
Tunnel details / Segmental lining / Performance data

Tunnel details

Tunnel length:		
TBM#1:	WS 7 to WS 6	5,303 m
and	WS 6 to WS 5	4,251 m
TBM#2:	WS 5 to WS 2	5,202 m

Minimum curve radius	approx. 500 m
Minimum radius of correction curve	approx. 450 m

The maximum gradient of the tunnel is 0.08%.
The TBM is designed for a maximum speed of 100mm/min.

Segmental lining

Outside diameter	5,600 mm
Inside diameter:	5,000 mm
Segment length:	1,500 mm
Ring distribution:	5 + 1/3 key

General arrangement drawings

A-4646-10	Index E	Tunnelling system
A-4646-94	Index A	Shield machine (active and passive articulation)

Installed power (preliminary)

Basic equipment	Main Drive	1,120 kW
	Erector	55 kW
	Thrust system	90 kW
	Hydraulics	25 kW
	Mortar pumps	43 kW
	Agitators	9 kW
	Screw conveyor drive	315 kW
	Compressor (industrial air)	55 kW
	Compressors (breathable air)	150 kW
	Steering oil	22 kW
	Filtration	15 kW
	Cranes	50 kW
	Secondary ventilation	45 kW
	Dewatering pump	15 kW
	Cooling water pump in	8 kW
	Cooling water pump out	45 kW
	Industrial water pump	3 kW
	Foam equipment	30 kW
	Gear oil lubrication	15 kW
	High pressure cleaning	30 kW
	Electrical sockets	75 kW
	Auxiliaries	55 kW
	Ventilation cassette lifting device	13 kW
	HV cable drum	5 kW
	Man lock heating	5 kW
	Tunnel belt extension	110 kW
	Total installed power (basic equipment) (approx..)	2,370 kW

- TBM preparation for BEAM** Preparation cutting wheel and TBM for the installation of the BEAM system.
- Pipe laying for cables
 - Boreholes through the cutting wheel back
 - Welded thread sockets for cable gland
 - At the respective disk cutter will be two pipe ends with 1" SAE flanges
 - Outgoing transport for the respective fixing sets of the cutting tools to specialist for insulation service
 - Provision of power supply
- Segment quick unloading** Provision of a segment quick unloading system.
- Two segment rings:
Cylinders and flames for four stacks, two additional gantries needed because of space restrictions in the first gantry (steel structure, bogies, pipes, etc.).
- TUnIS Navigation TBM^{Laser}** *TUnIS Navigation TBM^{Laser}* is a navigation system for EPB-Shield, Mix-Shield and Hard rock-TBM. Based on a total station and a target unit, mounted inside the TBM shield, the navigation system determines the precise 3D TBM position.
- The navigation system determines and calculates all necessary data and information for navigating the TBM along the tunnel axis.
- The system furthermore provides full documentation of the advance-data in a database. This database is the basis for reports, data exports (XLSX, CSV) or other analysis.
- Hardware:
- Target unit ALTU (hard rock proven) with integrated inclinometers for determination of roll and pitch for the highest demands of accuracy
 - Leica total station 3" class
 - Windows based industrial computer
 - Radio based signal transducers for wireless connection between moving and non moving components (e.g. between Total Station and driver's cabin)
 - 2 surveying prisms, 3 tribrachs, set of cables
 - Central box
- Software:
- Module Navigation (incl. total station relocation routine)
 - Module Map (Site maps, geological profiles)
 - Module Navigation history
 - Module Track chart
 - Module Alignment
 - Module Export (Data export of navigation data)
 - Module Reporting (Navigation, Direction check and Orientation report)

Emergency generator Diesel powered emergency generator to maintain essential services for safety purposes in the event of failure of mains power supply: secondary ventilation, emergency lighting, gas detection, dewatering pump, erector emergency vacuum pump

Prime power	150 kVA
Generator voltage	230 / 400 V
Frequency	50 Hz
Power factor	cos(phi) 0.9
Fire-extinguishing	included

Cold water set on back-up, space reserved only Space reserved for the installation of an air chiller. Dimensions to be defined during detailed design.

Scope:
 One additional gantry with connections to the networks.

Fire suppression system on hydraulic power pack Herrenknecht can provide a fire suppression system for the TBM back-up system which is installed over the hydraulic power packs. The fire suppression system consists of a cartridge-operated dry chemical network distributed by a series of nozzles.

When a fire is detected, the system is manually operated by a pneumatic actuator located close to the operator's station. The pneumatic actuator ruptures a seal disc in the expellant gas cartridge.

