403

CABLE SYSTEMS IN MULTI PURPOSE OR SHARED STRUCTURES

Working Group
B1.08

February 2010

WG B1.08

CABLE SYSTEMS IN MULTI PURPOSE OR SHARED STRUCTURES

Members:

Ray AWAD Convener (2007-2009) (CA)
Ken BARBER – Convenor (2004-2007) (AU)
Roberto BENATO (IT)
Ian BUTT (GB)
Frank DE WILD (NL)
Takeshi GOTO (JP) replaced
Yoshihisa TAKAHASHI (JP)
Jey K. JEYAPALAN (US)
Jeong-Tae KIM (KR)
Jordi MONTEYS (ES)
Christophe MOREAU (FR)
Kjell OBERGER (SE)
Colin PEACOCK - Secretary (AU)
Susumu SAKUMA (JP)
Rudolf WOSCHITZ (AT)
Kok Thean YOON (SG)

ISBN: 978-2-85873-090-2

"CABLE SYSTEMS IN MULTI PURPOSE OR SHARED STRUCTURES" TECHNICAL BROCHURE WORKING GROUP B1.08

1 INTRODUCTION

With the increase in demand and challenges of installing high voltage (HV) and extra high voltage (EHV) cables in dense urban and other locations structures such as tunnels and bridges for multipurpose use are becoming an attractive option. They offer a potential for reduced overall costs, environmental advantages and less disruption to the community in the installation, maintenance and replacement of cables and other services. However, the relative costs for the construction, operation or sharing structures have not been considered in any detail in this document.

The structure of this document is such that the reader can study Sections 1 to 5 and review the examples described in Section 8 to decide if a shared structure is appropriate. If it is decided to use a shared structure then Sections 6 and 7 that deal with the different technical and administrative issues, should be a useful guide in the design and implementation of such a system. Section 8 is a review of the international experience of HV cables in multipurpose or shared structures. Future trends are summarised in Section 9.

1.1. Terms of Reference

1.1.1 General

The recommendation to form Working Group B1-08 and its terms of reference were established by TF B1-14 comprising Susumu Sakuma (Japan), Yoshihisa Takahashi (Japan), Christophe Moreau (France), Wim Boone (Netherlands) and Colin Peacock (Australia). This was accepted during the SC B1 meeting in South Africa in August 2004.

1.1.2 Initial Terms of Reference

From the information it collected, the Task Force recommended that a Working Group be formed to accomplish the following goals:

- Establish the appropriate terminology
- Using a questionnaire developed by the Working Group (WG): collect comprehensive global information and experience on the use of multipurpose or shared structures for the installation of cable systems. The survey should not be limited to technical aspects such as type of cables, design of the structure, construction, installation, other infrastructure installed, mutual impacts, maintenance and operational constraints. It should also consider economical aspects, occupational health and safety aspects, administrative aspects, legal aspects, and decision-making aspects.
- Collate, summarise, and review the information
- Identify the issues that need to be considered when installing insulated cable systems in multipurpose or shared structures.
- Recommend guidelines for the use of cables in such structures.

1.1.3 Initial Scope of Work for Working Group

It was the recommendation of TF B1-14 that the WG should cover the following:

- Medium, High and Extra High Voltage cable installations.
- Solid (XLPE), fluid filled, and gas insulated cable systems.

- Multi-purpose tunnels and structures shared with piped services (water including hot or cold, gas and sewage), other utilities (other electricity services, telecommunications or pneumatic refuse collection pipes), and transport services (roads, rail and subways).

1.1.4 Membership

It was recommended that the WG should include representatives from the following sectors:

- Power system utilities (underground power cable utilities)
- Providers of other services that are potential or existing users
- Manufacturing
- Consultants
- Research and Academics

The WG was composed of permanent and corresponding members, but all members were asked to contribute, either by writing part of the document and/or by reviewing drafts. This final version represents a comprehensive view of insulated cable systems in multipurpose and shared structures throughout the world.

1.1.5 Time Schedule

The Working Group started work in April 2005 and were scheduled to produce a final report for discussion at the SC B1 meeting in Osaka, Japan in October 2007. This was later extended to be at the SC B1 meeting in Paris, France in August 2008.

1.1.6 TF B1-14 Survey

The results of the survey that showed there was enough interest in this topic to form a Working Group are included in Section 11.2.

1.2. Scope of Work

Due to the complexity of cabling in general, the group elected to mainly deal with cable systems of 50kV and above in multipurpose and shared structures where it felt that the investments are most likely to be made. However, there is no limitation to applying the principles to cables of lower voltages and EHV Gas Insulated Lines (GIL).

1.3. Definitions

The group adopted the definition of a shared structure from the American Public Works Association as follows:

"Any continuous structure containing one or more utility services which permits the replacement, renewal, maintenance, repair or revision of the service without the necessity of making excavation. This implies the structure is traversable by people and in some cases by some sort of technology"

In this document we are looking at multiple services by the same owner, multiple services by multiple owners or the same utility service by different owners.

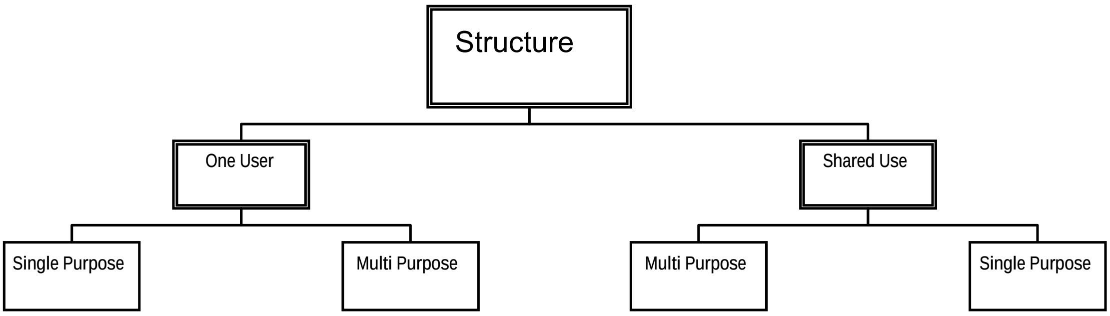


Figure 1.1: Various Forms of Structures

1.3.1 Single Purpose Structure

Any continuous structure containing one or more power cable systems which permits the installation, replacement, renewal, maintenance or repair of the services without the necessity of making either an excavation or disruption to any other services. This implies the structure is traversable by people and in some cases by some sort of technology.

1.3.2 Multipurpose Structure

Any continuous structure containing either a power cable system or systems and other services which permits the installation, replacement, renewal, maintenance or repair of the services, without the necessity of making either an excavation or disruption to any other services. This implies that the structure is traversable by people and in some cases by some sort of technology. It should be noted that a structure originally constructed for a single purpose may become a multipurpose structure at a later time.

1.3.3 Shared Structure

A single or multipurpose structure as defined above that is jointly used, owned or managed by several entities.

In Japan the term Common Tunnel is also used to describe a tunnel that is shared voluntarily by participating utilities.

2 TYPES OF STRUCTURES

2.1. Tunnels

Tunnels have been built since the early years of civilisation. They were used for mining, shelter or to secure a shorter and easier route than crossing difficult terrain such as mountain ranges. There are subterranean or sub aquatic infra structures. The world's oldest underwater tunnel is believed to be the Terelek kaya tüneli under Kizil River in Turkey. It is estimated to be more than 2,000 years old (possibly 5,000) and assumed to have had a multipurpose use including defence.

The preferred option for tunnels is single purpose use and one owner who also owns the services. Generally most owners appear unwilling to share the tunnel and the risks of shared occupancy. Shared tunnels are the exception unless there is a legal requirement or significant economic advantage.

Today tunnels connect countries, cross rivers and other waterways, provide a fast bypass for high traffic in large cities and thus reduce street congestion. Tunnels are also used to accommodate high voltage cables, GIL and other services such as: telecommunication cables, heating ducts, hot water pipes, sewage lines, water lines, chemical pipelines, petrochemical and gas lines.

In densely populated areas where excavating open trenches is expensive, discouraged or not allowed, tunnels offer a discrete way to build underground links that minimise the inconvenience to the population during construction, operation, maintenance and even replacement of the services housed inside these tunnels. They can offer protection against seismic forces.

Tunnels are normally designed for a life of a hundred years. It should be an integral part of the tunnel that it be designed and constructed to enable maintenance, repair and replacement of the services within the structure. It is imperative to study all aspects of a tunnel project considering the large capital investment needed for their construction and their potential high maintenance costs.

2.1.1 Tunnel Construction

Many techniques are available for tunnel construction using a variety of specialised equipment. Depending on the nature of the ground conditions where the tunnel is to be built, a specific technique might be the most suitable. Special geotechnical testing and geological interpretations must be undertaken in order to determine the composition of the different geological layers. Based on the findings, it is possible to select the optimal tunnelling technique and the machinery needed. Along the selected route of a given tunnel, the soil conditions may vary and it may be necessary to employ more than one tunnelling technique.

2.1.1.1 Cut-and-Cover Tunnels

The cut-and-cover method of tunnelling is often preferred for the construction of shallow tunnels whereby a trench is excavated, the tunnel constructed in the trench and the ground backfilled over the tunnel to the original ground level. There are two methods of constructing cut-and-cover tunnels: one is the “top-down” method which is used when the site needs to be reinstated as soon as possible and the other more usual is the “bottom-up” method.

In the “top-down” method the side support walls and capping beams are constructed from ground level, using contiguous bored piles or diaphragm wall method. A shallow excavation is then made to allow the permanent tunnel roof to be constructed using prefabricated beams or in-situ concrete. The surface is then reinstated except for the access openings. This method allows early reinstatement of roadways, services and other surface features. Excavation machinery is then lowered into the access openings, and the main excavation is carried out under the permanent tunnel roof, followed by constructing the base slab

The “bottom up” method requires the excavation of a trench and the tunnel is constructed within that trench. The method is undertaken in four steps: a trench is excavated, with ground support as necessary. A base slab for the tunnel is built within the trench. Using formwork the reinforced concrete tunnel structure is constructed in situ and after the concrete cures the formwork is removed. The trench is then backfilled and the surface reinstated. Alternatively the tunnel structure can be constructed using prefabricated reinforced concrete elements. A schematic diagram of these four steps of construction is highlighted in Figure 2.1.1.

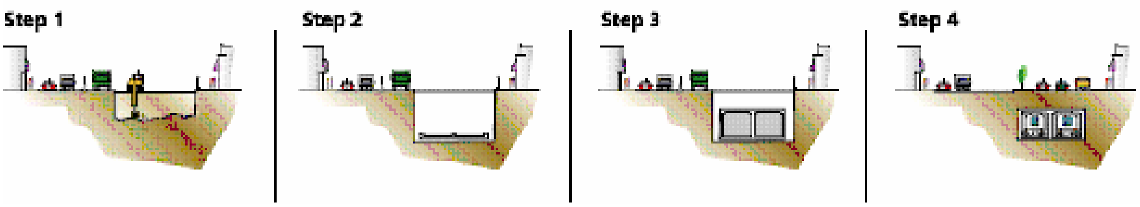


Figure 2.1.1 Example of cut-and-cover tunnel construction using the “bottom-up” method

Figure 2.1.2
Cut and cover tunnel under construction in Madrid (Barajas)

2.1.1.2 Immersed Tube Tunnels

The immersed tube type of tunnel is similar to the cut-and-cover tunnel but one which is constructed underwater.

A trench is first excavated in the sea bed and prefabricated segments, which are constructed on land, are sealed to ensure their buoyancy, are floated into position, and sunk into place within the pre-constructed trench. The segments are joined together and covered with a sand backfill and an outer rock layer to protect and keep them in position. The segments are subsequently drained to allow access to the tunnel.

An example of an immersed tube tunnel which is used for high voltage cables is shown in Figure 2.1.3. This tunnel has a central partition wall to separate the cable circuits. The cable circuits themselves may be cooled using forced ventilation or water cooling pipes.

