CHANNEL TUNNEL CONSTRUCTION LOGISTICS AND PRECAST AT SANGATTE SITE

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Sangatte Shaft

On both sides of the Channel it was decided to start tunnelling as close as possible to the sea. In France, Sangatte was chosen, to the west of Calais, at about 3.2 km from the Beussingue portal. Boring started on the UK side at Shakespeare Cliff, to the west of Dover.

Instead of using the exisiting adit, it was decided to design ***an enormous shaft as the project's nerve centre of all logistics*** *for tunneling activities in France. This difficult, unusual choice, has prooved afterwards to be one of the key decisions for the success of the project.*

Sangatte shaft is a vertical cylinder, 66 m deep, with an internal diameter of 55 m. The thickness of the concrete wall varies from 1.0 m to 1.1 m.The 3 marine TBMs started from the Shaft as did two of the landward TBMs - the Service Tunnel and the Running Tunnel South. The TBM excavating the latter was then turned around to drive the Running Tunnel North.

At tunnel level, the tunnels were enlarged to form the marshalling area. Under tunnel level, the shaft housed the structures and equipment for spoil treatment and pumping to Fond Pignon Dam. The water table is a few meters below ground level .The shaft is protected against water pressure and inflows by a surrounding flexible wall keyed into the Chalk Marl.

Functions during construction

Allow, in a proper, dry environment,
.TBMs logistics:

- erection and launching chambers,
- collect spoil,
- Store/recharge batteries for locomotives,
- supply tunnel linings produced at the precast plant near the shaft,
- supply grout for tunnel linings,

.Materials and personnel logistics:

- treat/evacuate spoil to Fond Pignon,
- evacuate seepage water to the water treatment plant on surface,
- connect ventilation and power from surface to underground.
- locker rooms for 1800 persons on surface ("Hangmen's Hall" as in coal mining), and access lifts for personnel,

.Overall construction management :

- house temporary Control Room and field engineering offices on surface.

Marshalling Areas

Sangatte Shaft during construction - From left to right: Precast plant, segments storage yard, Shaft under its temporary cover, maintenance and other temporary workshops, water treatment plant, and Fond Pignon Dam

From the marshalling areas was developped the entire railway traffic system .

Multi-stage excavation methods completed by using the Perforex method, were used to build this area.The first 70 m of the 3 tunnels towards both sea and land, were terminated by their respective TBM launching chambers.

Spoil Treatment

The treatment plant located at the bottom of the shaft had a capacity of 625 m3/h.
Spoil from the TBMs was hauled in special muck cars up to 5 tipplers, one per TBM, each one able to empty 3 cars. The cars were turned upside down. A special coupling allowed them to rotate while the rest of the train was in the normal position. The spoil was then taken by conveyors trough 3 feeders to 6 crushers, further thinned in the 3 wash mills, to produce a mixture with 90% water.

Spoil disposal: Fond Pignon dam

This slurry was then pumped 130 m upwards and 1600 m away to Fond Pignon by 8 piston pumps, through 8 pipes (diam. 250mm, capacity 90 m3/s each) .

Fond Pignon is a blue-grey lake covering some 30 hectares, extending between a dam made of white chalk built to store the spoil, and a similarly coloured cliff.

The dam is 40 m high and 1100 m long. The storage capacity , about 5.4 million m3, is sufficient for 3.0 million m3 of tunneling after recirculating decanted water to the shaft.

With time, evaporation and settlement, the deposits will solidify and the surface level will go down several meters.The site will be covered by suitable local species able to

Sangatte Shaft today : The Shaft is not covered any more. Inside, technical rooms, reconstitued tunnels, and ventilation ducts have replaced the former, complex tunnelling logistics. On surface, permanent facilitites (cooling, ventilation, fire fighting, diesel power plant) have replaced, in a now landscaped area, the huge construction facilities.

