bedrock	447	0	21	n/a
Mixed Ground	359	2	24	12
Soft Ground	297		3	0
Total		**2**	**48**	**12**

Cutterhead Intervention



Cutterhead Intervention



Cutterhead Intervention

- In rock daily maintenance interventions prevent excessive cutter wear
- In mixed ground, interventions may be frequent or infrequent
- Daily maintenance interventions even in mixed ground (Compressed Air) conditions will help prevent excessive cutter wear
- Excavating with damaged cutters may lead to major cutterhead damage
- Decrease in penetration rate and increase in thrust and torque require immediate inspection of the cutterhead

Summary

- First planning for interventions should be at the design stage
- Tunnel alignment and tunnelling method chosen to suit the ground conditions
- Contractor to propose intervention methods to suit his method of work
- Detailed intervention procedures implemented to ensure safe intervention
- Checklist for every intervention to ensure intervention parameters are appropriate to the ground conditions
- Plan for ‘unplanned’ interventions in mixed ground


Thank You