Adits For Long And Deep Tunnels

ITA - Working Group N°17
Long Tunnels at Great Depth

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In 2010, the ITA-Working Group N°17 published a revised version of the report entitled Long Tunnels at Great Depth.

The original 2003 report was revised to take into account the experiences of long traffic tunnels at great depths in the Alps. The Lötschberg base tunnel (Switzerland) was commissioned in 2006, and the Gotthard base tunnel was broken through in 2011. Investigation work is under way for the Lyon-Turin (France – Italy) and Brenner base tunnel projects.

This revision has also incorporated experiences from projects in China, Japan, Norway and Sweden, where projects are currently underway.

The report on Long Tunnels at Great Depths essentially focuses on the main tunnels with less attention paid to access galleries (adits). The members of the ITA working group N°17 felt it was important to look specifically at adits. Adit projects are part of the main projects and may have a significant impact on the alignment decided upon for the main tunnel, the construction conditions, safety during construction and operation, the work schedule and project costs.

In this report, the term adit refers to a gallery or shaft giving access to another structure. Generally, the main project structure is a very long rail or road tunnel at great depth. By analogy, the ideas developed in this report can also be applied to other types of projects, such as for hydraulic or hydropower facilities or storage caverns.

An adit starts at a place on the surface of the work site and leads to the main structure. Generally one or several caverns or galleries are set aside for site logistics and/or for the operation of the main structure.

An adit can be different type, such as inclined gallery, shaft, transverse gallery and parallel heading, which shall be chosen considering the terrain, geology as well as the purpose of the adit.

3 >> Function of adits of long and deep tunnels

Adits have several functions which evolve during the course of the project. The main functions of an adit during the several phases of the project are to provide or enable:

- Design phase:
  - Reconnaissance of grounds conditions
- Construction phase:
  - Access to the main tunnel
  - Logistics for the construction of the main tunnel
- Operation phase:
  - Access for maintenance personnel
  - Escape route and access for rescue teams
  - Ventilation and smoke extraction

The project engineer must make difficult technical choices between these different functions, since it is difficult to meet all the constraints at the same time.

These choices will affect the main project. The impact can sometimes be significant. For this reason, the adits shall be considered together with the main project as a whole.

3.1. RECONNAISSANCE OF GROUND CONDITIONS

Since work on the adits often starts before the main tunnel, it is important to take advantage of this to gain better geological and geotechnical knowledge of the ground for the main project Moreover, the construction method and countermeasures for the main tunnel can be demonstrated on the adits in advance.

If there are plans to dig investigation galleries for the main project, it is clearly judicious to excavate in required cross-sections and to choose an alignment which will be suitable for later use as an adit.

If possible, the route should be parallel to the main tunnel in order to ascertain the geology situation of main tunnel. At great depths, adverse tunnelling conditions must be taken into account, since this can significantly increase measures required in terms of the support, the cost and time needed to complete the project.
Example: St-Martin-la-Porte gallery for the Lyon-Turin project.

When there is great geological uncertainty, it is wise to begin the adits before the main tunnel in order to be able to adjust the latter's alignment, if necessary. Moreover, if necessary it is possible to complete the adit by a survey gallery at the bottom of the adit, parallel to the main tunnel.

The connection point between the adit and the main tunnel may also be positioned in relation to a difficult geological zone (fault zone, water under high pressure) to allow the treatment to be carried out independently from the main tunnel work.

The optimisation of the main project and the synergy between the access and reconnaissance functions should lead to overall savings. The best position of the connection point will be better determined by improved knowledge of the geological structure.

For geological studies, particular attention must be paid to risks caused by underground water, particularly when excavating galleries slope downwards.

3.2. CONSTRUCTION PHASE OF THE MAIN TUNNEL

3.2.1. Access to main tunnel

An adit's function is to join the main tunnel at an intermediate point in order to enable work to proceed from that point. The primary objective is to reduce the overall duration of the work.

For very long projects, as well as for site safety and logistic reasons, it is also necessary to reduce the distance between the working faces from the two main tunnel portals (transport time, ventilation).

3 >> Function of adits of long and deep tunnels

In certain situations, for example if the main tunnel portals are located in cities, most of the work must be undertaken from adits. This is the case with the Ceneri base tunnel in Switzerland.

3.2.2. Logistics for the construction of a main tunnel

The adit should be designed to fulfil the following functions:
- Transporting equipment and personnel
- Evacuating excavated materials (haulage)
- Supplying construction materials
- Evacuating clean and dirty water
- Ventilation (injecting fresh air and evacuating polluted air)
- Supplying electrical power
- Telecommunications
- Safety (escape route)
- Cooling (if necessary)

Depending on the size of the main work site and local conditions, these installations may be quite significant in size, in particular the ventilation ducts. It is sometimes necessary to build two parallel galleries or two shafts to ensure all the vital functions. The presence of two adits significantly increases the safety of personnel working underground. This may be imposed by national safety regulations.