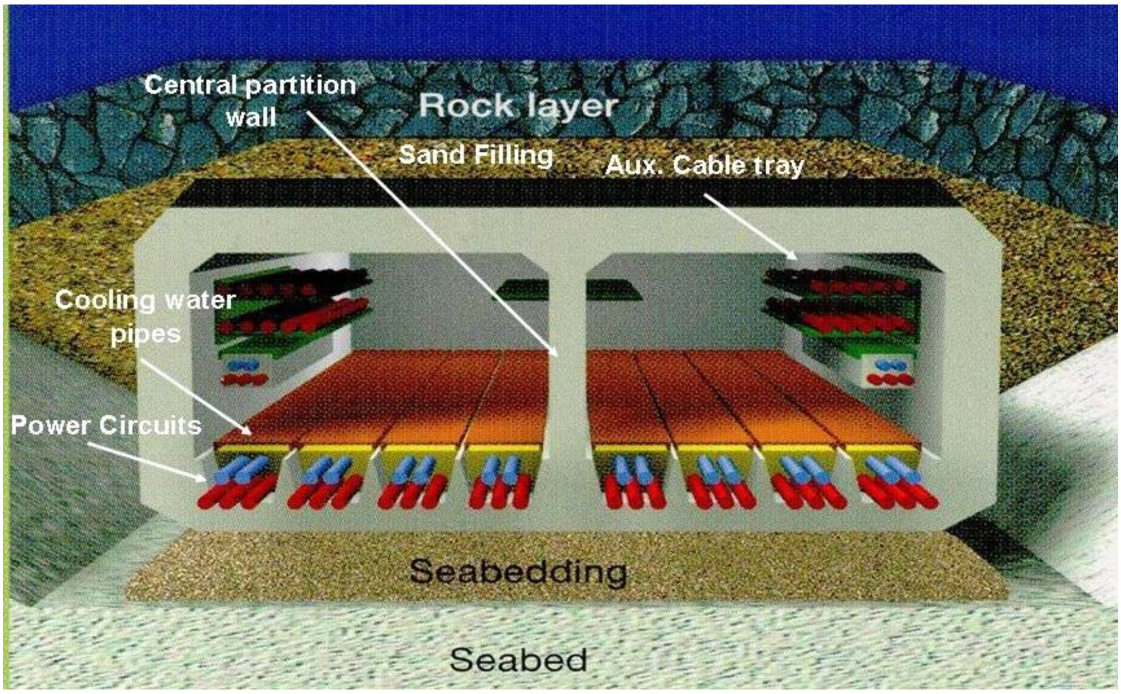


Fig. 2.1.3 An example of an immersed tube tunnel which is used exclusively for high voltage cable circuits. In this case power cable circuits are forced cooled.

2.1.1.3 Bored Tunnels using Tunnel Boring Machines

Tunnel Boring Machines (TBMs) feature a rotating, cutting head of a size equal to the full cross-sectional area of the tunnel to be excavated and are used to highly automate the tunnelling process.

The type and configuration of cutters on the cutting head vary depending on the anticipated geological conditions (see Figure 2.1.4 which shows the cutting head of a large diameter TBM). The cutting head will feature a means to remove the excavated material from the cutting area discharging to a continuous conveyor system which loads up a waiting spoil train to transfer back to the access shaft.

Depending on the specific dimensions of the tunnel, the TBM may have to be custom built. Alternatively an existing TBM meeting the main dimensions needed for the tunnel can be refurbished and used, which could reduce the project costs.

Some types of TBM, such as bentonite slurry and earth-pressure balance machines, have pressurised compartments at the front allowing them to be used in difficult conditions below the water table. This pressurises the ground ahead of the TBM cutter head to balance the external ground and/or ground water pressure. The operators work in normal air pressure behind the pressurized compartment, but may occasionally have to enter that compartment to renew or repair the cutters. This requires special precautions, such as local ground treatment to stop the ingress of water. Despite these difficulties, the newer types of TBM are preferred to the older method of tunnelling in compressed air, with an air lock/decompression chamber some way back from the TBM, which required operators to work in high pressure and go through decompression procedures at the end of their shifts.

Figure. 2.1.4 The cutting head of a large diameter Tunnel Boring Machine (TBM)

The support of the tunnel directly behind the TBM can be constructed using a variety of methods and materials and three of these methods are briefly described below.

2.1.1.3.1 Segmental Lining

Immediately after boring, the lining of the tunnel is constructed using prefabricated reinforced concrete segments which are hoisted into position by an erector and then fixed into position to form the circular tunnel shape (see Figure 2.1.5). The annulus between the outer diameter of the segment and the ground is filled with cementicious grout to stabilize the tunnel.

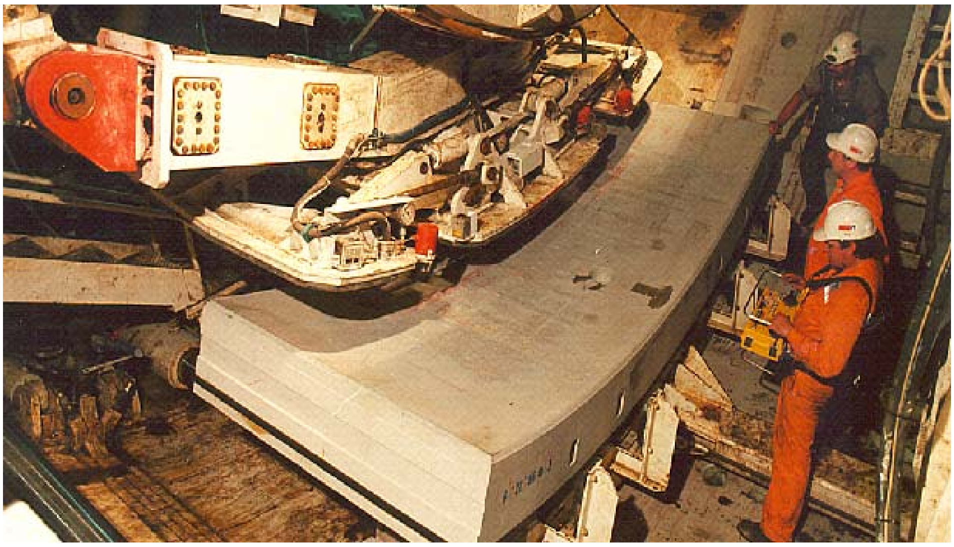


Figure. 2.1.5 A pre-cast segment is made ready to be hoisted into position within the tunnel

2.1.1.3.2 Pipe Jacking using a TBM

In the pipe jacking process the tunnel "pipe" is placed immediately behind the TBM and driven by hydraulic cylinders or "jacks" from the driving shaft to the receiving shaft. The individual pipes are prefabricated with reinforced concrete. When a pipe has been inserted to its full extent into the tunnel, the hydraulic cylinders are retracted at the driving shaft and the next pipe is placed into position to continue the cycle.

Considerable technical advances have been made with pipe jacking and lengths of up to 2,000 metres have been achieved. The use of computer aided guidance systems has enabled double curvature pipe jack tunnels to be constructed to a high degree of positional accuracy (see Figure 2.1.6 of a completed pipe-jack cable tunnel).

Figure 2.1.6 A completed pipe jack cable tunnel suitable for four circuits of high voltage cables

2.1.1.3.3 Shotcrete and mesh

For hard rock tunnels welded steel mesh and shotcrete are used as another method of support. Shotcrete is concrete with smaller size aggregates and is applied to a surface at great velocity either manually using a pneumatic pump or by a remote controlled robot (see Figure 2.1.7).

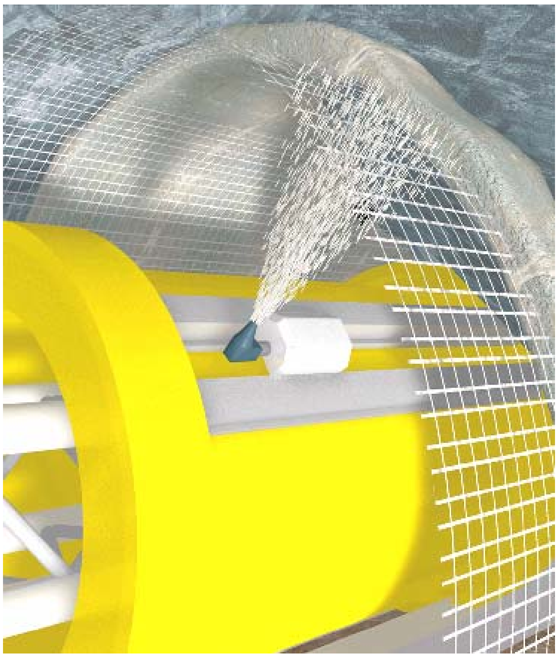


Figure 2. 1.7 A sche matic lay out s howing th e robotic application of sho tcrete th rough a welded steel mesh which forms the tunnel support.

Figure 2.1.8 Fire protection sheathing of the inner lining of a tunnel (designed to withstand 1350° C)

2.1.1.4 Drill and Blast and Road Header Machines

Where rock conditions allow, the tunnel can be excavated without the requirement of a TBM and more traditional techniques can be employed such as “drill and blast” and the use of special mechanical excavators which are called “road headers”.

Where conditions allow, the rock face can be drilled, explosives placed within the drilled holes are subsequently detonated shattering the rock. When declared safe to return to the area the debris is cleared and the tunnel support is installed.

Road header machines feature a relatively small-diameter boom-mounted rotary cutting head supported by a tracked base (see Figure 2.1.9). The cutting head is worked back and forth across the rock face by manipulating the boom. The rock debris is picked up at the base of the rock face by a conveyor system running through the base of the machine.

The road header method allows tunnels of various shapes and sizes to be constructed using a single type of machine which is not possible with a TBM. The method also allows the construction of multi-branched tunnels.

Fig. 2.1.9 A road header machine with boom mounted cutter head.

This type of tunnel excavation method is sometimes referred to as NATM (New Austrian Tunnelling Method) the main idea of which uses the geological properties of the surrounding rock mass to stabilize the tunnel itself. The NATM constitutes a method where the surrounding rock or soil formations of a tunnel are integrated into an overall ring-like support structure, thus the ground formations will themselves be part of the supporting structure.

2.1.1.5 Other Methods of Tunnel Construction

Other methods such as pipe jack and micro tunnelling could be considered. For more detail see Cigré TB 194 “Construction, Laying and Installation Techniques for Extruded and Self Contained Fluid Filled Cable Systems”.

2.2. Bridges

To cross waterways or similar physical barriers, electricity utilities can consider: overhead lines, submarine cables, tunnels, directional bores, existing or new bridges.

Today bridges offer a great way to connect different parts of cities, islands, countries and even continents. Without bridges the economic development of many parts of the world, particularly islands, would not have been possible. In the last century bridge spans and heights have been steadily increasing.

For bridges it is normal that they are multipurpose shared structures when cables are installed on them. Bridges built only for cables are in the minority.

Some issues to be considered when installing cables on bridges include:

- allowance for longitudinal movement and deflection of the structure,
- vibration from natural causes and from traffic movement
- the position of the cable installation and its accessibility
- wind stability and protection from solar radiation
- fireproofing and security from vandalism and other effects of human or animal activity
- protection of communication cables against induced voltages
- cable system installation methods including getting on and off the structure
- the effects of electric and magnetic fields on traffic management systems.
- the weight of cables and accessories on the bridge structure
- the environmental impact of the cable on the structure (eg leaking fluid filled cables)
- the ease of access for maintenance, repair and replacement
- the shortest most convenient low cost across an obstruction
- a corrosive marine environment for bridges crossing over salt water
- can sharing offer better security.

2.2.1 Bridge Movement

When installing cables on bridges special consideration must be given to avoiding localisation of stress on the cable at the point where the bridge expands and contracts. There are normally two solutions.

The first method is to support the cable on a “cable offset” using link mechanisms and universal joints to absorb the deflection angle occurring at the bridge gap. As an example, the large longitudinal displacement of the girder gap on a suspension bridge was solved in the Japanese “Honshu-Shikoku interconnecting link” project by applying a large cable offset using a link mechanism and universal joints for the appendant structure to absorb the deflection angle occurring at the girder gap.

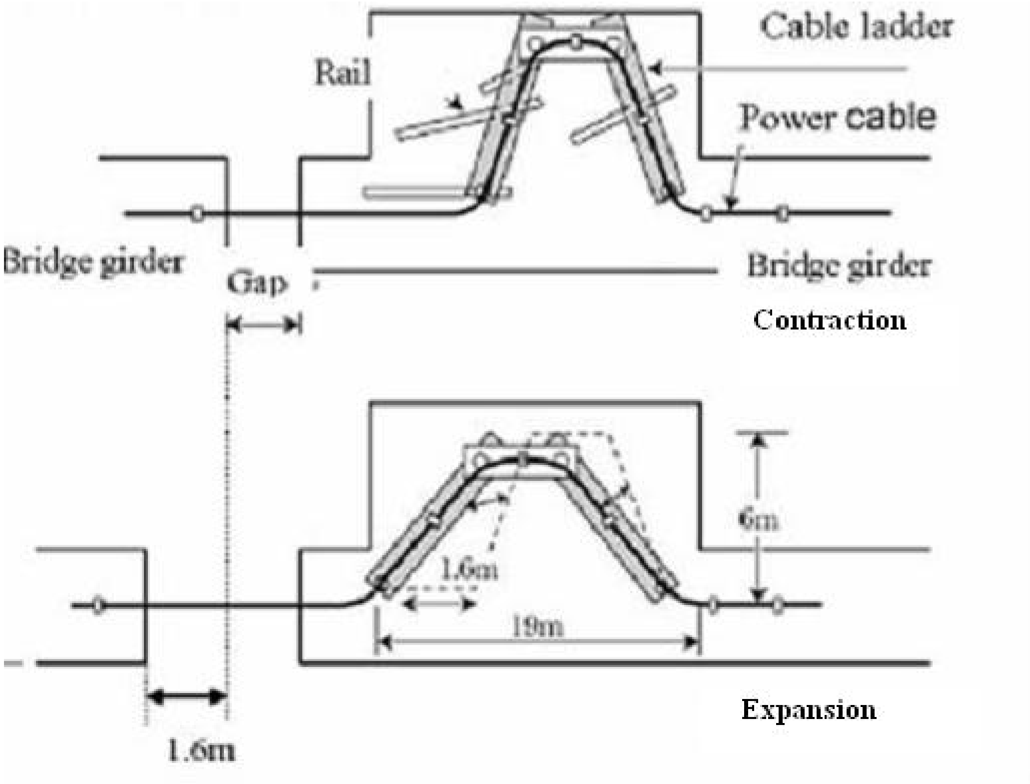


Figure 2.2.1 Typical Link Mechanism for Giant Pantograph

Figure 2.2.2 HV XLPE cables installed in a giant pantograph on a long suspension bridge

The second solution for bridge expansion and contraction was solved many years ago on railway bridges by attaching the cables to a specially designed 'bow spring' structure. This device has since been used on many road bridges in recent times as detailed in examples in Section 8 from Australia and China.