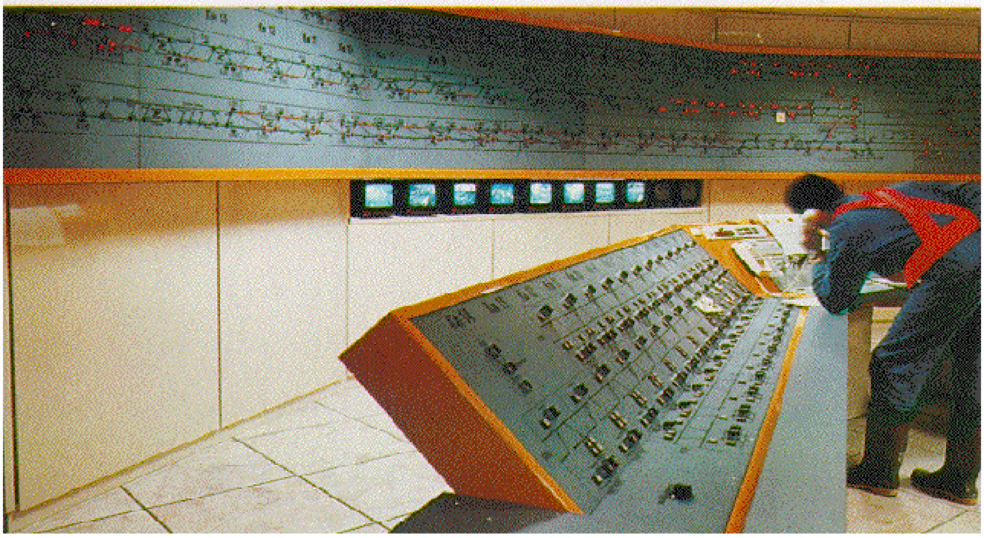
resist to the high salt content of the deposits.

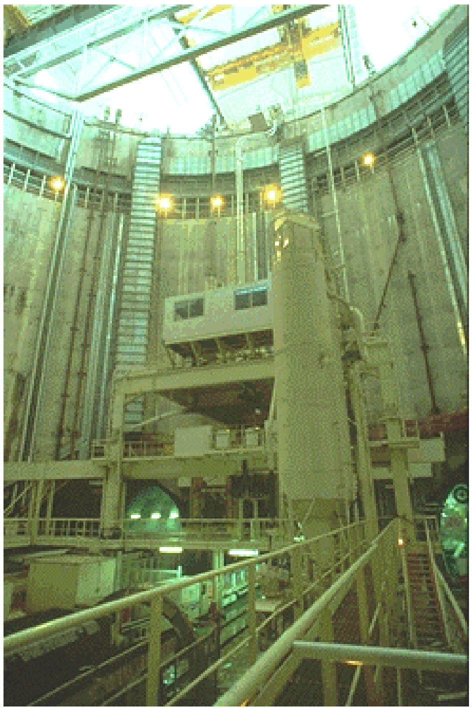
Linings supply - grouting

The linings, arriving from the precast works plant on pallets containing each a complete ring, were placed in the shaft by travelling cranes having a capacity of 60 tonnes. Another crane, capable of lifting 430 tonnes, was used for the installation of the TBMs.
The grouting made in the shaft by 2 plants (30 m3/h each) was dispatched to the TBM s, and finally injected behind the linings.

