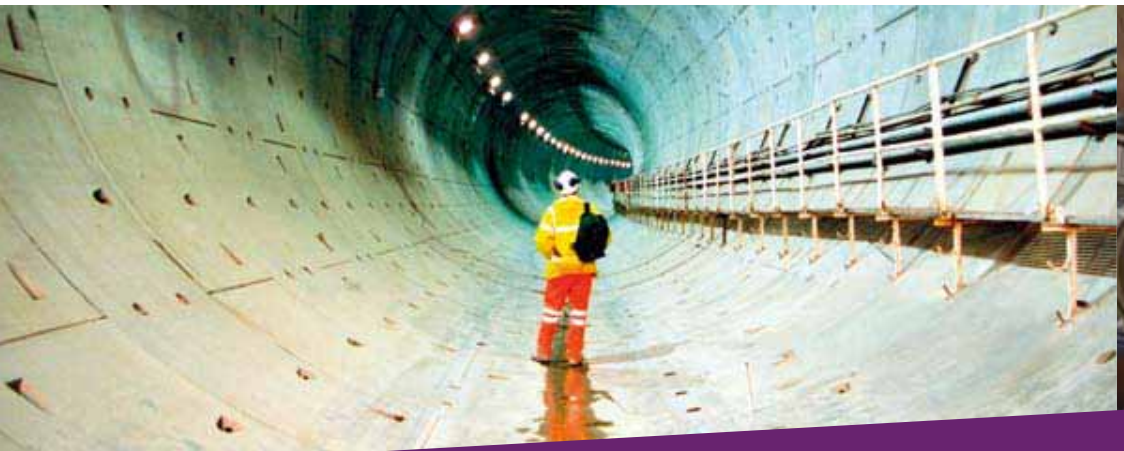
VINCI CONSTRUCTION | GRANDS PROJETS



# Tunnelling works:
## world class innovative solutions

# Combining experience with innovation

" **On a worldwide basis,** the potential of unused underground resources is colossal. "

Yann Leblais, *vice president of ITA-AITES (International tunnelling and underground space association)*

**VINCI Construction Grands Projets, a subsidiary of VINCI, the world's leading concession and construction group, designs and builds major civil engineering structures and buildings throughout the world.**

Our Tunnelling Division is devoted to the construction of all forms of underground works on all continents.

We bring to project teams our expert resources who provide all services from conceptual design through to construction.

Through value engineering and innovation we strive to deliver the optimum buildable solution for our Clients.

## A PARTNERSHIP APPROACH

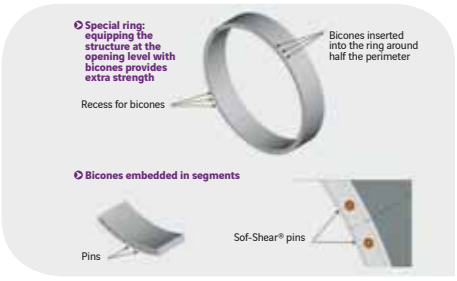
Tunnelling contains inherent risks due to the uncertain nature of the ground. We work proactively in partnership with our Clients and partners to identify and minimise risks. Our preference is to establish long term working relationships which are based on trust and openness. In doing so all partners derive mutual benefits and continuous improvement on every project.

# Innovation for our Clients

A86 Duplex example: from basic design principles to highly detailed solutions. The A86 project is a fantastic example of our ability to innovate at every stage in the special ring project development process to deliver technical excellence.

