INTERNATIONAL SEMINAR – LONG TUNNELS:

CHALLENGES FOR DESIGN CONSTRUCTION AND OPERATION

Tunnel Duplex A86
A Private Initiative

17 OCTOBER 2012
Summary

- 1-A86 Duplex overview
- 2- Interchanges
- 3- Safety Works and Equipment
- 4- Supervision, Control and Monitoring (SCADA)
- 5- Operations & Maintenance
In the west suburb of PARIS, since the late 80s, the A86 motorway was completed with the exception of a bar missing 10 km.

1972 to 1988: a study of 17 variants of plots and strong mobilization of opponents

Traffic congestion on the surface: 45 minutes for 10 km in a straight line
1988: proposal by a private company Cofiroute
- Fully underground project,
- Innovative design,
- To be financed through tolls.

1999: final DBFO contract awarded to Cofiroute
- 75 years concession
- Financed by Cofiroute through its balance sheet (no project financing)
- No public funding
Project organization

- **COFIROUTE** (Vinci Autoroute): Concessionaire / Operator
- **SOCATOP** (Vinci Construction, Eiffage, Colas): Design / Build contractor

- **€ 2.0 billion** private investment financed by Cofiroute
- 75 years **DBFO (Design-Build-Finance-Operate)** contract
- Financed only with tolls
Project goals

- Complete the missing link of A86 motorway
- Improve suburb to suburb travel
- Reduce surface travel
- Improve the quality of life of the neighborhood
An innovative design

Standard design: 1 tube per direction = 4 lanes

Innovative design: 1 tube per type of vehicles = 6 to 8 lanes
The Project

Eastern Tunnel

10 km
Two superimposed decks
Uni-directional traffic
Lightweight vehicles only

- Section 1 (4.5 km) opened in June 2009
- Section 2 (5.5 km) opened in January 2011
A sustainable project

- Project Location: Paris « Green Belt » area
- Reduction of disorders during building
- Surface traffic lightened by 15%
- Architecture design and above-ground facility location blends into landscape
- Limit visual impact on historical monuments (Versailles, …)
- Minimized above-ground facilities while maintaining safety
- Car emissions reductions
- Air quality observatory
- Noise reduction
3 Main Ventilation Plants located at motorway junctions
9 emergency shafts (2 with Intermediate Ventilation Units)
### Characteristics

Total length between Rueil-Malmaison and Pont-Colbert: 10 500 m
Length East 1 section from Rueil to exit A13: 5 400 m
Length East 2 section from entry A13 to Pont Colbert: 6 000 m

Design Reference Speed: 80 km/h (actual speed limit: 70 km/h).
Gradients: \( \leq 4.5\% \) or \( \geq 0.5\% \),
Horizontal curves: \( \geq 800\) m,
Vertical curves: \( \geq 6000\) m

Geology and tunnel profile:
- Tunnel profile is defined considering interchange points location and geological constraints; wherever possible, it is maintained in the best soil conditions to facilitate excavation (limestone and marl), which explains the presence of 2 at grade portions (1.2km long for East 1 section and 2.3 km long for Est 2 section)
- Between these 2 zones, tunnel profile is upgrade at 4.5% through the Fontainebleau sands to reach the surface and assure the interchange with A13 motorway.
Cross Section

- Doubling the link-up’s capacity
- Diversification of the interchanges with surface roads
- Significant reduction of each interchange’s surface
- Reduced impact on the environment
- Increased safety
- Designed for peaceful driving
Cross Section: Clearance and width

Clearance:

- Inside diameter of the tunnel: 10.40 m
- Allowed clearance for lightweight vehicles: 2.00 m
- Ceiling clearance: 2.55 m

Lane width:

- 2 x 3 m-wide lanes + 2.5 m-wide escape lane
- Or 3 x 2.80 m-wide lanes, near interchanges.
1. A86 Duplex overview
2. Interchanges
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Rueil-Malmaison Interchange View
Rueil-Malmaison Interchange Toll

Section 1:
Opening day 26 June 2009:
Interchange A86/A13
Underground Interchange with 3 levels and 8 junctions:
3 km secondary tunnels
Interchange A86/A13 Toll Aerial View
Interchange A86 Pont Colbert
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Skip underground led to the choice of the method of digging the tunnel:
13 geological horizons and 4 groundwater:
Tunnelier dual mode "earth pressure" and "slurry mode“  diameter 11,60 m
Slabs and pavement