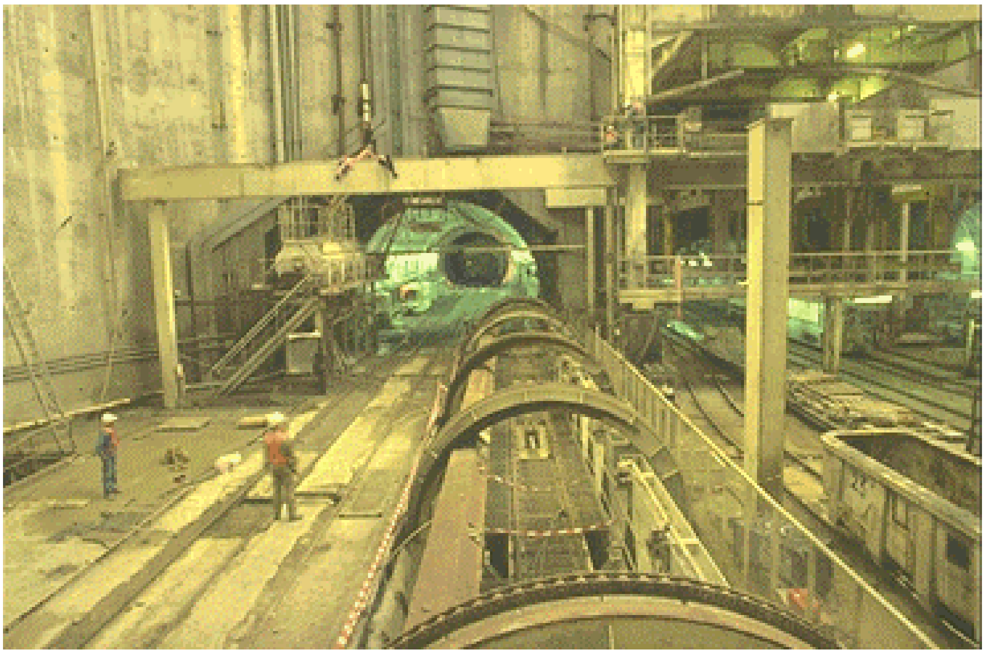
Changing constraints

Whatever the function to ensure (rail logistics in the shaft, power, ventilation, pumping,...), at least 4 different temporary





Above, left : Sangatte Shaft temporary Control Room, from where all construction activities were coordinated.
Above, right: Inside the Shaft - grout plants, ventilation ducts, and connecting pipes from surface to underground.
Below, left : The main travelling crane, able to lift a 500T-TBM. Right: A tippler, able to empty 3 spoil wagons.



systems have been succesively used, corresponding with the folllowing events: service tunnel junction, rail tunnels junctions, permanent systems installation.

They had to be progressively operated and decommissioned while permanent systems, of comparable capacity but totally different concept, were commissioned simultaneously.

Tunnel logistics

Rolling Stock

The French temporary railway included 180 km of 900 mm gauge tracks, 108 locomotives, and 591 purpose built wagons: muck cars (330), flat cars (187), manriders (21), concrete (32), grouting stations (21). It was operated 24 hours a day, carrying up to 20000 T of spoil a day, up to 6000 T per TBM.

69 locomotives (250 to 415 HP), powered by either battery or catenary, were used for construction activities. Batteries used in the service tunnel were of 580 V, 700 A, 8 tonnes, and those used in the running tunnels of 580 V, 900 A, and 13.8 tonnes.Special rooms built inside the shaft were dedicated to recharging. The 39 locomotives used for manriders, fire-fighting, emergency and maintenance were diesel powered.

Main convoys, dedicated to TBMs operation, comprised from back to front: flat cars for supply of rails, pipes, cables, etc..., 1 grouting station for injection behind the segments, and muck cars : 6 of 10.5 m3 for Service Tunnel, 12 of 14.7-m3 for Running Tunnels. Special convoys were dedicated to 350 special works behind the TBMs, such as cross-passages, piston relief ducts, equipment rooms, etc..