Figure 2.2.3 Typical example of a bow spring structure on a test bed

The vibration caused by the passage of cars and trains can be relieved by optimising the supporting interval of cables by taking into consideration the resonant frequency of cable and structure.

Bridges are an ideal medium and bridge designers should be encouraged to consider the installation of cables or other services at the design stage. The space and weight of cables, accessories and the additional structures such as pantographs on the bridge should be taken into consideration at the early design stage of the bridge itself.

In some cases, specially designed bridges are constructed for cables which later may be used for additional purposes.

2.3. Other Structures

The majority of multipurpose structures were shown to be tunnels (including shafts) and bridges. There are other structures such as elevated highways, underground car parks, arcades and risers.

The considerations and conditions that apply are similar to tunnels and bridges and as such it is not proposed to comment further on these types of structures.

The sharing of duct lines, cable chases and associated structures with other services and the installation of cables in pipelines or drains were not considered by the Working Group.

3 SERVICES AND GENERAL REQUIREMENTS

High voltage cables share structures with a variety of services: other electric cables, water pipes, energy pipes (gas or fuels), communications and control cables, heating and cooling pipes, compressed gas pipes, hydro pipes, roadways, and railways.

The electricity cables can be over a range of voltages and often belong to several owners.

Other services sharing the structure can belong to either the same or several owners.

3.1. Common Essential Services and Requirements

In order to ensure personnel and material safety and security, some essential services must be considered in the design and construction of multipurpose structures. They include:

3.1.1 Access and Exit

Access to the structure and in some cases to the services sharing the structure is normally controlled and restricted to authorised personnel. Exit from the structure must be also checked.

Some structures are equipped with smart magnetic access cards systems.

3.1.2 Security and Safety

Rules, procedures and permits should be agreed, known and applied by each user of the structure.

Workers shall be trained and have procedures in place to assess and control the risks for working safely around each others services in that particular environment.

A clear identification of each users services should be provided.

3.1.3 Communications (telephone stations or two way radios)

To improve safety for the public at large in structures shared with transport and utility personnel in particular, it is recommended that a reliable fixed or portable communication system be able to be provided. In the case of a fixed system, telephones would be installed and identified at regular intervals in order to reduce distance required to reach them.

If portable systems are favoured, some fixed antennas might be required to ensure the reliability of the communication system. Leaky co-axial cable or directional antennas for straight structures may be used.

3.1.4 First Aid

Correctly maintained First Aid stations should be provided at all locations where workers are supposed to carry out activities. A means of quickly transporting injured personnel should be installed for the structure. Workers should have their own first aid equipment and training appropriate to the work and associated risks.

3.1.5 Fireproofing Measures for Cables

To protect the cable and retard a fire’s progress through the structure, a physical protection of the cables can be used. Alternatively the cable can be manufactured with a fire retardant jacket or a fireproofing material may be applied once the cable has been installed. Cables can also be installed in fireproof troughing or buried in the case of tunnels.

Fire proofing cables and other potentially flammable services in tunnels is considered essential.

3.1.6 Physical protection of cables and accessories

Consideration needs to be given to the provision of barriers to provide physical protection to the cable system, particularly at joint locations. This may also protect personnel from failures and standing voltages from uninsulated parts of the cable system.

Consideration should also be given to the prevention of damage from vandalism or terrorist attack particularly at the shafts where cables leave tunnels and other transition points into or onto structures.

3.1.7 Cleaning and General Maintenance

Multipurpose structures should be kept as clean as possible. A maintenance program should be established in order to ensure that debris does not accumulate and that: all the essential services of the structure are working properly, hazardous materials are not stored in the structure and access /exit ways are clear.

3.1.8 Monitoring Systems

Video cameras located at strategic points could monitor access to the structure as well as monitor security and personnel safety.

Monitoring of air quality, humidity, temperature, fire and water levels in enclosed structures if applicable, should also be considered.

Monitoring systems for gas pipes are essential to detect any hazardous gas leaks.

3.1.9 EMF Mitigation

Adapting cable arrangements and minimum clearance distances to other services and access ways is a way to decrease the effects of EMF.

Where the calculated EMF exceeds prescribed values, mitigation arrangements have to be implemented in structure. Refer to Cigré TB 104 “Magnetic Field in High Voltage Cable Systems.”

The issue is also under consideration in Cigré Working Group WG B1-23. “Impact of EMF on Current Ratings and Cable Systems.”

3.2. Essential Services in Tunnels

In order to ensure personnel and material safety and security, some essential services must be considered in the design and construction of a tunnel. They include:

3.2.1 Lighting:

It is a common practice to provide lighting at the tunnel access areas only where activity in a tunnel structure is irregular.

However, where a tunnel is regularly entered it is recommended that some form of lighting system be provided to ensure that workers can carry out their activities safely without the need for extra equipment.

DC lighting systems could be an economic alternative because they can use a battery source in emergencies.

Where people regularly enter a tunnel a lighting system that is periodically inspected and maintained is recommended.

3.2.2 Ventilation:

An adequate ventilation system should be installed in order to provide a suitable atmosphere as well as to evacuate any undesirable gases and other contaminants.

In deep tunnels, ventilation systems may also be necessary to ensure a reasonable ambient temperature for workers.

The use of ventilation systems in case of fire requires a special study to be conducted in collaboration with the fire authorities. Ventilation systems should be designed to mitigate any fires within the structure. There is a balance between mitigating any fires within the structure and containing smoke density.

A ventilation system assists in the cooling of the cable system and increases its rating (see 3.2.11).

3.2.3 Drainage of Seepage

Ground water seeps into most tunnels, and will accumulate in the tunnel if not drained. The amount of seepage depends on the nature of the soil, type of tunnel construction, seasonal variations of the ground water table, hydraulic gradients and the depth of the tunnel relative to local water tables.

Accumulated water could cause damage to equipment, produce a foul smell in the tunnel and contaminate the tunnel's atmosphere. Draining the accumulated untreated water can take time and expense requiring water testing and permits for its disposal. If the tunnel is to be readily accessible it should be regularly monitored and drained.

Drainage pipes or troughs may be able to be placed to drain this water into pits where it could be collected for testing, treatment and disposal. Troughing in pedestrian access areas should be covered with grating to prevent injuries.

3.2.4 Emergency Exits and Procedures

To safely and quickly evacuate the personnel in case of an emergency, emergency exits should be provided at each end. Depending on the tunnel length consideration should be given to intermediate emergency exits. These exits should be unobstructed and properly identified. Regular and casual personnel should be familiar with the evacuation procedures. Annual evacuation training would help to verify the evacuation procedures.

It is recommended that warning signs, direction signs and instructions be placed along the tunnel.

Tunnel ventilation systems should operate to maintain any stairwells at a positive pressure with respect to any incident section of the tunnel during emergency operations. When the stairwell doors are open, the tunnel ventilation systems should operate to induce a fresh air velocity from the stairwell into the tunnel. When stairs are within shafts it is recommended that they are physically separated by a fire rated barrier from the rest of the shaft. Fire rated doors must be used at stairwells.

3.2.5 Communications

Dedicated communications are considered to be more important in multipurpose or shared tunnels than single purpose tunnels (see 3.1.3). This may be a specified safety requirement. The higher usage of the tunnel for working on the different services could also justify the installation and maintenance costs of the communication system.

3.2.6 Fireproofing Measures

Fire proofing cables and other potentially flammable services in tunnels is considered essential. Refer to Section 3.1.5

It should be noted that some designs of cables are not suitable for use in tunnels unless the tunnel is equipped with fire protection services such as sprinklers / sprays or the cable has some additional form of protection. It is also advisable to install compatible fire extinguishers in the tunnel to be used in case of a localized emergency. Longitudinal segmentation along the tunnel with fire doors between segments can also be considered.

3.2.7 Fire and Smoke Detection

Tunnels can be crowded places and are usually enclosed spaces underground with difficult access. A fire can result in a rapid build–up of heat and intense smoke generation in the enclosed space. The smoke produced by combustible materials used in cables and other electrical equipment can be toxic. This makes fire fighting in tunnels with cables and other flammable products difficult and dangerous. Tunnel fires can result in severe service discontinuity and property damage, even causing destruction of the structure

A detection system should provide an early warning so that swift action could be taken to prevent loss of life and material damage to equipment and the structure.

To reduce the risk of fire some utilities do not allow the use of open flames in tunnels. However, this may prove to be difficult as some welding of metallic infrastructure may be necessary. Consideration should be given to introducing rigorous hot work permit procedures to control these types of activities.

3.2.8 Pipe Leak Detection

To minimise damage from chemical discharges and prevent engulfment of personnel from hazardous atmospheres it is recommended that appropriate leak detection systems be included with any pipelines carrying potentially hazardous chemicals or other substances.

3.2.9 Protection of Personnel

Depending on working conditions, in addition to basic personal protective equipment, rescue equipment and emergency breathing apparatus for confined spaces have to be provided. Workers must be trained to use this equipment.

3.2.10 Cable Rating

Ventilation and cooling systems, generally using water or refrigeration, may be designed and installed in the tunnel in order to increase the rating of the cable system. These systems require space allocation in the structure and regular maintenance. If practical it maybe better to increase the cross sectional area of the conductor of the cables as the additional cable cost may be more economical than that of the installation, operation and maintenance of the cooling system.

There may be limits imposed on the air temperature due to personnel access or other utility needs and these limitations are usually lower than the limitation of the cable conductor temperature.

3.2.11 Transportation Systems

Depending upon the length of the structure, a means of transportation for the installation and maintenance of services and for evacuating personnel may be required for some tunnels. The choice generally depends on the length, gradients and accessibility of the tunnel. Effective transport and mechanisation systems require less people to be in the tunnel, lessen the exposure to risk and reduce installation costs.

Special consideration must be given to the means of powering vehicles to ensure that no noxious gases are released into the tunnels atmosphere. Electric vehicles and powered machinery using catalytic converters are commonly used where access is possible.

In tunnels where an overhead “I” beam has been installed an electrically powered transportation vehicle can be used undertaking remote surveillance using PTZ (Pan-Tilt-Zoom) cameras in normal light and infra-red. The vehicle could also have a limited fire-fighting capacity.

3.2.12 Vermin Barriers

Protection against vermin migration and population of the tunnels is necessary. The use of poison at the entrances of the tunnel is a common practice.

A removable vertical barrier at the entrance of the tunnel is commonly used to prevent vermin intrusion and does not restrict access when required.

Hygiene procedures such as avoiding food or waste storage are important in the prevention of vermin intrusion.

3.2.13 Emergency Power Supplies

In order to ensure the safety of personnel and the installation in case of loss of the main electric power supply, it may be advisable to install an emergency generator that would automatically come on line. The generator capacity should be sufficient to ensure the essential services such as lighting and air ventilation. To ensure its availability when needed, it is recommended that regular maintenance is carried out on the emergency generator

Emergency exits and communication systems should be operable at all times people are in the tunnel.

3.3. Essential Services on Bridges

Bridges are more visible than tunnels and usually there is greater exposure of the public to services installed on them. However, some services installed on bridges are in enclosed spaces and should be given similar considerations to tunnels. Generally in order to ensure security, personnel and material safety, some essential services must be considered in the design and construction or modification of bridges as multipurpose structures. They include:

3.3.1 Mechanical Protection

Cables and others services installed on a bridge may be subjected to vandalism and animal attack. Mechanical protection should be provided in order to protect installed equipment.