Drive comfort:
continuous rolling slabs
anchored to the end

Pavement clear coated synthetic
with titanium oxide
Safety works

- «Two tunnels in one» - One-way traffic

- Emergency alcoves and shelters every 200 m

- Independent ventilation for each level
Redundancy of emergency access ways

- Emergency access and exit shafts to the surface, every 1,200 m.
- Accident level and safe level are connected by recess with escape stairways every 200 m
safety works 3D Views

Safety recess with Escape stairways

Smoke exhaust niche
Typical excavation sequence after ground treatment or congelation

- Forming openings in lining
- Installation working platform
- Excavation and support (steel ribs and shotcrete)
Recess and shafts construction

congelation with thermal control
Recess and shafts construction

Completed safety recess

Completed ventilation recess

40 safety recesses (every 200 m)
28 ventilation recesses (every 400 m).
Exit shafts for emergency services

7 Standard emergency shaft 20m to 90m high
Other Safety works

2 Intermediate Ventilation unit
and emergency shaft
GENERAL EQUIPMENT

- Ventilation and smoke control system
- Fire-fighting system, drainage and water mist
- Lifts for evacuation
Overview of Ventilation System

Sens Pont Colbert – Rueil

125 m³/s
tous les 400 m

Sens Rueil – Pont Colbert

125 m³/s
tous les 400 m

65 ventilateurs
56 accélérateurs
4 rideaux d’air
Débit installé 2 000 m³/s
Rueil Malmaison Ventilation Unit
Specific Hazard Investigation

- Heavy trucks are not allowed in the tunnel: The energy produced by a light car in fire is ten times lower than by a heavy truck.

- A ventilation simulation tool was developed for the project and was used for the hazard investigation.

- Design fire curves

  Main tunnel fire

  ![Main tunnel fire graph](image)

  Access road fire (interchanges)

  ![Access road fire graph](image)
Smoke Control System

- Powerful smoke extraction system: fire exhaust dampers located every 400m (110 to 130 m$^3$/s extraction)
- Pressurized shelters and shafts to prevent smoke spread from one roadway to the other and assure a safe path of evacuation
Smoke Control System

**Design criteria:**

- **Longitudinal smoke control**
  - $V > 2 \text{ m/s}$

- **System designed for maximum tunnel traffic flow:**
  - 3,400 vehicles/hour/direction when opening to operation
  - 4,400 vehicles/hour/direction long term operation

- **Emergency pressurization in the escape staircases:**
  - 2 pressurized staircases upstream the fire place
  - 6 pressurized staircases downstream the fire place
Fire & emergency ventilation site test

Site fire and smoke control test in the Tunnel:

- Tests from 2 MW to 15 MW (Eptane)
- One test with 3 vehicles 15MW
Operations emergency procedures

- Traffic control and detection:
  - T0 = fire or incident start time
  - T0 + 2 minutes: maximum automatic incident/fire detection delay

- Traffic management:
  - T0 + 2 minutes: traffic shutdown at the tunnel entrance (toll barrier)
  - T0 + 3 minutes: activation of other traffic management device (barriers into main tunnel, at the access roads connections...)

- Emergency Ventilation:
  - Air velocity maintained >1 m/s before fire fine localisation and smoke control activation
  - T0 + 3 minutes: pressurisation of the safe roadway and shelters
  - T0 + 4 minutes: smoke exhaust activation depending on the predefined scenario
Specific Hazard Investigation

Sample Scenario:
Espace trafic supérieur

Time-visibility diagram:
Test performed for each fire location with different traffic or climate conditions
(more than 500 fire scenarios)

NS-ET 43
Vers Rueil
Pente : 4.5 %

NS-ET 42
Sample Scenario : Espace trafic supérieur

NS-ET 41
Vers échangeur A13

3400 vêh/h (2 voie)

TD 21
0 TD 20
Arrivée du module AgEx en provenance de Rueil

Arrivée du module AgEx en provenance de PC

Dernier véhicule quitte l'espace trafic sain à T₀+11
Ouverture des ET vers espace trafic sain

Activation fermeture tunnel
Mise en route du scénario de désenfumage
Désenfumage à 100 %

Départ des sapeurs-pompiers
Arrivée des premiers sapeurs-pompiers
The fire-fighting system enables safe and instantaneous supply from the fire hydrants located every 200 meters along the traffic ways of the East tunnel and the interchanges.