Power

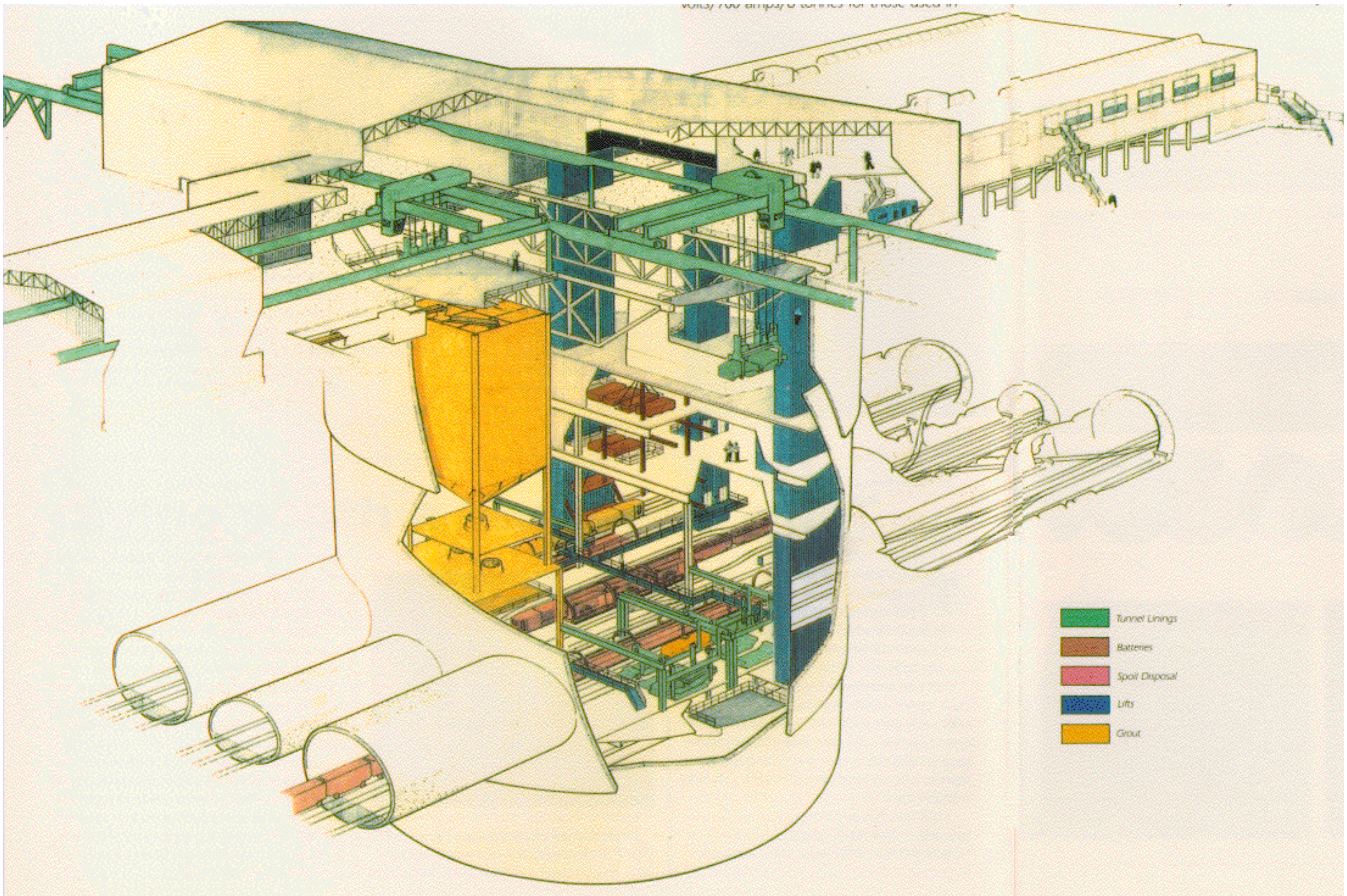
The high-voltage power supply of the site was in 90 kV through two 90/20 kV transformers of 36 MVA each. Medium-voltage distribution included nine specialized substations, with tunnel power supply of 20 kV and 3.2 kV for lighting. A 9.7 MVA-emergency diesel plant was dedicated to TBMs, ventilation, lighting and pumping systems.