The mechanical protection of the cables on the bridge should be designed such that no part of the bridge can be easily dismantled and techniques that enhance the security of the mechanical protection should be employed.

For cables which are naturally ventilated the mechanical protection shall allow for air to enter and to exit, but shall not allow the intrusion of sharp and potentially dangerous objects.

When the equipment is inaccessible, the less visible the equipment is the better the protection against vandalism.

Consideration should be given to the prevention of exposure to fires under the structure.

3.3.2 Exposure to Weather

Where the cables are exposed to weather, consideration must be given to how weather will impact on cable system as well as the safety and work of personnel. Weather protection may be required to be designed into the structure.

Exposure to solar radiation can affect the rating of cables and could deteriorate a cable's outer protective covering. Solar shielding devices or coverings can be used to protect cables from the sun.

3.3.3 Public Safety

When a cable is visible or accessible to the public a physical barrier and clear identification of the electrical hazard shall be provided.

3.3.4 Height Safety

Workers have to wear and use equipment or other means adapted for working at heights in accordance with local regulations.

4 SHARING ARRANGEMENTS FOR UTILITY SERVICES

The various sharing arrangements can be best shown in the following diagram:

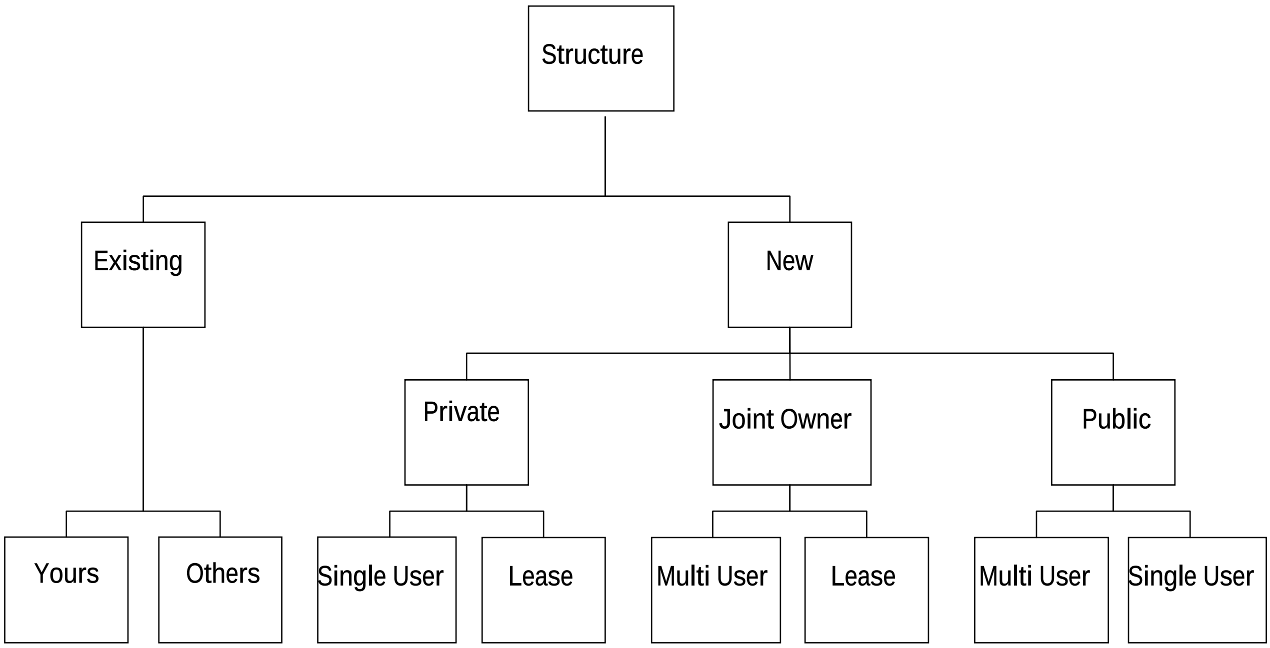


Figure 4.1 Various Sharing Arrangements for Existing and New Structures

4.1. Sharing Existing Structures

The following is a flowchart of issues to be considered in proposing sharing an existing structure for HV cables:

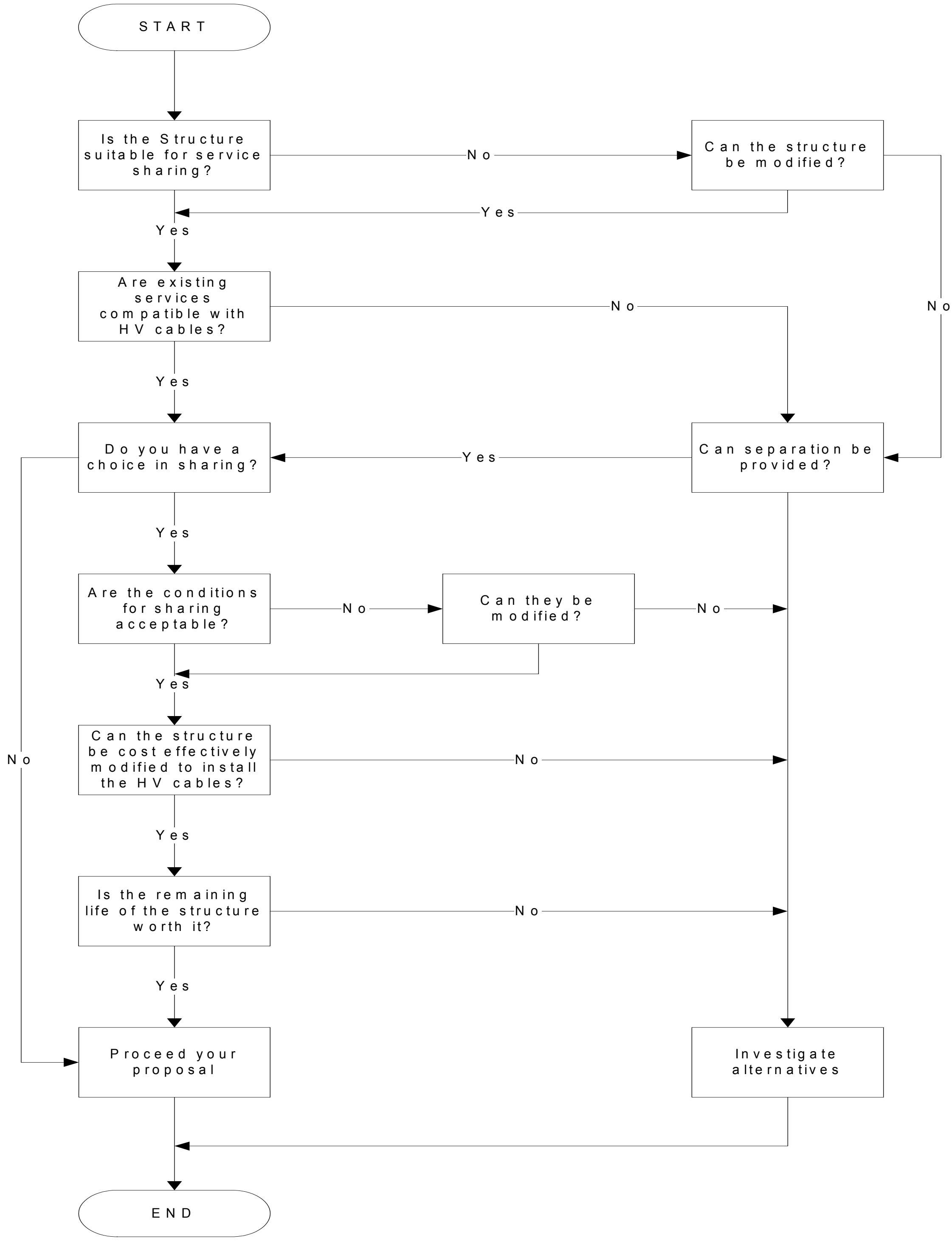


Fig 4.2 Decision Flowchart for HV Cables to share an existing structure

4.2. Sharing New Structures

4.2.1 Designed to suit purpose

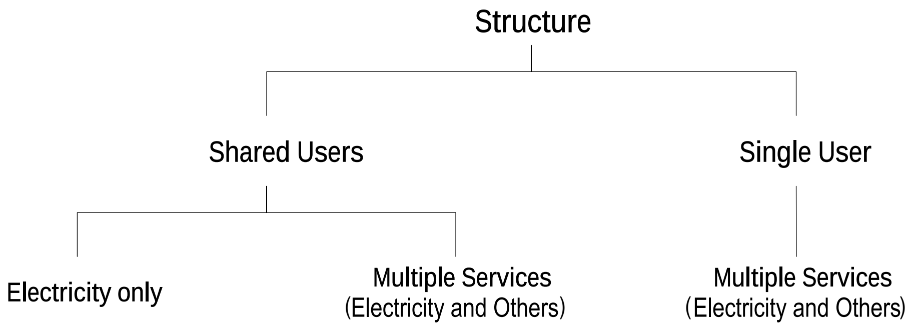


Fig 4.3 Sharing Arrangements

4.3. Physical Separation of Utility Services

In some countries there is a requirement to have separation whereas in other countries there appeared to be no requirements. It depends upon the country and local or user requirements and accepted risk practices.

It is normally easier to share a new structure than an existing one as they are designed to suit purpose.

4.4. Obstacles to Sharing a Structure

According to the results of the working group survey, utilities are reluctant to share structures if there are other ways of achieving the desired objective even if they incur a higher cost. The main issues are safety, security, technical and legal. The importance of the installation and its compatibility with the other services could hinder the negotiation process.

For legal and safety reasons some utilities would not assume the responsibilities related to sharing a structure. However, in some countries local rules would impose sharing a structure by alleviating the costs or dismissing alternatives.

4.5. Investment Risk

Considering the major capital investment and operating costs involved, it is important to undertake an investment risk analysis. Usual risk analysis techniques can be used. To ensure the viability of sharing a structure it is important to consider any future services that may be installed as well as the actual project

5 ISSUES TO BE CONSIDERED IN THE FEASIBILITY STAGE

It has been assumed that other options have been dismissed before committing to a partnership agreement for sharing a structure. These options would include single purpose structures, open cut construction, Horizontal Directional Drilling (HDD), submarine cables, overhead construction, the availability of existing access ways, Gas Insulated Lines (GIL), super conductivity and distributed generation.

Sometimes it is not exactly known what utilities are going to use the proposed structure. Then engineering the structure can be a difficult task which either enables or disables future usage possibilities. Many technical and non technical issues have to be considered during the project feasibility phase. The following highlights some of the main issues.

5.1. Technical Issues

When considering power cables installed in a multipurpose structure with other services some technical issues that should be considered are:

- electromagnetic compatibility between the power cables and sharing systems;
- fire behaviour of cable systems and other systems;
- possible fault occurrence and external effects of the fault;
- maximum length of cable link without the use of shunt reactive compensation.
- the effect of cables on the structure and its performance.
- the effect of environmental conditions on the cable system.

These issues may have differing impacts for the type of multipurpose or shared structure.

Tunnels are becoming more popular in busy urban centres where permission cannot be obtained to excavate or later re-entry would be difficult or not allowed.

It is often difficult to incorporate cable systems into existing bridges that were designed for a specific purpose. New bridges may be designed to provide for future services.

5.1.1 Magnetic field and electromagnetic interference

Cable design and arrangements together with the adoption of minimum clearance distances to access ways and other services are ways to reducing the effect of electro magnetic fields (EMF) from power cables. The effect of EMF on people is a controversial topic and access in structures is more likely to be arranged to minimise the EMF exposure.

When the EMF is above prescribed values, EMF mitigation devices should be implemented in structure. The effects of transient electric and magnetic fields induced during short circuit conditions that can affect electronic devices connected to communication or signal cables installed in parallel with HV cables are not considered here.

5.1.1.1 First Example: a double circuit 400kV cable installation in a tunnel

The following example is given to show possible orders of magnitude of magnetic fields generated by power cables in a structure. Fig. 5.1 shows the arrangement of the double-circuit power cables in the tunnel.