## CONCEPTUAL INNOVATION

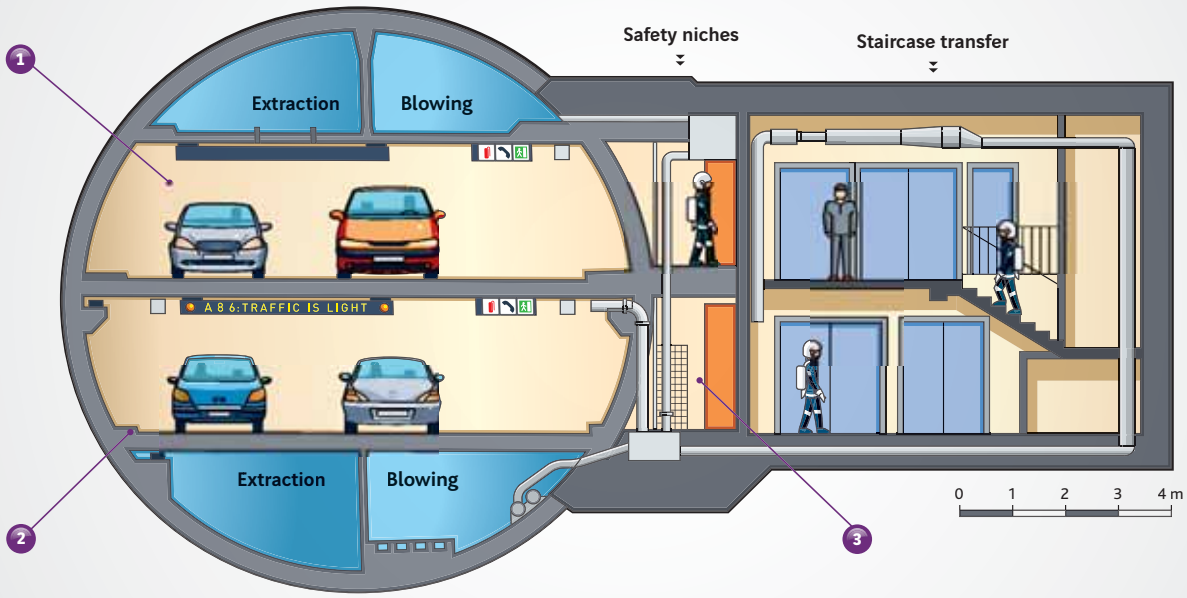
The A86 Duplex was the first tunnel designed with two superimposed levels of traffic, each level consisting of two lanes plus an emergency lane. Safety considerations were incorporated from the outset of the design process and resulted in a number of provisions (refuges, traffic monitoring, system, etc.) which will ensure public safety in the case of accidents.
By reducing the travelling time from 45 to 10 minutes, the tunnel will significantly contribute to a reduction of $CO_2$ emissions.




**1 An innovative TBM**
We developed a 'multi-mode' TBM capable of working in two different modes: EPB for tunnelling through clay and slurry for sandy ground. This is one of the many innovative concepts which contributed to the successful delivery of the tunnel.

**2 Inner structures: exceptional methods**
Designing the inner structures, in particular their connection with the lining, and developing the construction methods for building these inner structures concurrently with the tunnel drive, was a major challenge successfully overcome by our team.

**3 Construction of the safety niches**
The utilisation of the bicone Sof-Shear®, developed by VINCI Construction Grands Projets in partnership with Sofrasar, eased the creation openings in the segment lining, by minimising the amount of temporary works.



# Technical expertise to find the right solution

Our **considerable knowledge of tunnelling techniques** and our ability to capture our Clients' vision for a project in our conceptual designs sets us apart from others.

The major factor influencing both the design of underground structures and the tunnelling methods to be used is the nature of the ground itself.

Having completed over 1,000 km of tunnels, shafts and caverns, we have mastered every kind of tunnelling technique, from deploying conventional methods to driving state of the art tunnel boring machines.

On each and every project, our experts review and evaluate the ground conditions and draw on the range of available proven techniques to develop and implement the most suitable and buildable solution.

We then work with our Clients and their representatives to develop the optimum detailed design.

## IN-HOUSE DESIGN CAPABILITIES

We are able to combine our practical construction knowledge with the engineering expertise necessary to develop the best solutions to the most difficult tunnelling challenges.

We have an in-house team of qualified and experienced engineers, who develop projects from initial optioneering through to the development of detailed drawings and specifications used to realize the construction works.

**Typically our in-house engineering team can:**

- Evaluate the options for excavating the tunnels.
- Develop the proposed excavation methods.
- Design temporary supports and the permanent lining.
- Design ground treatments such as grouting, ground freezing or others.
- Specify and monitor the manufacture and commissioning of the TBMs and related equipment including slurry treatment plants.

# Working across the world

VINCI Construction Grands Projets operates all over the world. Wherever there is an underground challenge we are keen to work with Clients to find a cost effective solution.