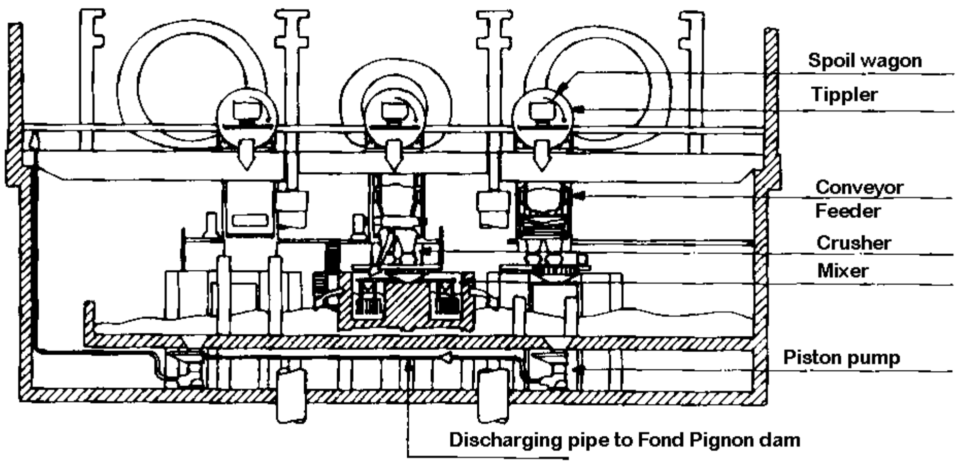
Ventilation

Ventilation was based on use of electric power except for manriders and emergency vehicles. Design criteria included control of polutants, heat, and air speed, hydrogen (produced by bateries) dilution, and 300 l/s of fresh air per m2 of tunnel cross-section. Toxic gases were monitored by sensors .

At first, up to 7500 m-long flexible ducts, diam.1200mm, were delivering 5.5 m3/s to the TBM in Service Tunnel. Diam.1600 mm delivering 13.5 m3/s were used in running tunnels. 13 fans from 8 to 37 m3/s and 22 to 110 kw have been used.

This was completed before breakthrough by a full-section air network exctracting 180 m3/s up to the last cross-passage excavated, using 3 fans on suface (90 m3/s-550kw each). Used air was rejected in surface, leaving the shaft and 2 tunnels completely smoke-free in case of fire.





Above : Overall view of the Shaft.
Left : the spoil treatment plant located at the bottom of the Shaft.

After breakthrough, undersea temporary plants delivered 120 m3/s (full section) per rail tunnel and 30 m3/s in service tunnel, from UK to France.

Pumping

Design Criteria included: linings leakage (1 l/s/km), normal marine TBMs water seepage (15 l/s), process water (10 l/s/tunnel), accidental marine TBMs inflows (up to 150 l/s under 11 bars max) plus crossover works (up to 500 l/s).

The pumping system was able to manage, in normal use and per tunnel:37 l/s under land, 100 l/s (60 m) under sea, plus 350 to 500 l/s in case of emergency.

Each of the 3 marine tunnels used over 60 pumps: 4 at the TBM head (1x25 /s, 3x75 l/s), and per km : 2 pumps and a storage tank (2x150 l/s-54 kw, 250/200 mm pipes) for normal flow, plus 1 for emergencies (350 l/s, 210 kw, 300/400 mm direct pipes to the shaft).The shaft included a 3500 m2 storage capacity, 4 main pumps (325 l/s, 210 kw, 70m) plus underland tunnels capacity (40 l/s +150 l/s for emergencies).

Temporary Control Room (PCC)