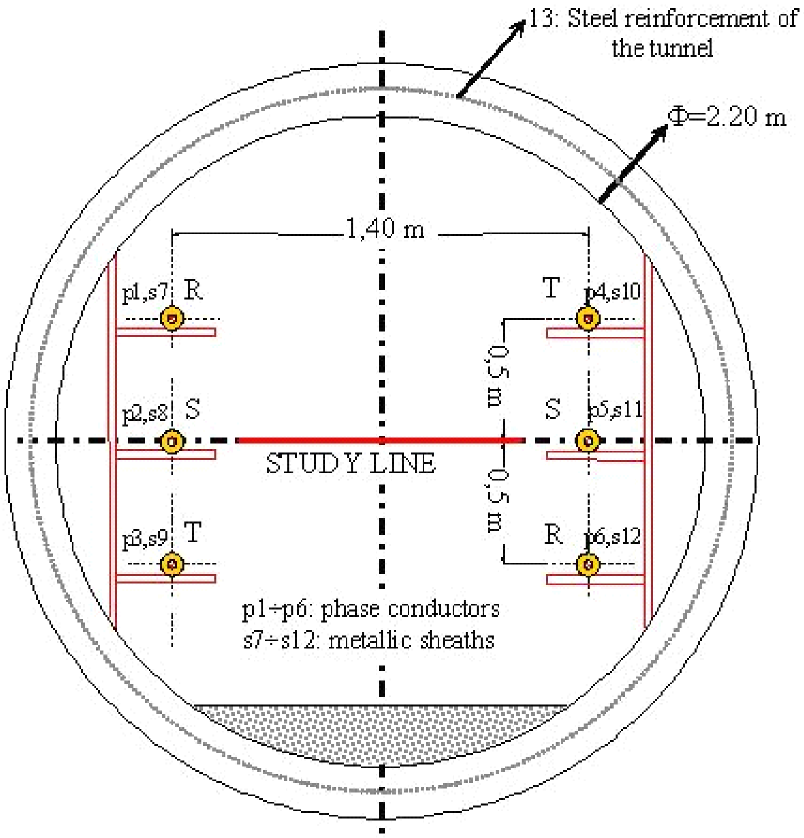


Figure 5.1 Double Circuit HV XLPE cable installation in a tunnel

Cross sectional area	mm^2	2500 Cu
Rated Voltage	kV	400
Shield area	mm^2	500 Al
Unit length resistance of phase conductor at 20°C in DC	mΩ/km	7.2
Unit length resistance of phase conductor at 90°C in DC	mΩ/km	9.2
Unit length resistance of phase conductor at 90°C in AC	mΩ/km	10.8
Unit length resistance of the metallic shield at 79°C	mΩ/km	66.3
Phase – shield unit length capacitance	μF/km	0.241
XLPE dielectric constant	εr	2.3
XLPE loss factor	Tan δ	0.0007
Unit length inductance for the cable spacing in fig. 5.1	mH/km	0.65
Capacitive current with UB0 B= 400kV/√3	A/km	17.50

Table. 5.1 Typical electric parameters of an HV XLPE cable

For HV single core cable installation of long lengths, is normal practice that the metallic sheaths are cross-bonded. The use of a structure's steel reinforcement for bonding point earthing can be effective if it is electrically continuous with enough cross section to drain any current derived and it is ensured that condition is maintained for the life cycle as a cable tunnel. Otherwise earthing continuous conductors (ecc) can be either embedded in the floor or placed in suitable positions

To reduce the line asymmetry and to enhance the cancellation of the induced shield voltages, in addition to the shield cross bonding, the cables can also be physically transposed.

In order to asses the external magnetic fields a loading current of 1788 amps was considered. The currents in the phases and the calculated induced currents in the sheaths are shown in table 5.2.

The phase arrangement is considered as “asymmetrical” or RST-TSR, also known as “low-reluctance configuration” that generates the lowest magnetic field.

Currents [A] for the computation of EMF				
Phases			Sheaths	
R	1	|1788| ∠108°	7	|8.4| ∠-109°
S	2	|1788| ∠-12°	8	|8.6| ∠134°
T	3	|1788| ∠-132°	9	|9.1| ∠16°
T	4	|1788| ∠-132°	10	|9.1| ∠16°
S	5	|1788| ∠-12°	11	|8.6| ∠134°
R	6	|1788| ∠108°	12	|8.4| ∠-109°

Table. 5.2 Currents for the computation of the magnetic field generated by the HV double-circuit system

The values in table 5.2 show that by cross bonding and phase transposition the sheath currents are relatively low. These calculated current values are 0.5 percent of the phase currents, although values of this order may be difficult to attain in practise due to physical constraints although it may be easier to achieve in structures than when direct buried.

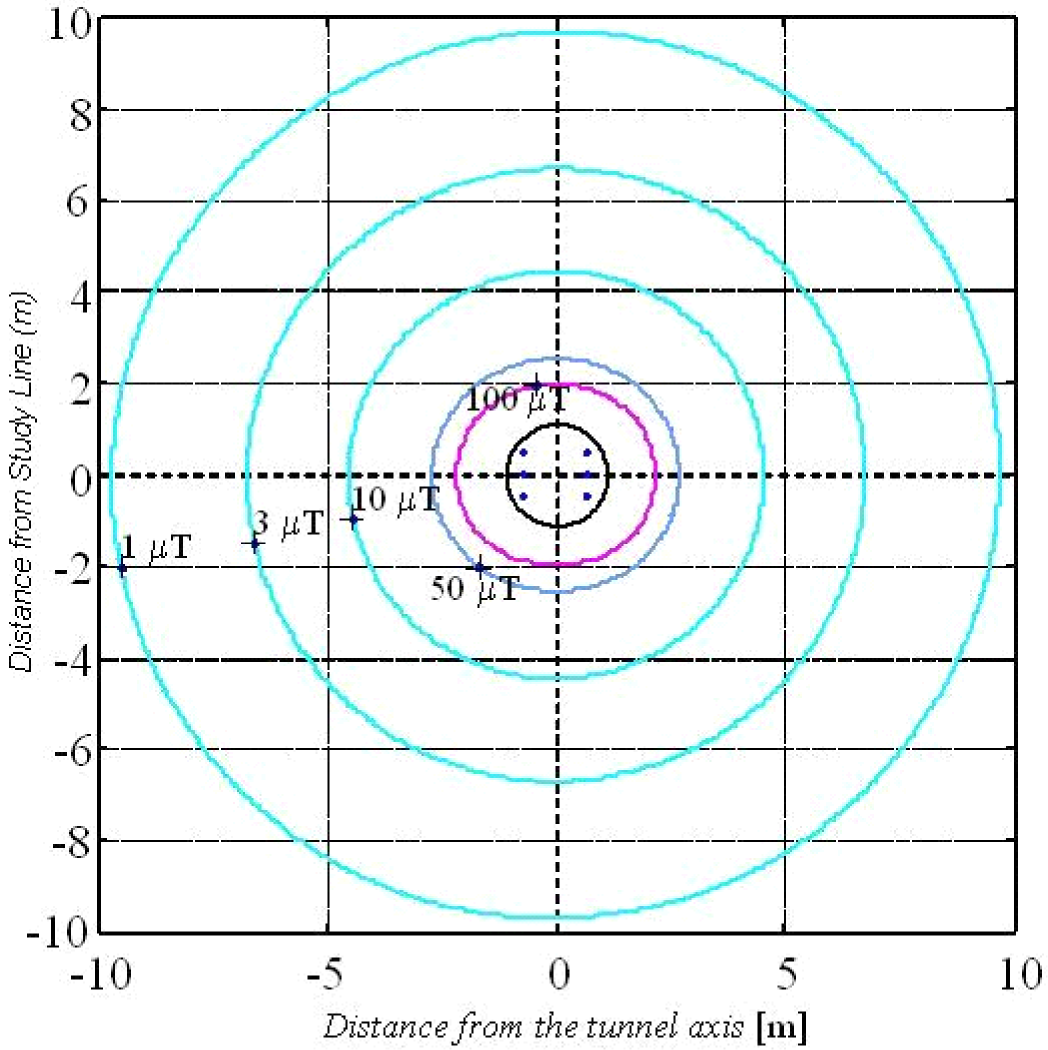


Figure 5.2: Magnetic induction levels outside the tunnel with current flows of 1788 A per circuit, cross bonding and phase transposition

Fig. 5.2 shows the magnetic field levels when the cable systems are operated at 1788 A per circuit. Magnetic field values outside the tunnel decrease very rapidly.

In relatively shallow burial depths for structures, such two metres in the Madrid "Barajas" Airport Project, the magnetic field levels at one metre above ground are below 100 μT.

Figure 5.3 shows the magnetic field along the study line shown in fig. 5.1 at 1.1metres above the tunnel floor. In this case the magnetic level inside the tunnel is high reaching a maximum value in the order of 1600μT. Due to the phase arrangement the magnetic field at the centre of the tunnel is zero in accordance with the magnetic field theory. The magnetic field values in the proximity of the cable systems are high because of the cable configuration and the returning sheath current phasors are low. The shielding effect is minimised by cross-bonding that is necessary for optimal transmission rating.

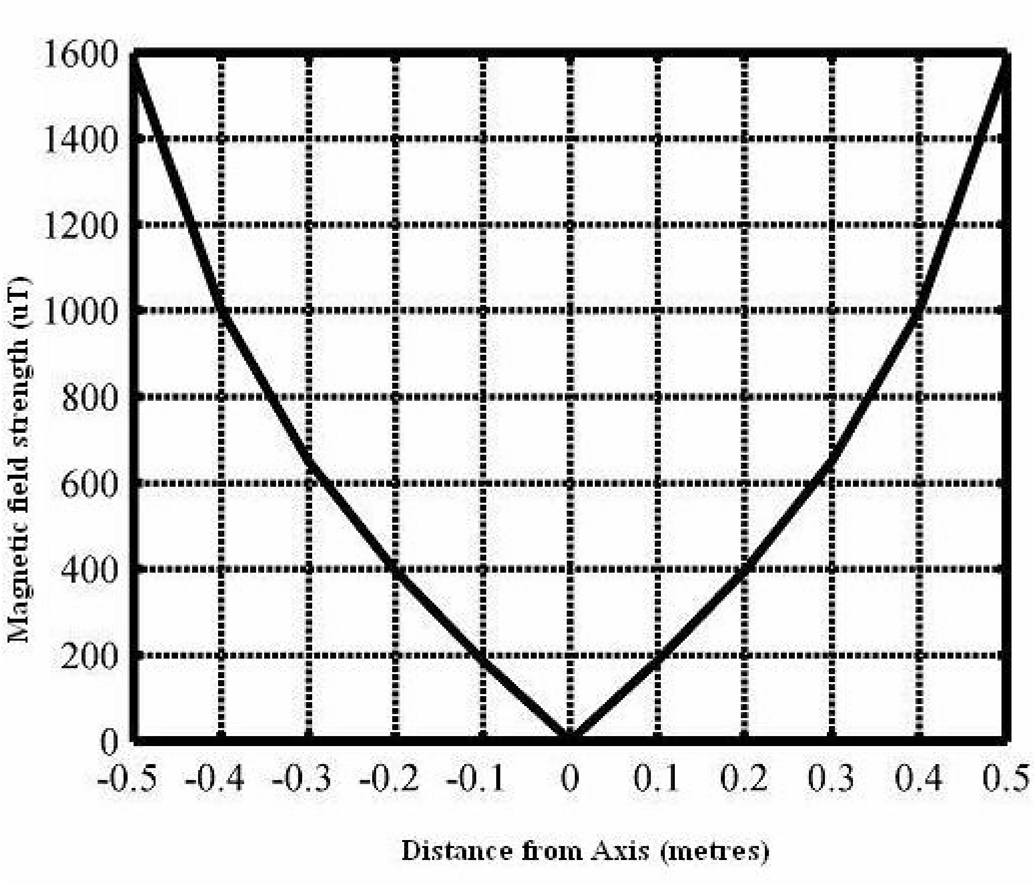
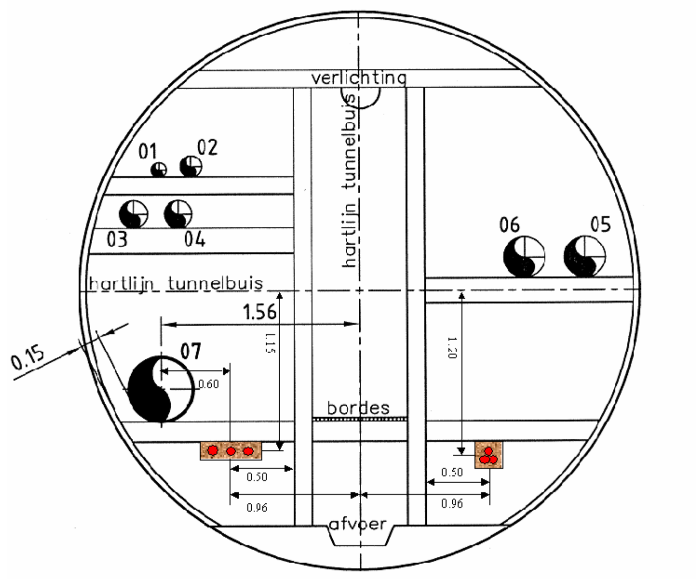


Figure 5.3: Magnetic induction levels inside the tunnel (along the study line shown in fig.5.1) for cross bonded with phase transposed circuits each carrying 1788 Amps

In this case of a single purpose structure access of personnel for maintenance can be made with lower loadings or de-energised circuits. For multipurpose structures special consideration may need to be given to other circuit configurations that would reduce the emf effect. Where strong magnetic constraints are present, there is a possibility of using magnetic field mitigation techniques such as shielding by ferromagnetic materials or passive loops. See references 13 and 14.