We have a core team of experienced and qualified tunnellers (from miners to project managers) who are used to working overseas. They have a proven ability to adapt to new environments and different cultures. Our approach is to establish a core project team of experienced people and recruit and train local personnel to bring benefits to the local economy.

## FORGING STRONG LOCAL PARTNERSHIPS

We are keen to develop long lasting partnerships with Clients and local contractors. This enables us to continue to improve the service we provide by understanding Clients' needs and local conditions wherever we work.

**United Kingdom: A partnership of over ten years with Morgan Est**

Our relationship with British contractor Morgan Est (formerly Miller) began in 1997 when we were selected to construct 14 km of tunnels under London's Heathrow Airport. The Joint Venture was also awarded two contracts on the Channel Tunnel Rail Link including the North Downs tunnels.

These prestigious and successful projects formed the basis of a long term relationship that has delivered motorway widening, multi-span bridges and railway infrastructure. Over a decade of continuous cooperation later, both companies have derived significant benefits from the relationship.

We were recently awarded a major tunnelling contract as part of an upgrade to London's sewerage network and will continue to pursue future projects together.

**Egypt: A thirty year partnership with the National Authority for Tunnels**

VINCI Construction Grands Projets has, since 1981, participated in the construction of all three lines of the Cairo underground system and delivered major road infrastructure improvements.

From 1981 to 1987, VINCI Construction Grands Projets participated within a consortium to deliver Line 1 under a turnkey contract. Line 2 commenced in 1993 and required the use of slurry machines, a relatively rare technique at that time. As Line 2 works concluded in 1998 the opportunity arose to transfer all resources to construct the El Azhar road tunnels. Since 2008, we have led the consortium constructing Line 3.

Over the years, our Clients have greatly appreciated our ability to collaborate with them to reliably deliver high quality projects in a spirit of true partnership.

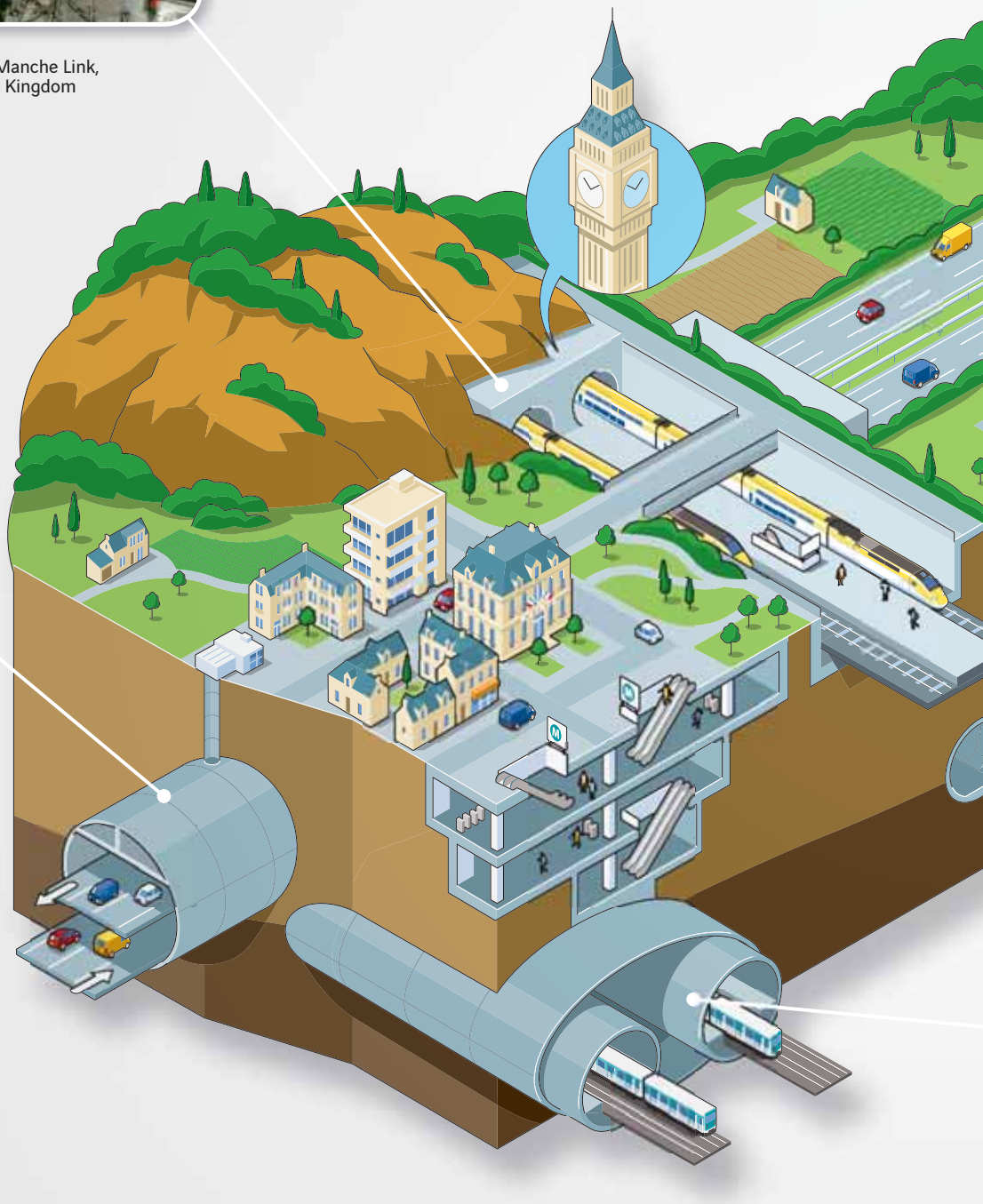
## Projects underway and major achievements of VINCI Construction Grands Projets in tunnelling works