This in turn, pressurizes and fluidizes the dry chemical extinguishing agent in the tank, ruptures the burst disc when the required pressure is reached and propels the dry chemical through the network of distribution nozzles over the protected areas suppressing the fire.

The system consists of a dry chemical agent storage tank, expellant gas cartridge, distribution plumbing and nozzles, manual actuator and automatic detection system.

Erector mounted drilling equipment: adapter plate and power supply Provision of the adapter plate for the erector mounted drilling equipment, including the connection to the power supply.



Safety equipment	Emergency telephones	in the man lock
	Refuge chamber	optional
	Gas detection system	O ₂ , CO ₂ , CO, CH ₄ , NO ₂ , SO ₂
	Smoke alarm (acoustic / visual)	1 set
	Water curtain	behind the back-up
	Fire extinguisher	supplied by JV

Miscellaneous	Personnel container	with tables and chairs
	Number of seats	4 No
	Toilet	place foreseen
	Workshop	1 No
	Storage area	1 No

Refuge chamber Serving as protection against flue gas and smoke in case of fire in the tunnel behind the TBM. Does not provide protection in case of fire on the TBM itself. Complete with external connections for power supply, phone and compressed air. Inclusive lighting, emergency lighting seating and first aid kit.

According to British Standard.

Compressed air supply Not included

Quantity	2 No
Locations	1x middle section and 1x rear section
Capacity	12 persons
Maximum duration	20 hrs.
Additional trailers	2 No

- Gas detectors for CO₂, O₂ and CO
- Emergency lighting with battery backup
- Positive pressure within chamber
- Door with porthole with flap
- Telephone
- Stretcher
- Chemical toilet
- First aid kit
- Water box
- Flash light
- 1 No. Breathing Protection Unit (BPU)
- CO₂ scrubber cartridges
- CO filters
- O₂ bottles



Electrics

Complete electrical installation from point of connection of customer power supply. PLC control of all TBM functions from operator control cabin. Socket outlets with appropriate earth leakage protection are located throughout the shield and back-up equipment. Lighting installed throughout shield and back-up inclusive emergency lighting in event of power supply failure.

	Primary voltage	15,000V and 20,000V, switchable
	Secondary voltage	400 V
	Transformer (preliminary)	3,000 kVA
	Transformer type	silicone fluid
	Control voltages	24V / 110 V
	Lighting	110 V
	Valve voltage	24 V
	Frequency	50 Hz
	System of protection (electric motors)	IP 55
	PLC Type	S7 (Siemens)
HV cable drum	Capacity	350 m
	HV cable	not included
	Cable type	H07 RN-F

TBM communication system Communication system to facilitate communication between shield, control cabin and TBM back-up. Communication devices installed in strategic locations

Phone	4 No
Camera (CCTV)	3 No

Control cabin

Air conditioned control room housing to facilitate efficient and safe TBM operation. Ergonomic layout of controls with 15inch color monitors for full visualization of all operating parameters

	Control cabin	1 No
	Monitors (1 x VMT, 2 x visualization, 1 x CCTV)	4 No
	Visualization language	English
Data acquisition	Data acquisition system	1 No HK EPB Standard on TBM



Tailskin grease pump	<p>PLC controlled air operated barrel pump complete with all necessary pipes and hoses for supply of tailskin grease to the cavities of the wire brush system. Pressures pre-set in operator control cabin. System capable of automatic and manual operation. TBM auto shutdown if grease is not available</p> <p>Tailskin grease pump 1 No Barrel size 200 l</p>
Main drive lubrication system	<p>PLC controlled air operated barrel pump complete with all necessary pipes and hoses for automatic lubrication of main drive and screw conveyor drive. TBM auto shutdown if grease is not available</p> <p>Grease pump labyrinth seal main drive 1 No Barrel size 200 l</p>
Hydraulic system	<p>Continuous off-line filtration and cooling of other consumers to achieve oil cleanliness in accordance with ISO 4406 classification 16/13 or better. Oil level and temperature are continuously monitored with auto shutdown when preset limits are exceeded. Water cooling (pressure) is continuously monitored with auto shutdown in the event of non-supply of cooling water.</p> <p>First fill not included Filter unit yes Oil cooling equipment yes Oil tank 1 No</p>
Cranes	<p>Segment crane 1 No Material handling cranes (grease drums) 1 No Rail laying crane integrated in segment crane Tunnel belt extension crane 1 No Auxiliary rails crane 1 No</p>

Ventilation

TBM ventilation system comprising duct storage and handling system for connection to customer supplied primary tunnel ventilation duct as well as secondary ventilation system for effective ventilation in TBM and back-up area.