Magnetic fields are present around in service alternating current (AC) cable systems. The magnetic field strength is limited to values given in national and international regulations. These limits are being debated and it is possible this could result in special limitations on the magnetic field in certain situations. Therefore magnetic field management becomes important in situations where the power cables are installed in a multipurpose structure.

5.1.1.2 Second Example: A multi purpose tunnel with two 150 kV power cable circuits



Tunnel Cross Section

Figure 5.4 A multi purpose tunnel with two 150 kV power cable circuits and multiple pipes for gases and liquids (water, chemicals).

Figure 5.4 gives an example of a multi-purpose tunnel where limits were imposed on the magnetic field inside the tunnel. The tunnel has an access way down its centre line. The cross section on the right of the figure is of the same tunnel in a preliminary study in which the positioning of HV cables was studied to minimise the effects of emf. A trefoil cable arrangement for both circuits was chosen for the installation symmetrically mounted on each side of and below the access way. The cable and phase arrangement were configured to keep the magnetic field in the tunnel as low as possible. With the two separate cable circuits in trefoil, the magnetic field in the middle of the tunnel, where the walking path is located, was minimised.

Figure 5.5 shows the resulting magnetic field (vector magnitude) with the circular coloured area showing the magnetic field in the cross section of the tunnel and the rectangular wire frame showing the walking area in the tunnel. The cables are also shown in the figure. The magnetic field in the walking area of the tunnel is effectively minimised by the cable arrangement. It reaches zero at a certain point in the walking area. The maximum value of the magnetic field in the walking path was calculated to be 20 μT and this complied with the governing limits. However, it can also be seen that directly next to the cable systems, the magnetic field attains high values. Access to this area may be strictly controlled for example by declaring the walking area open for all personnel, while the area close to the cables may only be accessed by authorised personnel or when the circuit is de-energised.

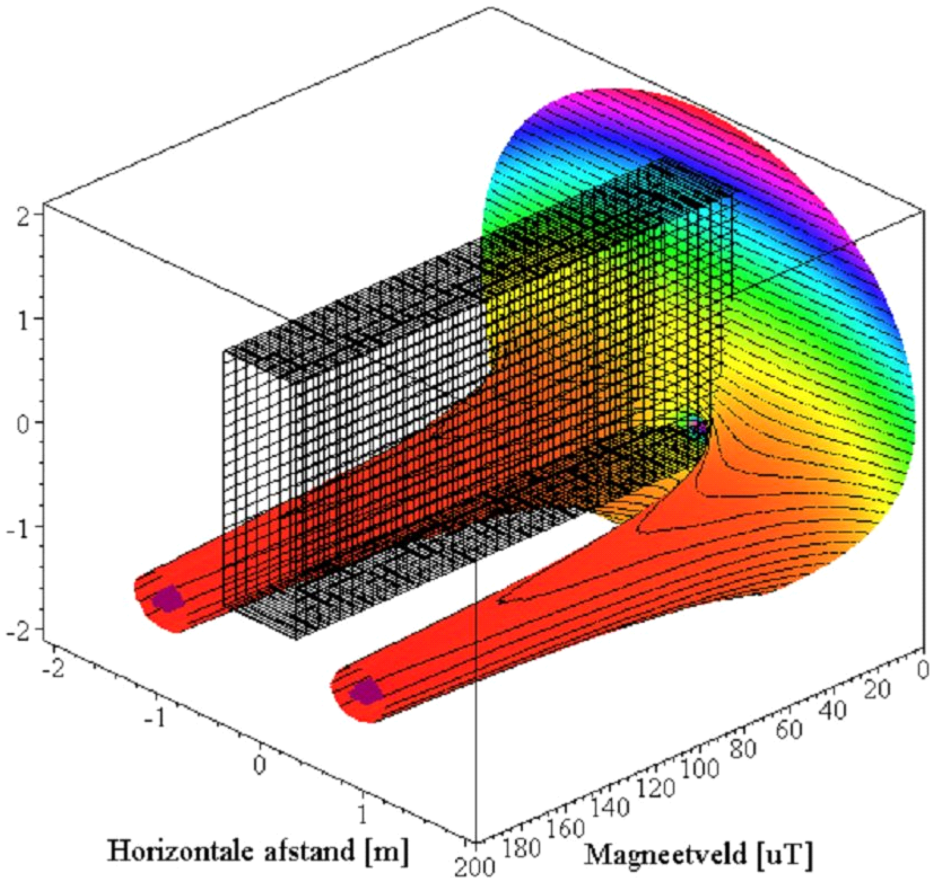


Figure 5.5: The magnetic field in the tunnel at maximum cable loading.

5.1.1.3 Magnetic field and electromagnetic interference in shared structures"

There is a possibility of electromagnetic interference between power cables and systems running parallel for long lengths in multipurpose structures. The electromagnetic interferences must be carefully assessed particularly if the cables and the circuits are likely to be affected by induction are very close.

The problem of electromagnetic interferences must be considered also for direct current (DC) cables.

A static magnetic field generated by a direct current cannot induce voltages or currents on electrical circuits. However, DC converters generate harmonic voltages and currents on the DC and AC sides. The problems of electromagnetic interference from DC transmission can be reduced by using cables with a metallic sheath that is thick enough and solidly bonded. This will allow the induced currents to circulate in the sheath and provide a good screening effect. Even if this sheath has a high resistivity, such as lead, it has a discrete screening effect at harmonic frequencies.

In conclusion, the increasing importance of magnetic field limitations may result in special cable arrangement and optimisation within the structure. This may result in access restrictions in structures. Cable design and arrangements, installation practices and regulations should be closely coordinated when considering cable system installations in multi-purpose structures.

The impact of EMF on the cable systems and their ratings is covered by WG B1-23 "Impact of EMF on Current Ratings and Cable Systems".

5.1.2 Fire Behaviour of Cables Installed in Shared Structures

Fire prevention and detection are key issues when dealing with power cables in multi purpose or single purpose structures. The aspects of fire deriving from the presence of the cable insulation and associated accessories should be carefully assessed, particularly in tunnels. The following deserve careful consideration:

- the possibility of electrical discharge from the power cable systems due to endogenous causes (short-circuit and overload);
- the possibility of electrical discharge from the power cable systems due to exogenous causes (fire on other systems or objects in the multi purpose structure such as trains, cars etc
- the possibility and mode of propagation of the fire along a tunnel, shaft or other structures.
- the mode of combustion of the cables and accessories (thermal power involved, fire loads and production of toxic and visibility-obscuring fumes, aggravating the fire in general).
- acrid or other toxic gases produced by the combustion of cable system materials

The fire performance of cables used in shared structures should consider the following parameters:

- Fire spread = height burned by the fire, (m)
- Peak HRR (Heat Release Rate) maximum average power released over 30secs, (kW)
- THR (Total Heat Released) by combustible materials, (MJ)
- TSP (Total Smoke Production) by combustible materials, (m^2)
- FIGRA (Fire Growth Rate), (kW/s)
- SMOGRA (Smoke Growth Rate), (m^2/s).

and including as an additional parameter the emission of acid gases.

This approach is very rigorous, extremely complex and demanding. A major study financed by the European Community was conducted by a group of researchers from various different European bodies and laboratories, led by P. Van Hees. See reference 17.

The European Commission has implemented decision 2006/751/EC where the cables to be used in building (tunnels, bridges and civil works are considered buildings) should be classified in accordance with EN 13501-1:2005 “Classification fire products and building elements”. See reference 47.

Until recently there was limited technical literature and discussions on this topic but at Jicable ‘07 a paper by Philippczyk et al referred to the fire hazard assessment of power cables in tunnels. The fire performance of MV and EHV cable in a tunnel was investigated using a modified FIPEC horizontal reference test scenario. See reference 20 for further details.

Another paper by Dhupil et al. (reference 21) also investigated the use of Flame Retardant (FR) sheathing materials but only for medium voltage cables. The results show a great reduction of FIGRA to between 40-60 % of the value demonstrated for an equivalent cable with a non FR polyolefin sheath.

Therefore FR sheaths on EHV cable in tunnel installations should be of paramount importance since a cable fire involving a non FR sheathed EHV cable could result in a massive fire with limited opportunities for fire fighter access. The consequence of such a fire in a tunnel without a fire protection system could be the complete destruction of the tunnel contents plus significant structural damage to the tunnel. All too often fire behaviour is concentrated on the assets within the tunnel rather than the tunnel structure itself. Even if a major fire takes place and the cables are totally destroyed replacement cables can usually be installed but if the tunnel structure itself fails then this can become a major civil engineering exercise particularly if inundation has taken place. Damage to the tunnel structure can be mitigated by providing fire protection to the inner lining of the tunnel (see Figure 2.1.8) but this may limit the radial flow of heat through the tunnel walls.

The Jicable paper by Philippczyk indicated that HV or EHV XLPE cables protected by a thin aluminium foil barrier and the best halogen free flame retardant (HFFR) sheath failed a FIPEC test. Therefore, care should be taken in considering this type of cable in a tunnel unless there is an adequate fire/sprinkler protection system or other control measures. Similar considerations should be given to fluid filled or impregnated paper cables.

Conversely an HV or EHV XLPE cable design protected by a corrugated stainless steel sheath with a FR PVC or HFFR outer sheath performs well in a similar fire test. This cable has been used in the Auckland New Zealand and Sydney Australia tunnels without the need for fire protection.

The emission of acid gases could also be very damaging to the safety of people, services and the structure of the tunnel itself.

5.1.3 External Effects of Insulation Failure

In particular the external effects of a short circuit for alternating current (AC) and direct current (DC) cable systems are different. In case of an insulation failure for AC cables and accessories, the arc energy can be extremely high and could result in an explosion that could cause injury, damage nearby installations or may initiate a fire. See reference 22 for further details.

For DC cable systems the situation is quite different since the fault current does not exceed two to three times rated current and after about 10 to 40 milliseconds no more than the set current remains. Therefore the arc energy is not so high avoiding external damage even when taking into consideration the capacitive energy stored in the cable.

In most cases of cable insulation failure the immediate damage is localised even if the arc energy is high. However, the arc can also initiate a fire that could destroy other materials in the vicinity. Suitable measures can be taken to counter the collateral effects of insulation failure such as passive screen protections of steel or other materials. Taking such countermeasures along the whole cable route in a structure is a major work and cost that adds a serious burden to the operation and maintenance of the system. Because the risk of a cable failure is relatively low such countermeasures may only be considered for the accessories.

5.1.4 The Need for Shunt Reactive Compensation

In the future, with the possibility of high capacity and long cable installations the limit length without the use of reactive compensation deserves consideration. Especially when an EHV cable must be installed inside a long multi or single purpose tunnel the need for reactive compensation plays a very important role in considering the land bulk impact for shunt reactive compensation. For further information see references 23 and 24.

5.1.5 Rating

The continuous rating of cables installed in tunnels or similar enclosed structures can be calculated using the methods described in IEC 60287 for simple situations, but complex cases require more sophisticated calculations such as using finite element analysis. The rating is determined by:

- the number and arrangement of cables,
- the space where the cables are installed,
- the heat supplied by other elements in the structure (hot water, steam pipes etc.)
- the temperature inside of the structure enclosed space.

Disposing the heat produced is essential in the structure's design. In some cases such as bridges, natural ventilation could be enough to maintain temperatures within acceptable limits. In underground tunnels natural or forced ventilation may be needed or the cross sectional area of the cables increased. Models for cable rating evaluation are readily available. WG21.08 published a paper describing a numerical method of calculating temperatures and hence cable ratings in ventilated tunnels.

For dynamic cable ratings, measuring the operating temperature of the cable by means of an optical fibre within the cable or on the outer sheath is recommended. This allows an estimation of the rating in the actual conditions and prediction of the maximum rating under the present conditions through a cable model. Information can be found in CIGRE TB 247 "Optimization of power transmission capability of underground cable systems using thermal monitoring".

In the case of a tunnel cable ratings and the number of cable circuits that could be accommodated depend on the capacity of the cooling system whether natural ventilation or mechanical systems. In most cases to optimise the installation it is necessary to install a distributed temperature sensing (DTS) system to monitor the temperature of each cable circuit. Often the DTS system is connected to the SCADA system to activate the cooling system or notify the system operator to make load adjustments.

An example of the application of periodic ventilation and dynamic modelling is given in Section 8.7.1

5.1.6 Earthing

Earthing metallic supporting structures of cable systems, the metallic parts of other services, metallic piping and telecommunication cables has to be considered for multipurpose structures. Most safety regulations require that all metallic parts exposed within a structure are earthed. It is imperative that contact and step voltages are maintained within the safe limits recommended in standards such as IEC 60479. It is also recommended to earth exposed metallic parts to help prevent corrosion.