The logistic functions often require the creation of caverns.

The use of conveyors for haulage is recommended since this reduces requirements in terms of ventilation and intermediate storage of excavated materials.

3.3. OPERATION PHASE FOR TRAFFIC TUNNELS

Under national and international safety regulations, and depending on the length of the main tunnel, it may be necessary to create intermediate access point to the surface for maintenance personnel and rescue teams.

The adit could also be used as ventilation and smoke extraction gallery.

To avoid unnecessary costs, the project designers should try to exploit the synergies with the other functions of the adits. In almost all cases, the adits used for construction may be transformed into escape routes.

4 >> Design of adits

4.1. GENERAL CONSIDERATIONS

Adits should be considered as normal tunnels when designing the temporary support and final lining, and defining safety regulations during their construction. As much attention should be paid to designing the adits as the main project itself.

For galleries excavated downwards, particular attention should be paid to risks caused by underground water, since this water must be pumped to the surface. This requires major facilities and significant power supply. The pumping system should be scaled with a sufficient margin to cope with heavy, periodic water inflows.

4.2. LOCATION OF THE WORK SITE AND PORTAL

Usually, projects for long tunnels at great depth are undertaken across mountain ranges. Work site locations from where it is possible to build an adit are rare and difficult to find. The location of the work site is based on many criteria among which the following:

- The alignment of the main tunnel
- The difference in level between the surface and the main tunnel
- Sufficient outdoor space, for adit construction, but also for the future working site of the main tunnel
- Accessibility: existing roads, access by rail, access by cable car, access by helicopter to evacuate injured persons
- Power supply: need to build new electrical power lines and plants
- Water supply
- Natural risks: landslides, rockfalls, avalanches, risk of flooding etc.
- Risk of environmental impacts
- Political risks: attitude of local population
- Geology and hydrogeology

4.3. CHOICE BETWEEN DESCENDING GALLERIES AND VERTICAL SHAFTS

Usually, for the purpose of access to the main project, when the condition is available, transverse adits, parallel headings and inclined adits are firstly considered and then vertical shaft. The shafts are considered only when the other types of adits are not possible at the job site or for purpose of ventilation.

Generally, the work sites are located at a higher elevation than the planned connection point with the main tunnel. There are two options for adit projects:

- An inclined descending gallery
- A vertical shaft

The length of the inclined gallery is inversely proportional to its slope. An optimal slope of 8 to 12% has often been used on several large projects. Inclined galleries are often preferred to vertical shafts since they offer many advantages:

- Safety: allowed self-rescue of personnel, no risk of falling from a great height
- Haulage: less risk of falling loads when transporting materials
- Faster excavation than with vertical shafts
- Use of conventional equipment
- Simpler groundwater management than with shafts

Vertical shafts excavated from the surface may offer advantages in certain particular cases:

- Favourable geology for vertical structures
- Need to reduce the volume excavated
- For ventilation purpose. If an additional ventilation duct needs to be made and if it is possible to reach the connection point via an other way before, a shaft made by raise-boring is often an excellent option.

4 >> Design of adits

4.4. DISTANCE BETWEEN CONNECTION POINT OF THE ADITS

It is difficult to define an optimal distance between connection points of the adits of a long and deep tunnel.

The distance between the adits of a long and deep tunnel depends on several parameters:
- Access possibilities from the surface
- The length of the adits
- An acceptable lead time for the customer
- The financial costs
- Safety regulations (national or international)
- The geology
- The ventilation
- Site logistics: transport means, evacuation of materials

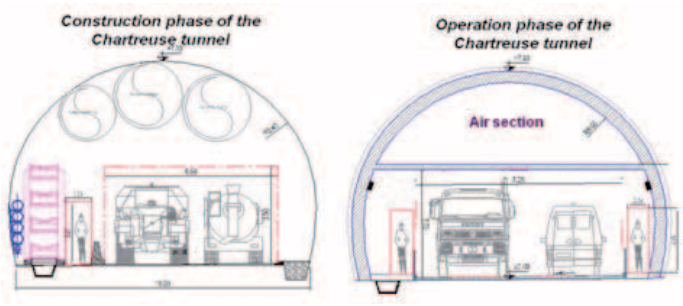
For example, for the Lötschberg base tunnel (Switzerland), the average distance between the adits is 11 km; and in the Gothard base tunnel it is 14 km. For tunnels by D&B in China and Japan, the distance is usually about 4 to 5 km. It could be even less when fast construction is required or poor geology shall be treated in advance.

4.5. DESIGN OF THE CROSS SECTION

The interior cross section of an adit can be greatly simplified, if essential purpose is only to build an access route to the main tunnel.