A fire hydrant is installed in each emergency refuge area.
In the event of a major fire or a major accident, the Water Mist system must:

- Prevent or slow down the fire spread to other vehicles,
- Confine the fire source (heat release rate and extension in space)
- Reduce the impact of the fire (temperature, toxicity....) on people during evacuation
- Improve the conditions for the emergency services to intervene.

Tests in the Tunnel

Preliminary Tests with car fire
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SUPERVISION & CENTRAL CONTROL CENTRE

The Supervision and Central Control System gives the operator the means of efficiently operating the tunnel by:
- Traffic management
- Centralised technical management

For this purpose, the SCADA system performs the following tasks:
- Inform the operator (real-time)
- Control and manage the technical device
- Manage the alarms, providing traceability and records

The SCADA has additional tasks:
- Computer-aided assistance to the operator in making a decision
- Traffic events forecast
Ergonomy of the Control Center

Constant and real-time monitoring of traffic events and equipments status
Traffic Management

- No congestion allowed inside the tunnel, achieved by traffic control on entrances and exits, and within the tunnel
- Automatic Incident Detection
- Variable Message Signs
- Customer Assistance Patrol
- FM radio broadcast override
Electrical Equipment (EPC-E&M)

- Ventilation and smoke control (EPC-CW)
  - 65 axial ventilators
  - 56 jetfans
  - 4 twin air curtains (18 accelerators each)
  - 56 variable speed drives
  - 310 motorised fire dampers

- Fire-fighting, drainage and water mist systems (EPC-CW)
  - 9 pumps
  - 11 drainage pumps
  - 135 fire hydrants and manifolds
  - 17500 sprinkler nozzles

- Lifts and technical room ancillary device (EPC-CW)
  - 7 lifts in the emergency shafts, 6 lifts in the ventilation units
  - Technical rooms ventilation, air conditioning and fire detection systems
Traffic Signs
- 62 variable messages signs
- 340 signs for lane allocation
- 16 access controls
- 9 systems to detect oversized vehicles

CCTV
- 400 cameras

Emergency telephone system
- 120 emergency telephone units
- 700 emergency call pushbuttons

Traffic management
- 50 traffic data collecting stations (counting, speed)
- Automated system for detecting bottlenecks on each exit slip road
Power Distribution
- 10MW installed power
- 4 x 2,000 KVA emergency power generators
- 80 km of 20KV HV cables
- 400 km of 400V LV distribution cables

Inside/Outside lighting units
- 10,000 lighting units in tunnel and covered slip roads
- 350 outside lighting units

Fire Detection
Electrical Equipment (EPC-E&M)

- Telephone, intercom

- Transmission system
  - Counter rotary twin fibre optic ring, SDH 155 Mbits

- Access control of vehicles and staff

- Supervision and central control system
  - 150,000 control points
  - 16 canton automated units
  - 75 offset entry/exit racks
- Automated detection of stopped vehicles
  - 160 video analysers

- Radio-communications
  - 25 km of broadcast cable

- Speed control
  - 36 control radars

- Toll
  - 8 tollbooths at Rueil-Malmaison
  - 9 tollbooths at Vaucresson / A13
  - 8 tollbooths at Versailles / Pont Colbert
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Emergency vehicles

Specially designed emergency vehicles

- Customer assistance patrol
- One agent at each entrance of the tunnel
- Access to the site of the incident within five minutes
Operations and Maintenance

- Traffic
  - Average traffic: between 25,000 and 30,000 vehicles per day
  - Between 40 and 45% of electronic toll transactions
  - Rise of the second section faster than the first section

- Breakdowns, accidents and fires
  - 1 breakdown every 2 days
  - 1 accident all equipment 2 to 3 months
  - 2 departures on fire since the opening of the tunnel

- Events: mainly oversize

- Staff
  - 100 employees, including 75 agents operating:
    - 65 agents viability and security and supervisors
    - 10 receivers and maintenance technicians
End

Thanks for your attention