# Mastering all tunnelling techniques

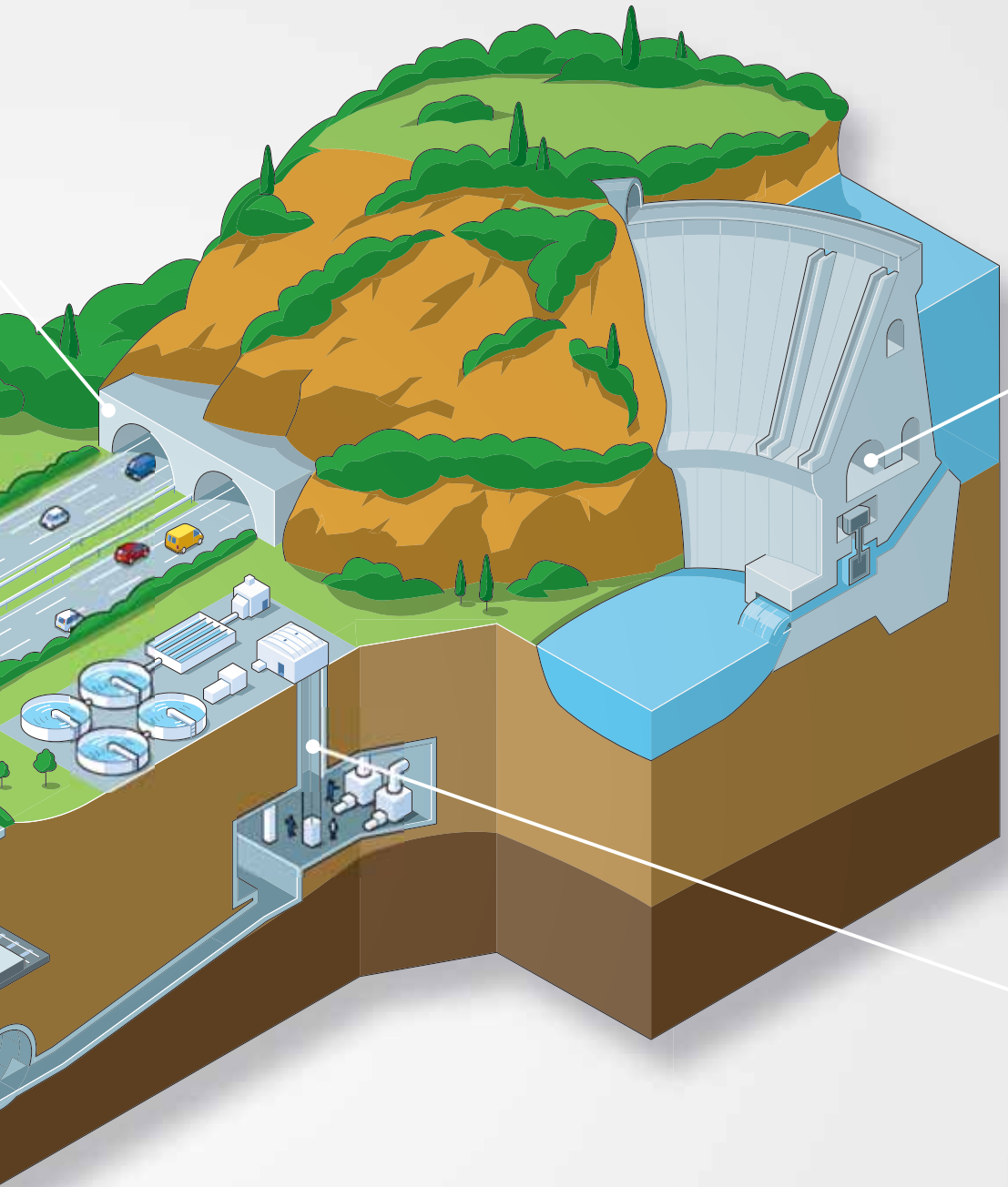
Maliakos-Kleidi road tunnel, Greece

Trans Manche Link, United Kingdom

A86 Duplex tunnel, France



# to serve all types of projects



Xiaolangdi undergound power plant, China

A86 Duplex emergency well, France

Magenta metro station in Paris, France

# From Tunnel Boring Machines to

From smallest to largest, from soft ground to hard rock, we have already driven Tunnel Boring Machines (TBM'S) in all conditions.

## Tunnel Boring Machines

We deployed our first hard-rock TBM in 1981 on the Grand-Maison dam located in France and our first slurry TBM in 1982 on a metro line in Lyon, France. Since then we have remained at the forefront of international tunnelling techniques.

From remote project locations, to tunnelling under the busiest airport in the world, we are capable of adapting our tunnelling techniques to suit all our Client's constraints.

Our teams have experts in all aspects of TBM operations, from segments manufacturing to TBM breakthrough. We use our longstanding relationships with specialised suppliers to ensure we are fully familiar with state of the art developments in products, techniques and equipment.

Over many years VINCI Construction Grands Projets has developed a significant portfolio of world class tunnels which includes all TBM techniques.

**Lefortovo road tunnel - Moscow, Russia**
This 2.3 km long road tunnel was constructed using a slurry shield. The combination of its large diameter (14.22 m excavated diameter) with the sensitive environment required a strict settlement monitoring regime.
A comprehensive scheme of real time monitoring and compensation grouting was implemented for tunnelling underneath the Alexis Military University.