The gallery cross-section shall be built to allow two dumpers or trucks to pass each other easily. A pedestrian way could be necessary according to national safety regulations. For example, for the Lötschberg base tunnel and the Lyon-Turin (F / I) the adits have a cross-section of 70 m^2.
The inner dimension also depends on the number of working point at the bottom of the adit, and the construction method for the main tunnel (for example access TBM). Taking into account the operational phase could lead to oversize the adit.

There must also be enough room for all other logistical equipment, in particular:
- Conveyor belts
- Ventilation ducts (if there is no second gallery or shaft)
- Water pumping equipment
- Electric and communication cables



Preliminary design of Lyon-Turin Chartreuse tunnel (French section)

In vertical shafts, in addition to the lift and logistical equipment, a sufficient cross-section must be left free to allow the air to circulate.

The permanent support should, if possible, have the same life span as that in the main tunnel. A final lining is not essential. In inclined galleries, the traffic roadsurface must be carefully designed. A roadsurface made of reinforced concrete is a tried and tested solution. If the road surface becomes too smooth, it will need to be milled a few centimetres in thickness.

4.6. PARTICULAR ISSUES ON CONSTRUCTION METHOD

Whatever the solution chosen for the adit (inclined gallery or vertical shaft), water management is essential to the success of the project.

In the event the pump system fails, a lake will form rapidly at the working face and will have to be pumped to the surface later.

The pump system and its electrical power supply must have sufficient capacity to cope with significant, unplanned water inflows.

The use of TBM is not recommended for excavating inclined galleries unless you are certain you can control the risks of the machine being flooded. Probe drilling and pre grouting equipment should be implemented in case a TBM is adopted.

In vertical shafts, water-sealing injections shall be performed to avoid permanently working under falling water.

5 >> Safety and environment for adits under construction

Normal tunnel safety regulations are also valid for inclined galleries but additional measures must be taken.

5.1. BRAKING OF VEHICLES IN DIFFICULTY IN INCLINED GALLERIES

Because of the slope in inclined tunnels, procedures for verifying vehicle brakes must be enforced. Vehicle drivers should be given clear instructions, in the event of brake problems, to react immediately by driving their vehicle against the side of the gallery wall, rather than continuing straight ahead and gathering speed. Additional devices can be placed on the walls of the gallery to reduce the impact of a vehicle.

One possible solution is to install emergency braking zones filled with gravel at regular intervals along the downward lane (e.g. gallery of La Praz&Modane, Lyon-Turin).

5.2. SPECIAL MEASURES TO FACILITATE THE WORK OF RESCUE TEAMS

During the construction phase, rescue teams (fire-fighters) should already have the required equipment to intervene at a great distance (vehicles equipped with an independent air supply in case of emergency).

If these vehicles cannot turn round in the adit, enlarged area should be put in place at certain interval (turning area to enable vehicles to go in both directions).

Rescue teams must train regularly on site. It is absolutely essential to install clear signposting at the foot of the adit so that rescue teams do not get lost in the labyrinth of the gallery or set off in the wrong direction.

5.3. VENTILATION

The ventilation should take into account the difference in elevation and the slope of the adit.

Once excavation has started to progress in the main tunnel, the ventilation system becomes complex. It is absolutely essential to create a detailed plan of every phase of the ventilation system and set up a centralised ventilation control station. The control centre should also be informed in real time about the presence of workers in the galleries. To do this, electronic devices for monitoring the presence of workers should be installed in the complex gallery systems (In some countries this system is obligatory according to safety regulation).

5.4. SPECIAL MEASURES FOR VERTICAL SHAFTS

The consequences can be fatal if people or objects fall in a vertical shaft. This risk should be anticipated and protective nets or roofs installed above the working zones. Mining industry regulations can normally be applied to vertical shafts.

5.5. ENVIRONMENT

The excavation of shafts or inclined galleries can have a significant impact on underground water and surface springs.

To reduce risks, injections should be undertaken as work progresses and, if necessary, reconnaissance drilling carried out. It should be noted that at great depth it is not always possible to completely seal off all water flows and a significant environmental impact is always possible.

It is essential to monitor water sources years in advance. Alternative water supplies should also be considered in the event the sources used were to dry up. Pregrouting should be adopted in those situations.

If dams are located near the work site it is essential to ensure they are strictly monitored. A drop in the level of the water table may cause the ground to compact and the structures to move.

Reusing materials is a key to sustainability: If possible the excavated materials from the adits should be reused as aggregate to build the main tunnel.

6 >> Special issues concerning adits

The project engineer should identify as soon as possible the necessity of building adits for the main project.