In general an earth continuity conductor of sufficient size should be installed along the structure to provide earthing points to all metallic parts installed or to be installed in the future.

Where cable screens are not directly connected to adequately sized earthing points, the size of the earthing conductor and electrodes have to be large enough to safely conduct short circuit currents to earth.

Metallic sheath or metallic screen of high voltage cables in multipurpose structures have to be earthed at adequate intervals or specially connected to reduce the induced voltage due to transmission currents. The non cross bonded joints and terminations at both ends of the structure are normally selected as earthing points.

5.1.7 Earth Potential Rise

Step and touch voltage requirements are to be considered in case of short circuit in the cable either resulting from through faults or failures in the cable systems within the structure. Readers should refer to the Technical Brochure by WG B1-26 "Earth potential rises in specially bonded screen systems"

5.1.8 Heating

As mentioned in Section 5.1.5 cables generate heat due to losses in the conductor, the dielectric and the sheath. This heat has to be managed to maintain the tunnel temperature within acceptable limits for personnel and other services. Dynamic models have been developed using heat sources, thermal resistances and thermal capacitances. For more information refer to references 25, 26 and 27. These models can be applied to analyse the thermal conditions. The most effective and simplest way is to remove the heat generated in the structure is by means of natural ventilation that could be boosted by a mechanical ventilation system that uses normal available ambient air. Forced ventilation removes the generated heat axially from a tunnel or enclosure rather than dissipating it radially into the surrounding environment.

5.1.9 Induced Voltages

The load current magnetic field around the cables can induce currents in metal objects such as metal pipes of other services within a structure. Some countries set limits on the induced voltage produced under normal operating and short circuit conditions. These limits are often easily met when the magnetic fields generated are low such as installing cables in trefoil configurations and where cables are bonded at both ends. Similarly when the distance between cable and pipes is large and when the pipes do not run in parallel for very long lengths, determined by the lay-out in the tunnel. In other circumstances this could also be achieved by installing insulating flanges in the pipelines at the entry and exit points of the tunnel.

Induced voltages can also damage electronic equipment connected to the communication or signal cables installed in the structure.

Cable sheath transposition and protection is recommended for long cable lengths, refer Technical Brochure TB 283 "Special Bonding of High Voltage Power Cables"

5.1.10 Structural Support and Dynamic Loading

In the design of the structure and the supporting elements for the cable it is needed to consider the static and dynamic forces associated with the utility services using the structure and the replacement or repair of these services in the structure.

Cross sectional area of the multipurpose service area is determined by the:

- number of services,
- number of circuits,
- dimension of any proposed or future pipes or cables,
- space for installation and maintenance for each service.

Design of the space for maintenance and repair of each service has to be considered so that the work does not interfere with the operation of other services. In Japan the typical width of access ways for maintenance is around 800mm, which should be enough space to allow the installation or replacement of cable circuits. The distance between cable supports and to the structure floor is determined by the space required for cable installation and future replacement. All static forces such as the weight of cables and accessories and dynamic forces such as the thermo-mechanical force of cables and the forces produced by short circuit currents should be considered in the design of the supporting brackets and fixing arrangement.

5.1.11 Size Requirements and Constraints

The inside diameter of a tunnel and the space required on a bridge should be carefully evaluated. This evaluation study should include the possible addition of future circuits and other services. It should be possible to install the cables, accessories and services as well as to maintain them and eventually remove them.

5.1.11.1 Intersecting Tunnels.

For instances where two tunnels intersect the design for the placement of services on the walls and floors of the tunnels must be closely studied and the civil engineering design of the intersection should ensure that the minimum bending radii of all existing and future services entering the side tunnel is not compromised.

The placement of the individual services at intersections must never impede emergency access routes out of the tunnels.

A badly designed and badly planned tunnel intersection can severely restrict the number and type of future services that can be installed within the tunnels.

In instances where the range and extent of future services are unknown consideration should be given to extend the height and depth of the tunnel at the intersection in order to create service galleries. These galleries allow for the management of services crossing into the side tunnel and allow for services to continue along the main tunnel without blocking the entrance to the side tunnel.

For bored tunnels any intersection is best placed at a shaft position where there generally is sufficient room within the shaft to construct galleries. Intersections where an adit joins a bored tunnel can cause particular problems and the cost for the construction of service galleries at such intersections can be prohibitive.

Space for service galleries at the intersections of Drill and Blast tunnels, road header tunnels and cut-and-cover tunnels is usually easily accommodated during the design and construction process.

5.1.12 Length and Configuration of the Structure

The task of installing cables, accessories and services in short tunnels and on short bridges should be easy for experienced crews. However, for longer tunnels and bridges many factors have to be considered. Cable pulling requires careful planning and some features such as side access holes to the tunnel would reduce the time required for this operation

On at least one very congested installation the cable drum diameter and drum width were such that a cable drum could be lowered to the bottom of the shaft and the cable installed from there before repeating the operation for the next drum.

On major long span bridges, it would be necessary to bring the cable reel (drum) closer to the actual pulling site.

5.1.13 Accessibility

Material, equipment and personnel transportation through a long tunnel or on a long span bridge represents a technical challenge that requires planning to ensure it is done safely. Two vertical shafts may be required to install the tunnelling machinery and allow the evacuation of the excavated materials during construction. Furthermore, an electric or other emission free vehicle could be considered as a means of installing cables, transporting personnel and materials. Large equipment needed for installation and maintenance may have to be assembled in place.

The most common method of cable installation in tunnels utilises static caterpillar hauling machines as vehicles can only be rarely used for installing cables within tunnels. Accessibility for transportation through the tunnel can be enhanced by installing an overhead “I” beam at the tunnel soffit which may also be used for the “curtain rail” cable installation method.

5.1.14 Cables

To minimise costs of the project, cables of over one kilometre in length have been installed in tunnels and on bridges. Special reels and arrangements could be necessary to allow for the pulling of such a long length.

In tunnels, cables could be installed in free air or enclosed in troughs that prevent the possibility of fire propagation resulting from a major failure. The clamping arrangement and the distance between the clamps should be studied.

For cables on bridges, it is essential to study the thermo mechanical behaviour of cable systems under different load conditions, also their expansion and contraction relative to that of the bridge structure. Expansion loops may be necessary to accommodate these differences and are described elsewhere in this publication.

5.1.15 Environment Constraints

During installation, maintenance and repair work, it is possible to use or generate some substances that can be harmful to people and the environment. It is important to know the properties of all materials and substance being used and their impact on personnel and the environment. The Material Safety Data Sheets (MSDS) of materials used must be referred to and the recommended controls put in place. Measures should also be taken to protect the personnel and the environment by reducing or eliminating such substances. The use of special cloths, masks and the installation of local ventilation and filters as well as trays under the accessories are possible measures.

5.1.16 Potential Occupants

Many structures are underutilized and could accommodate some new installations in the space available. The owners should consider any prospective or potential partner. However, a careful study should be undertaken to ensure that any new equipment to be installed is compatible with the existing structure, equipment and services.

5.1.17 Impact on Other Services

Some special precautions may be necessary to protect the different installations from being impacted by other installations or equipment. It may be necessary to install an enclosure to protect high voltage cables and accessories from each other as well as from other services such as water or gas mains.

5.1.18 Effect on the Structure and its Performance

The weight of the cables, accessories and supports attaching them to a bridge and their effect on the bridge’s performance must be carefully analysed.

The weight of cables, accessories and supports for future circuits must also be considered in the structural design of bridge itself. To control the bridge movement within the allowable range, dummy weights for the future cables may need to be considered.

The installation of a long high voltage cable circuits on an existing bridge would add a substantial static load as well as exert some dynamic forces to the structure. A detailed study of their integration should be undertaken by a specialist in order to determine the necessary modifications and ensure the safety of both. It is imperative to also consider the vibrations of the bridge structure caused by vehicular or train traffic that would be transferred to the cables and accessories. Special vibration damping arrangements may be needed in order to prevent premature failure of the cable system.

How bridge movement and vibration have been covered in more detail in Section 2.2.

In a short circuit situation (that may be elsewhere in the network): large forces will act on the cables that will lead to cable movement. Also, if high pressure pipeline valves are closed or opened there can be a huge pressure wave, leading to movement of the pipes when they are not adequately fixed in the structure. Fixing utilities to the structure is on the other hand difficult as the cables or pipes may expand and contract due to temperature differences.

5.2. Non Technical Issues

5.2.1 Safety Aspects

All safety aspects concerning personnel and equipment should be addressed in the feasibility and design phases of multipurpose structures. The following is an attempt to cover the most important aspects and is by no means exhaustive.

Fire and possible smoke resulting from burning materials have to be either prevented or brought t under control as quickly as possible. Although it is very difficult to entirely prevent fires as combustible materials are used in cables, gas pipe lines and other installations, it is important to install some monitoring or protection systems to meet any eventuality.

Any tunnel ventilation systems should operate to maintain any fire rated stairwells at a positive pressure relative to any incident section of the tunnel where the atmosphere becomes hazardous. See section 3.2.4.

Local regulations may regard a tunnel as a confined space. Even if this is not the case, hazards such as engulfment and exposure to a toxic, combustible or oxygen depleted atmosphere should be investigated for tunnels.

Maintenance and operation crews should be familiarised with the functioning of such systems.

Personnel should be provided with personal protective equipment appropriate to the location and work undertaken, such as gas detectors, personal safety lamps and breathing apparatus.

Working on bridges normally involves working at heights and may involve road or rail traffic. Fall arrest personal protective equipment would be necessary together with consideration of other prevention such as barriers and safety nets. Bridge work will also be influenced by the height, length, type and specific characteristics of the bridge. Local regulations related to such situations must be taken into account as with any other construction or maintenance work.

5.2.2 Access

Access to tunnels and reserved spaces on bridges should be limited to authorised personnel. Many commercial technologies are available to control access such as: special key systems with restricted copying rules, magnetic cards, closed circuit TV systems and electrically controlled access doors.

A record of all penetrations by utility crews should be kept. It should include the names of persons entering the restricted areas, time of entrance and exit, a brief description of the work to be done, an inventory of equipments and vehicles (if any) as well as any other information the utility considers pertinent. If more than one utility share the structure, special mutual agreements should be negotiated to cover the modalities of access of their respective personnel.

5.2.3 Vandalism

Vandalism is an irresponsible act and is considered a criminal offence. However, it can also inflict serious damage to a utility's property. It ranges from its simplest form of graffiti paintings to the more serious attack on installations. The best deterrent to vandalism is the use of strict access controls and effective surveillance. As mentioned above, the selected access control system could be simple or very sophisticated, depending on the importance of the installation.

For extremely important and strategic installations, security guards posted at the main entrances are recommended. In some countries military protection is provided for such strategic installations, particularly to deter any potential terrorist attacks. A third level of security described as "Asset Hardening" has been recommended to prevent damage in case the security provided is breached or compromised.

5.2.4 Surveillance

It is recommended EHV and HV installations in multipurpose tunnels and bridges have some kind of surveillance system. The type and the level of sophistication of such systems could be decided upon depending on the location of the installations in the structure as well as its importance. Monitoring by video cameras could be suitable for some remote installations while actual human control would be more suited for easily accessible ones located in more frequently visited locations.

5.2.5 Rules and regulations

National and local as well as an organisation's rules and regulations on safety and other relevant issues need to be rigorously followed. All evacuation routes, distance to exits, and important emergency telephone numbers should be well posted at regular intervals in tunnels or on bridges. Local authorities should be made aware of the details of all installed equipment. This would facilitate the work of emergency personnel such as police, firemen and paramedics who would be called upon to provide assistance during rescue operations. Emergency plans should be prepared and approved by the utility management. Regular training exercises should be practised by the utility crews and local emergency personnel to ensure the highest level of safety and security.

5.2.6 Communications

An efficient and reliable communications system should be installed and used during the construction phase. A permanent communications system should also be envisaged to enhance the safety and security of operation and maintenance personnel. Fibre optic communication cables are preferred to regular copper wires as they are not influenced by magnetic fields that could induce undesirable noise. Phones should be installed at regular intervals in order to facilitate the communications for utility and other crews.

5.2.7 Agreements on sharing of capital and maintenance costs

Considering the fact that tunnels and bridges should require rather large capital investment, careful planning is of utmost importance. In case of shared structures, it is imperative that the involved parties should prepare some feasibility studies as well as negotiate and conclude a detailed agreement prior to embarking on the project. It is not unusual that such preparation and negotiation would take more than a decade. In some countries, such as Japan, it is mandatory to conclude a long term agreement covering seventy five years representing almost the entire expected life of the structure.

5.2.8 Limiting access to different utilities

In the deregulated energy markets, it is possible to have many utilities sharing the same structure for their respective purposes. In such cases, it would be preferred that access to different installations be limited to the personnel working for the owner of the equipment. This could be achieved by dividing the tunnel into individual compartments separated by physical barriers. This would immensely reduce the possible damage caused by accidents on other utilities equipments or by other personnel. However, it also makes for larger structures or impedes space for access and work.