**Hallandsås rail tunnels - Sweden**
A key constraint associated with the construction of this 10.9 km long rail tunnel was to keep at all times the water inflow in the tunnel within very strict limits to avoid affecting the water table.
To that effect, a hard-rock TBM capable of working also as a slurry machine was developed to ensure up to a maximum of 13 bars confinement pressure.

**Water distribution network**
**Brightwater - Seattle, USA**
Located within very abrasive glacial deposits, the 5.3 m diameter TBMs suffered extensive wear. Maintenance and repair works required extensive hyperbaric interventions at high pressures, up to 5.8 bars.

**Access tunnel to T5 terminal**
**Heathrow Airport - London, United Kingdom**
To minimise the settlement on the surface while constructing this 9.2 m excavated diameter tunnel at a shallow depth under Heathrow Airport, a TBM capable of working in Earth Pressure Balance mode or in compressed air was developed. The tunnelling of these twin tunnels, each 1,250 m long, was successfully completed without any adverse effect on the airport operations.

Over the past 20 years, our teams

# conventional tunnelling

Whether using traditional drill and blast techniques or mechanized methods in soft ground, **we design and construct tunnels using NATM or SCL methods,** including the design of ground improvement schemes, the installation of waterproofing and secondary lining.

## Conventional tunnelling

**Drill and blast**
**Soumagne rail tunnel - Belgium**
Constructed using the drill and blast technique, this 5,940 m long tunnel, east of Liege, is the longest existing rail tunnel in Belgium.