Primary (tunnel)	Air duct magazine (without air duct)	1 No + 1 spare No
	Capacity	100 m
	Diameter	1,500 mm
	Lifting device	1 No
Secondary (TBM)	Secondary air duct	600 mm
	Axial flow fan	1 No
	Power	30 kW
	Silencer	2 No

Industrial air / breathable air

Installed in back-up to provide compressed air as required for foam generation and operation of hand tools. Complete with air distribution via pipes / hoses for TBM and back-up system. Sockets with quick couplings at strategic locations on TBM and back-up for easy connection of air operated tools. NOT suitable for supply of breathable air to man lock.

Compressor	1 No
Type	Atlas Copco GA55
Capacity at 7.5 bar	10 m ³ /min
Power	1 x 55 kW

Compressor system for breathable air

Installed in back-up to provide breathable compressed air to man lock. 2-line system pipework throughout back-up and shield to provide failsafe air supply. Interlocked with emergency generator in the event of failure of mains power supply.

Compressor	2 No
Quantity assumed	2 No
Type assumed	Atlas Copco GA 75
Capacity at 7.5 bar assumed	13.8 m ³ /min
Power	2 x 75 kW
Compressed air tank	2 x 4 m ³
Filters	included

Foam equipment

Foam equipment for the supply of foam and polymer as conditioning material for the excavated ground

Foam	5 No
Maximum foam capacity	180 m ³ /h
Tenside Tank	1 x 1000 l
Tenside pump	1 No
Water pump	1 No

Water circuit	Back-up installation to supply cooling water to main drive and hydraulic system. Connected to tunnel line via hose reel during TBM advance. Filtration in feed line. Return water can either be used as industrial water or discharged into the tunnel line.		
Cooling water	Capacity cooling circuit (first)		45 m ³ /h
	Required pressure on TBM for normal operation		4 bar
	Water in (max)		25 °C
	Cooling water pump in		7.5 kW
	Cooling water pump out	provided by JV	
	Power		45 kW
	Buffer tank internal circuit		150 liter
Cooling water line extension	Hose extension type		hose reel
	Quantity lines		2 No
	Capacity		25 m
	Pipe size		80 mm
Industrial water	Industrial water inlet	from cooling water circuit outlet	
	Industrial water pump		15 kW
	Industrial water capacity		50 m ³ /h
	Consumers	Foaming, conditioning, fire water curtain	
	Separate water control valves		2 No
Industrial water line extension	Hose extension type		hose reel
	Quantity lines		1 No
	Capacity		25 m
	Pipe size		80 mm
Dewatering	Dewatering pump in the shield area to pump spillage water out of the shield		
	Pump in the tailskin		30 m ³ /h
	Power		3.7 kW
	Dewatering tank		5 m ³
	Return dewatering pump		1 No
	Power		15 kW
Dewatering line extension	Hose extension type		hose reel
	Quantity lines		1 No
	Capacity		25 m
	Pipe size		80 mm



Tunnel belt conveyer Not included in the described scope.

Interfaces:

Width	800 mm
Provided power	110 kW

Segment handling

The segment crane is installed in the upper deck of the back-up structure to handle pre-cast segments between flat wagons and segment feeder.

The segment feeder is installed in the invert section below the bridge structure to feed segments to the ring erection area. Towed by a chain from the shield structure.

Segment feeder (for one ring)	1 No
Segment transfer crane	1 No
Gripping system of segment crane	vacuum

Annular ring gap filling
 (primary grouting)

Installation of a bi-component grouting system with A-component, B-component and flushing lines in the back-up. In order to prevent plugging of the grout lines, the B-component line is equipped with a non-return valve. In addition, a flushing line is installed. The mixing point of the two components is placed in an independently dismountable box in the tailskin.

Pumps for A-component	4 No
Type	eccentric screw pump
Capacity	115 l/min
Power per pump	7,5 kW
Total power	30 kW
Tank for A-component	6 m ³
Pumps for B-component	4 No
Type	eccentric screw pump
Capacity	1 l/min
Power per pump	1.5 kW
Total power	6 kW
Tank for B-component	1 No
Flushing pump	1 No
Capacity	23 l/min
Power	6.5 kW



Back-up system

All trailers are of portal structure running on auxiliary rails. The back-up system is completely furnished with all handrails, walkways and steps / ladders, and ventilation ducting as necessary and provides free and unobstructed man access along the TBM from the rear of the back-up equipment.

The back-up concept is designed for mucking out by tunnel belt conveyor.