Detailed studies and analyses, balancing cost and risk, should be made in order to decide:
- if the global context leads to prioritize the survey function or the final functionality
- the best period to start the construction of the adit depending on several criteria (level of definition of the main tunnel, geology, planning etc)
- if the adit construction is better carried out by an independent contract from the main tunnel (e.g. an anticipated construction lead to prefer an independent contract)

It is recommended to have an adaptable market for the adit construction, in particular if the survey function is essential.

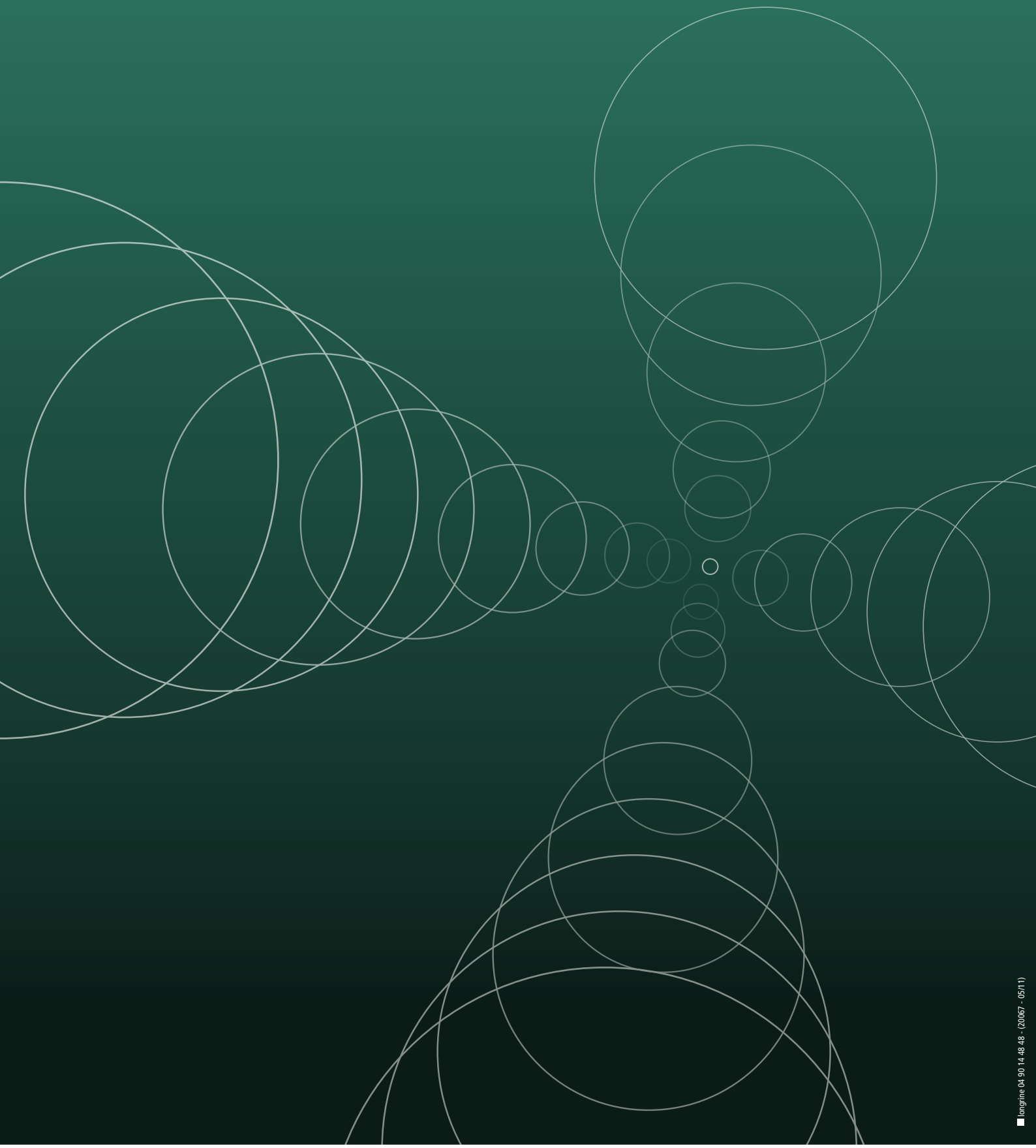
Lötschberg Base Tunnel Switzerland, adit of Ferden during construction

7 >> Risk assessment and management

A risk assessment and management system should be implemented according to the ITA guidelines and national regulations.

8 >> References

- ITA Report N°004 – Long tunnels at great depth (Working Group N°17, 2010, ISBN 978-2-9700624-3-1)
- ITA Guidelines for the Design of Tunnels (TUST 1988, p. 237-249)
- ITA Guidelines for Tunnelling Risk Assessment (TUST 2004, p. 217-237)
- ITA Report N°001 – Guidelines for good occupational health and safety practice in tunnel construction (Working Group N°5, 2008, ISBN 978-2-9700624-0-0)



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