**Lining**
**Mitholz Rail tunnel - Lötschberg, Switzerland**
With 26 km, the Mitholz tunnel, excavated using drill and blast technique, is the longest stretch of the Lötschberg tunnel (34.6 km) and serves to piggyback passengers and vehicles between the cantons of Berne and Valais, in the heart of the Swiss Alps.

**Mechanical solutions**
**North Downs Tunnels**
**London, United Kingdom**
This 3.2 km long tunnel is part of the high-speed rail connection between the Channel Tunnel and London. This 155 $m^2$ tunnel was excavated in soft ground (chalk) using mechanised excavators. The primary support consisted of rock bolts and shotcrete and was subsequently covered by a cast in situ concrete lining.

**Ground improvement**
**Ground freezing - Paris, France**
On the A86 Duplex project in Paris, the construction of the safety niches in soft ground, under water, required the implementation of a large variety of ground treatment solutions, ranging from grouting to ground freezing.

have constructed **775 km of tunnels.**

## Large caverns and shafts

The formation of large caverns and deep shafts is regularly required to house metro stations, waste storage, underground powerhouses or similar facilities. These projects often require bespoke solutions such as purpose-made equipment for shaft sinking and complex excavation sequences for large caverns. Our teams draw on past experience to develop the best construction methods to meet the particular challenges being faced.

### Shafts of ANDRA - France

**FOCUS**

**Constructing 500 m deep shafts for underground research laboratory**

Feasibility study and construction of two shafts 500 m deep and a network of 340 m of tunnels to access a research laboratory used for scientific tests for the underground storage of radioactive waste. With a diameter of 5 and 6 m, the excavation of these wells required VINCI Construction Grands Projets to develop specific tools.
The surface of these wells has necessitated the establishment of 10,000 $m^3$ of Self Compacting Concrete (SCC).

# Safety first!

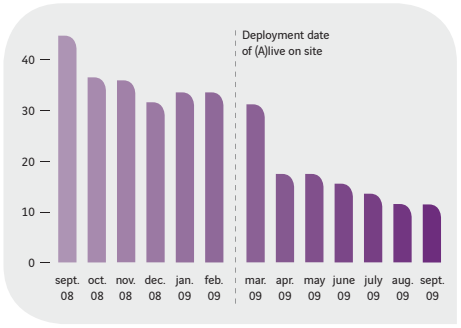
Tunnelling is a particularly hazardous activity due to working in confined spaces, uncertain ground conditions and the use of heavy equipment. It is therefore vital that we adopt our «Safety first!» policy on all our projects.
**Our strategy is to ensure that all of our employees are actively involved in making their worksites safer.**

## (A)LIVE ON SITE

(A)live on site is a safety program developed by VINCI Construction Grands Projets. It is designed to ensure that everyone recognises the role they have to play in delivering projects safely and involves familiarisation with the site specific risks.

Video footage is recorded on site to capture good and bad safety practices. This is then screened in the local language at compulsory site meetings attended by all staff, subcontractors and workforce personnel.

By demonstrating the key issues using this powerful communication method, VINCI Construction Grands Projets raises awareness of the site specific safety issues. It also invites discussions on best practice and improvements and encourage teams to formalise results into firm commitments.




Accident frequency rate over a 12 month period

(A)live on site was implemented on seven projects in 2008, in French, English and Arabic. Results show a direct correlation to a reduction in the accident frequency and gravity rates. By the end of 2009, 1,100 people had benefited from the program, now available in 9 different languages.

At the VINCI 2009 Innovation Awards, the Safety prize was awarded to (A)live on site.


## Innovating to improve safety

### FOCUS

**▶ VINCI Innovation Awards winning motorised rescue chamber**

Fire is one of the main risks faced by tunnellers. In Sweden, as part of the works for the Hallandsås tunnels, the project team developed the first self-sufficient rescue chamber mounted on rails which can be driven in a toxic atmosphere. This chamber can hold 20 people, protecting them from smoke and harmful gases, providing a highly efficient facility in the event of underground fire. This idea won the Equipment prize at the VINCI 2007 Innovation Awards.

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