Number of gantries (with chosen options)	14	No
Steel structure bridge section	1	No
Back-up wheels	single type, mechanical, fix	
Auxiliary rails	optional	
Consoles	provided by JV	
Auxiliary rail length	3.0	m

Railing up area

Upon completion of 6m TBM advance sufficient space is available in front of gantry #1 to install a further 6m length of track. Inside the tunnel the rails are transported on cars from where they are carried to the bridge section for installation in the tunnel invert.

Rail length	6	m
Track gauge	900	mm

Feasibility of increased track gauge has to be confirmed, increased number of gantries will be charged extra.

Back-up conveyor belt

The back-up belt conveyor takes the discharged material from the screw conveyor and transports it to the loading point of the tunnel belt conveyor. The material is charged from the back-up belt conveyor to the tunnel belt conveyor by a muck chute.

Length	see TBM drawing
Width	650 mm
Power	45 kW
Speed	0-2.5 m/s
Capacity	520 t/h
Belt scales (weighers)	2 No
Belt type	flame resistant
Muck laser scanner	included

Man lock

Two chamber / 3 door arrangement flange mounted to the rear pressure bulkhead in the crown of the shield. Supplied in full accordance with EN 12110 safety regulations. Air pressure regulation system installed in shield to maintain constant confinement pressure in the excavation chamber during compressed air interventions

Type	2 lock / 3-door system
Operating pressure	5.0 bar
Main chamber capacity	3 person
Emergency chamber capacity	2 person
Length (approximate)	2,000 mm
Diameter	1,600 mm
Fully equipped with	Oxygen decompression connections All control valves Exhaust silencers Pressure gauges Clock Thermometer Telephone system (emergency) Chart recorders Heaters Fireproof seating Water sprinkler Lighting inclusive emergency lighting

Erector

Rotary ring erector with longitudinal travel along tunnel axis. Precise and accurate movement with 6 degrees of freedom for easy placement of segments and avoidance of damage. Wireless control panel for ease of operation (emergency cable control panel supplied also). Erector head with independent rotate and tilt movements. Segment lift by means of gripping system

Type	center free ring erector
Gripping system	vacuum
Degrees of freedom	6
Rotation	approx. +/- 200°
Travel along tunnel axis	2,000 mm
Telescopic movement (radial)	1,200 mm
Erector head slewing	yes
Erector head rotation	yes
Erector head tilting	yes
Operation	radio remote controlled + cable controlled

Screw conveyor

Mounted to a machined flange in the pressure bulkhead of the shield front section to convey excavated material from invert of excavation chamber to TBM Belt conveyor. Heavy duty construction. Drive unit for variable speed mounted in spherical bearing to avoid eccentric forces resulting from deflections of drive shaft to affect drive unit. Cast steel flights on screw.

Type	telescopic, reversible
Diameter	800 mm
Installed power	315 kW
Variable capacity (70% filling)	309 m ³ /hr
Earth pressure sensor installed	1 No
Injection point for soil conditioning (water)	3 x 3 No
Inspection hatches	2 No
Max. grain size	520x260 mm
Variable speed	0-24 rpm
Torque nominal	199 kNm
Breakout torque	224 kNm
Variable capacity (70% filling)	229 m ³ /hr
Telescope stroke	1,000 mm
Rear gate	1 No
Fail safe closing gate system	included
Type	Nitrogen buffer storage
Front gate	1 No
Type	butterfly type
Wear protection of auger	Hardox blocks welded on first three turns
Wear protection of casing	Hardox stripes welded on full length in bottom part of casing

Screw conveyor: second discharge gate

Design and manufacturing of an emergency discharge gate at the outlet of the screw conveyor. Including box between the two gates.

Thrust cylinders

Thrust cylinders arranged in groups according to configuration of the segment ring. Steering by means of individual control of operating pressure of each cylinder group. Excellent control over load distribution on segment lining ring thus preventing ring distortion or movement. Digital display of stroke and pressure for each cylinder group. The thrust cylinder units are used, refurbished components.

Quantity of shoes		16 No
Single or double cylinders	decision in detailed design period	
Thrust force at 350 bar		28,500 kN
Max. Thrust force @ 420 bar		34,200 KN
Max. stroke		2,500 mm
		(Electronic limitation)
Extension speed		100 mm/min
Extensometers (stroke measurement)	for each group	
Groups		4 No.
Hydraulic thrust cylinder bedding		1 Set

Active articulation
 (front shield articulation)

The articulation cylinders are used, refurbished components.