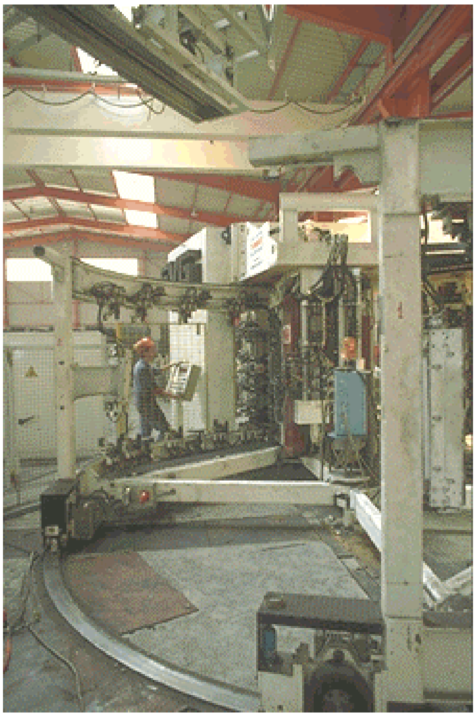
All tunnelling activities were monitored and controled 24-hours a day by the Temporary Control Room, through mimic or video view of all mobile and fixed equipment, thanks to a powerfull redundant control system able to centralise all numerical/radio/phone communications, vocal and optical alarms. 33 persons, 6 per shift, operated 3 main desks :

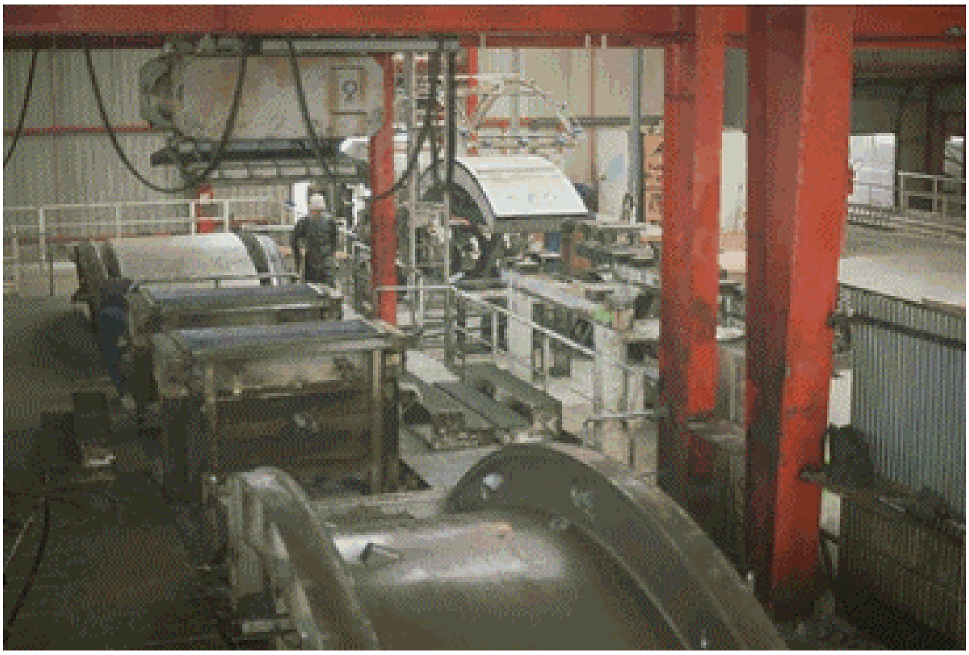
- ***Safety desk (PCS)*** connected by direct phone to all emergency services (firemen, ambulances, hospitals, etc..),
- ***Fixed Equipments desk (GTC)***, including visual permanent control of power, ventilation and pumping, connected to 8000 sensors in tunnel and served by 2 DIGITAL PDP11 calcultators, 1 PB400 MERLIN GERIN programmable controler, 3 LAC COMPLEX Computer networks.
- ***Rail Traffic desk (PCT)***, including vocal communication with all vehicles, and optical monitoring of all rail activities on a large mimic served by 4 PB400 programable controlers. A dedicated software allowed automatic management of itineraries, location and composition of convoys, tracks and catenaries reservations, and even rolling stock status.

Precast plant

Support to the ground in the excavations carried out in the TBM drives, the cross-passages, the piston relief ducts and other connections between the service tunnel and the running tunnels was provided by preformed tunnel linings.
Some 700 junctions between tunnels have been built in UK and FR.Special preformed linings have been designed and erected in the main tunnels at these locations.