Cylinders		8 No
Dimensions		320 / 220 mm
Stroke		300 mm
Nominal force at 350 bar		22,518 kN
Stroke measurement		4 No

Cutting wheel	Closed-type cutting wheel suitable for bi-directional mixed face excavation. Disc cutters on full face to facilitate easier breakout through concrete or boulders.		
	Diameter		5,900 mm
	Opening ratio		35 %
	Direction of rotation		2 No
	Direction of excavation		2 No
Cutting tools	17" single disc cutters		26 No
	Type	double wedge lock	
	Pressure compensator		yes
	Exchange of cutters	backloading	
	First set of cutting tools	included	
	Spacing (face area)		100 mm
	Disc exchangeable against rippers		yes
	Set of auxiliary tools for cutter handling		yes
	Center disc cutters		8 No
	Scraper tool (approx.)		38 No
	Bucket lip		16 No
Rotary union	Rotary unit for injection and hydraulic lines		1 No
	Lines		5 No
	Water nozzles		8 No
Wear protection and detection	Wear protection on face	Hardox plates	10 mm
	Wear protection on gauge area grill bars	Hardox	400 mm
Injection points	Quantity		5 No
Grain size	Grain size limiter		240 mm

Cutting wheel drive	Fix installed electrical main drive complete with three-lip sealing system		
	Installed power		1,120 kW
	Variable speed		0 – 3.7 rpm
	Nominal torque		4,623 kNm
	Exceptional torque		5,178 kNm
	Breakout torque		5,640 kNm
	Main bearing outside diameter		2,600 mm
	Bearing design	3 axis roller	
	Bearing life in accordance with DIN ISO281		>10,000 hour
	Main bearing replaceable in tunnel		yes
	Main bearing manufacturer	Hoesch Rothe Erde or SKF	
	Electrical motors		7 No
	Power per electric motor		160 kW
	Gear oil: first fill		included
	Grease lubrication: first fill		included

Basic equipment

EPB TBM Shield 5,860mm diameter	Applied standards:	BS 6164 for tunnelling machines
	Shield type	EPB Shield with active face support
	Diameter	front section 5,860 mm middle section 5,850 mm
	Highly corrosive salty air considered	included
	Structure confirmed by FE Analysis	included
	Operating pressure (max.)	5.0 bar
	Earth pressure sensors	6 No
	Compressed air regulating device	2 No
	Type	Samson
	Diameter pressure wall door	600 mm
	Probe drilling lines DN100, inclined, with valves	6 No
	Drilling lines DN100, horizontal, with valves	2 No
	Bentonite lubrication ports in the skin DN50	12 No
	Shield wear protection	hard facing
	Disc cutter replacement tools	included
	Safe access for operatives and maintenance personnel	yes
	Breakthroughs in pressure wall	included
	Active articulation joint	1 No
	Platforms and ladders	included
Tailskin	Welded tailskin. Grout injection lines and grease lines integrated into steel structure. Wire brush seal replaceable from within tunnel.	
	Diameter	5,840 mm
	Excluder plate	270°
	Wire brush sealing system	3 row
	Grout injection line DN50 (double)	4 No
	Grease lines	4 x 2 No
Shield concept with an active and a passive articulation	Integration of an additional passive tailskin articulation, the main drive is fix installed. The articulation cylinders are used, refurbished components.	
	Cylinders	12 No
	Dimensions	180 / 80 mm
	Stroke	150 mm
	Articulation joint	2 No
	Additional shield length	500 mm

Performance data

Ring build time : Theoretical ring build time = 20min

Thrust cylinders : Max. extension speed thrust cylinders (mode advance) = 100mm/min
 Max. retraction speed thrust cylinder (mode ring building) = 1.750mm/min
 (for 6 thrust cylinders = 3 pairs)

Penetration :

Rock Description	Share		Unconfined Compressive Strength (UCS)	Estimated Max. Penetration
	[m]	[%]		
Rus Formation Mixed Face Rus Calcareous & Rus Gypsum	600	4,10%	7,84 (Av)	20,0
			59 (Max)	5,9
Rus Calcareous	13.733	93,80%	29 (Max)	20,0

The penetration calculated according to the Colorado School of Mines Model.

The calculation was performed with an unconfined compressive strength / Brazilian tensile strength ratio of 12:1. If rock is considered to be tougher, penetration will decrease.

The face is assumed as homogeneous and isotropic: face instability, blocky tunnel face, jointed, fractured or mixed face is not considered in the penetration calculation. If these condition appears penetration rate should be reduced.

Penetration calculation based on the use of new HK cutter rings on 17" HK disc cutters.