On the UK side preformed linings have been fabricated in reinforced concrete or spheroidal graphite cast iron (SGI) segments, although a limited number of the openings in the main tunnels have incorporated structural steelwork. The ground





Precast segments manufacturing facilities: Frameworks are produced by automatic machines (above, left), filled with concrete in rotatory moulds (above, right). Once finished and after 7 days minimum in the storage yard, a purpose-built carrier takes the rings (below, left) to a storage area near the Shaft (below, right).

conditions of the UK side of the Channel allowed the use of non-bolted expanded ring closed by a wedge key. The segments used at Shakespeare Cliff were made on the Isle of Grain, 160 km away.

On the French side, bolted, watertight precast concrete segments were designed to comply with the choice of the construction equipment (i.e. full-face double shielded) and to limit water inflow .

To guarantee both quality and supply of the segments, TML had to create its own manufacturing facilities. The French ones were adjacent to the Sangatte shaft.

Steel Yard

The steel yard covered an area of 13,000 m2 and produced the frameworks, made with reinforcing steel on an automated line.
The steel yard was organised around an automatic 3-dimensional cutting, bending and welding machine producing 460 frameworks per day, with a maximum rate of one framework every 1.5 minutes, and 60 tonnes per day.
The diameter of the reinforcing steel were 8 and 12 mm. The tolerance required for the fabrication of frameworks was 5 mm.

Manufacturing facilities

The frameworks were then hauled to the 11,000 m2 precast factory, placed in moulds and filled with concrete ,and then cured in a drying tunnel before being stored pending delivery .

The precast factory consisted of up to 6 segment casting and curing units, each working with a rotary caster with 44 moulds filled horizontally by a mixer having a peak pouring capacity of 1,200 m3 per day. Concrete was highly vibrated during this operation.
The curing tunnels accelerated the concrete setting with tempreature regulation between 30° and 40° C . The moulds were stripped after 7 hours.
The segments were then automatically transferred to the finishing units for marking and placing the seals.

Over 250,000 segments have been produced at Sangatte facilities.

Segments storage Yard

Tunnel segments were stored before being shipped to the TBMs on a 26,000 m2 area . After having spent some 9 hours in the curing tunnels of the factory , segments waited for a minimum of 7 days before being loaded onto pallets, each containing one full ring, composed of 6 segments.
The pallets were then taken by purpose built segment carriers, able to carry 64T, to a further storage area close to the shaft, where travelling cranes brought them to the TBMs when required.
Stock management at this scale, up to 30,000 items weighing 7 tons each, relied largely upon computerization. This enabled to trace every segment (date/time of manufacture, production line, mould numbers, etc...) as well as the precise amount of stock available at any time.

High Performance Concrete, Quality Assurance

Extensive studies and sophisticated tests allowed to design a highly compact concrete, 1000 times more watertight than traditional high quality concrete, the strongest concrete ever produced in the world, compatible with the long life (120 years) of the works.
The segments, 90 days after leaving the curing tunnel, had a strength of up to 70 to 100 Mpa, to be compared with the 50 Mpa in the pressure vessel of a nuclear power plant.
Lining had to meet extremely stringent dimensional criteria. In addition to the frequent checks made on the moulds to ensure that their settings were corrected before tolerances were exceeded, a special machine was developed to check the dimensions of segments with exceptional accuracy, +/- 0.1 mm. This lead to a remarkably low rejection rate, under 1.7%.

TML, THE CHANNEL TUNNEL CONTRACTOR, IS A JOINT VENTURE BETWEEN: Balfour Beatty constructions LTD, Bouygues S.A., Costain Civil Engineering LTD, Dumez S.A., Société Auxiliaire d'Entreprises S.A., Société Générale d'Entreprises S.A., Spie Batignolles S.A., Tarmac Constructions LTD, Taylor Woodrow construction holdings LTD, Wimpey major projects LTD.

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