Figure 5.6 shows the application of barriers applied to segregate the space within a structure. By the application of such barriers, the individual owners can establish and apply their independent management, safety, access control to their infrastructure.

Figure 5.6 Concept layout of services planned for a Japanese urban environment

5.2.9 Organisational complexity

The complexity of this will depend upon such things as the willingness of prospective partners, local rules, cultural aspects and the regulatory environment.

5.2.10 Impact between different services

Issues a user should consider include the impact of the energised cables on other services and people, the ease of installation, maintenance and replacement. The required level of security required for each service.

5.2.11 Barriers to sharing

Those interested in sharing a structure should ensure there are no impediments to sharing with others such as local regulations, capital investment, running costs, financial arrangements and insurances.

5.2.12 Investment Risk

To ensure a sound investment decision a risk analysis for the cable system and other services sharing the structure should be evaluated for: the installation, normal operation and for a failure of one or more of the utility services.

Evaluation of the cable system should consider the following criteria: thermal, electrical, mechanical and ambient conditions.

The results of the risk analysis are implemented in a risk management system. In this system, risks and measures to control them are correlated. A cost/benefit analysis must substantiate that the proposed measures are feasible and attainable. The risk analysis may require one or more of the following conditions to be met:

- The tunnel has to be cooled to control the temperature.
- The tunnel has to be divided in zones with different levels of magnetic field
- Controlled of access to authorised personnel.
- The calculated induced voltages on other metal structures must not exceed specified limits
- The cables have to be properly fixed to withstand short circuit forces and to allow thermal expansion,
- Safety procedures have to include proper monitoring & protection systems to detect temperature, leakages and smoke in the early stages.
- Maintenance procedures have to be clear and effective to avoid damaging other systems,
- The process of extinguishing possible fire may need special attention, as the fire brigade may only go down into the tunnel in case of fire alarm if their safety can be demonstrated.

If these conditions can be fulfilled, the cable installation in the structure may be considered a manageable risk feasible option and necessary approvals requested. Approvals may be given under the assumption that the systems present or intended in the structure and their related behaviour like: failure mode, leakage, fire, reliability of alarms, maintenance and its management satisfy the necessary statutory or other requirements.

5.2.13 Legal constraints

The legal constraints to sharing structures depend upon the national and local laws and policies of the structure owner. It is understood that in some countries it is illegal to install power cables on road or rail transport bridges.

5.2.14 Future Plans

The design of shared structures should always consider the practical and financial aspects of any future planned or possible projects.

5.2.15 Management

All infrastructures in which cables are installed need to be managed. It is obviously easier to manage a single owner structure than a shared structure. This is why utilities generally prefer to use their own structures.

In most of the cases, a structure is owned either by a single entity, by the government or a public agency. The management of a structure is normally delegated to the owner or a utility responsible for one of the services contained in the structure. In the second case it is generally the utility that is the main user of the structure.

The designation of the manager of the structure has to be decided at an early stage of the planning of the structure. It is preferable that the manager can be selected as early as possible, during the feasibility design or construction of the structure. This improves the potential for an optimal investment and better operational and maintenance of the structure.

5.2.16 Ownership

There are three entities concerned with the structure:

- the owner, responsible for the capital investment in the structure. In most of the cases a structure is owned by either a single entity, by government, or by a public agency.
- the manager, generally responsible for ensuring the continued provision of the operating services in multipurpose structure.
- the occupants, generally utility services responsible for their own installation and equipment.

It is common that the owner is also the manager.

As a general rule, it is better to clarify contracts or other agreements the functions and responsibilities of each entity.

The interest of the local community has to be considered. They include residents, local businesses and motorists. They are not directly implicated financially with the structure but are impacted by the project, particularly during the construction and installation phases.

The community can also be the owner and the manager of the structure through the local administration. In such cases it is preferable to ensure that the responsibilities of different administrative departments are clearly understood.

5.2.17 Bridges

Existing bridges built for another purpose may not be suitable for the installation of heavy power cables and accessories due to physical or loading constraints. However, designers of new bridges should be encouraged to consider the integration of other services. In some cases this may not be acceptable as the investment could not be justifiable. Refer to Section 2.2 for more details.

6 ISSUES TO BE CONSIDERED DURING THE PROJECT PHASE

6.1. The Life of Structures.

The life of structures such as tunnels and bridges made with concrete is commonly assumed to be about 100 years. When analysing a project, the life expectancy of the structure is often assumed as 70 to100 years. The life of the networks installed in the structure is generally lower than that of the structure itself. For power cables a value of about 40 years can be assigned. However, there are cables in service even after 80 years of operation so it should be understood that many factors affect the service life of a utility.

6.2. Local Regulations

6.2.1 Construction

Construction of tunnels and bridges is normally subject to local national codes. In some countries international construction standards are followed. Design aspects, soil testing to carry out geotechnical studies and construction details should be prepared and executed by qualified and specialised personnel.

Access to such construction sites should be limited to those involved in the project such as engineers, technicians and inspectors as well as workers belonging to the utility and contractors. As mentioned above, safety rules and regulations should be rigorously applied.

6.2.2 Maintenance

Local regulations concerning inspection and certification should be followed. It is recommended that periodic preventive maintenance be carried out in order to preserve the structure of the tunnel or bridge as well as to ensure the safe operation of the power cables. Major repairs and renovations may be required in case of major deterioration of the structure.

6.3. Compatibility of Services Sharing a Structure

Rules need to be established to ensure the proper operation of the services contained within the structure and to reduce the risk of malfunctions.

6.3.1 Sewage or Storm Water Collection

Sewage or storm water collection systems may or may not be separated. Separated systems are preferable in order to facilitate more efficient wastewater treatment. These systems could be designed either as gravity or forced mains. It is recommended that these systems be placed at the bottom of the shared structure. It limits the consequences of a possible leakage on the other networks and especially on drinking water.

6.3.2 Drinkable Water

Drinking water is carried in pipes under higher pressures generally between 3 to 12 bars. To avoid possible growth of bacteria in the water where possible the water pipes should be located away from heat sources such as power cables. The heating of the water is influenced by flow rates, tunnel lengths, air temperature and movement in the structure.

The requirements of the local water authority would need to be addressed in the feasibility phase and pipe insulation may need to be considered. To avoid water damage from possible pipe leakage it is preferable not to locate cable systems under water pipes.

As a general rule it is recommended that drinking water lines are placed:

- above sewers or storm water collecting systems
- under power transmission and distribution cables to keep the water as cool as possible to discourage the bacterial growth in the water
- under communication networks
- not above and away from heating pipes.

6.3.3 Heating

Heating systems are composed of either steam or hot water carrying pipes with temperatures up to 250°C and pressures up to 40 bars. The main constraint on the other services is due to their heat losses and the consequential temperature rise within the structure. However, they may provide desirable levels of temperature and humidity in the structure that would help reduce the corrosion of metallic parts. An application of an appropriate thermal insulation will reduce the losses, otherwise air circulation is generally used. It is recommended that heating systems are located:

- away from drinking water lines
- away from gas pipes to avoid gas expansion that may lead to distribution problems.
- away from power cables to reduce the negative effect on their rating.

6.3.4 Gas

Pipes for gases lighter than air should be placed in the higher part of an enclosed structure where they are also less prone to mechanical damage. Then if a leak occurs gases will accumulate at the top of the structure and leakage detection installed at the top of the structure will be more effective.

Pipes for heavier than air gases could be placed anywhere within the structure, however, it is recommended the pipes and detection systems are placed in the lower areas of the tunnel to minimise the risk of engulfment. When working in an environment where a potential gas leak could occur it is imperative that personnel are provided with gas detectors and appropriate personal protection and escape equipment

Gas is usually carried in pipes under pressures between 0.5 and 25 bars. Due to potential explosion hazard from combustible gases the structure must be equipped with gas leakage detectors and a warning system. Natural or forced air circulation should be installed in the structure to allow remove any leaking gases. To ensure a correct metering of gas volumes, gas pipes may be insulated.

It is recommended that gas pipes are placed:

- in the appropriate section of the structure, as discussed above.
- above drinking water where possible, in case of water leakage.
- away from heating

- away from power cables. A minimum separation distance should be specified to ensure any fault on the cable system does not damage gas pipes and risk greater damage.

In some cases gas pipes and power cables are not allowed in the same enclosed space due to the risk of explosion. All gases should be considered on a case by case basis and in all cases local regulations should be strictly followed.

6.3.5 Power Networks

All voltage levels of power cables may by present in a structure. Due to the risk of fire or damage in the structure or cable system insulation failure, precautions need to be taken, for example: fire delay jacket material, mechanical protective devices.

It is recommended that power cables are located:

- above drinkable water (in case of possible water leakage)
- not close to other services particularly gas pipes and copper telecommunication cables to avoid emf disturbances. Depending on the service concerned a minimum separation distance needs to be specified.

6.3.6 Telecommunication networks

Telecommunication networks may be composed of either optical fibre cables or twisted copper cables. These cables are used for transmission of data. Copper cables running in and parallel and close proximity could have high voltages induced upon them under power cable through fault conditions.

It is recommended that telecom cables are placed: away from other services and separated from power cables to avoid emf disturbances and risk of confusion. Depending on the service concerned a minimum separation distance will need to be specified.

While the distances are not usually long enough to result in high induced voltages, they should be investigated. The design and configuration of power cables can also have an influence upon voltages induced in the copper communication cables. Possible solutions ‘are insulating copper telecoms to withstand the possible induced voltages, installing isolating transformers at either end of the structure or revise the design of power cables.

6.4. Safety

When various services are contained inside the same structure, it is often considered that the task management becomes more complex. Although shared structures are harder to manage, evidence was not found that showed failure rates of various utilities in these structures was higher than those in dedicated structures. In practice, risks are limited when identified and taken into account at the commencement of a shared structure project or when a modification of an existing structure is under consideration. In various countries some rules are specified to make this happen for example, minimum distances between need to be recognized:

- risk for the service generation (power transmission, water delivery,…)
- risk for the network itself (cables, water pipe, telecommunication fibre, …)
- risk for people who may be inside the structure
- risk for the environment external to the structure

The origin of these risks may be external, for example, earthquake, flooding, or internal originating from the services installed in the structure. Considering cable systems, internal risks are described in Section 5.1.3.

The most damageable risk for cable systems is when a failure (short circuit) of the internal insulation of the cable system occurs. Service generation is no more possible, cable system is damaged, and the risk for people in the vicinity of the failure is high.

In order to minimise the risk for people who work on cables in shared structures, most electrical utilities use operating and safety rules. These rules depend on the type of work to be done and, in general, are described in an agreement protocol signed by all operational parties using the shared structure (including management, maintenance and safety).

Here is an example of safety rules that can be followed in a shared structure:

- Never operate alone in the structure (excepted in particular cases that require the use of signalling devices).
- consult the other services in order to jointly decide on the appropriate safety rules.
- before the work, ensure air circulation and possible evacuation.
- ensure that no people not belonging to the working team are inside the structure and take precautions against unexpected entrance.
- wear hearing protection in case of noisy work.
- as a general rule, wear relevant protection equipment.
- ensure that there is no fire or explosion hazard (oil or gas leakage detectors).
- no smoking.
- provide each member of the working team with portable safety lighting.
- in case the structure is made up with vertical parts shafts, safety systems to prevent falls have to be used.
- when a working operation (eg civil works, welding, other work involving heat processes etc.) is carried out in the structure that may cause damage to the cable system or other services installed in the structure, all cables or other sensitive services close to working operation have to be protected by troughing or other physical barriers. The intent is to prevent the networks in operation from mechanical damage.

All safety aspects concerning personnel and equipments should be addressed in the design of multi shared structures. The following is an attempt to cover the most important aspects and is by no means exhaustive.

6.4.1 Fire

The need for fire monitoring systems to provide an early warning signal in case of fires was raised in Section 5.2.1. Temperature monitoring systems can indicate the presence of fire and smoke detectors indicate the presence of smoke. The increase in temperature from a fire can be relatively slow in comparison to smoke generation so smoke sensors are preferred as smoke expands quickly and is readily detected.

Appropriate type of fire extinguishers that could be used in case of localised emergencies should be placed at regular intervals or provided by maintenance and operation crews. Ultimately, a sprinkler / spray system could also be considered. Crews working in the structure should be familiar with the operation of such systems.

6.5. Segregation

Segregation is possible when a structure is subdivided into separate compartments for use by various utilities. Each compartment is devoted to one service. It presents the advantage to limit the impact of other services on the service in a given compartment (during operation and maintenance). It makes the operation and maintenance of the services easier.

Segregation needs more space than a structure with a common compartment. Minimum space for access by people is necessary in each compartment. Rules of safety need to be enforced in each of the compartments. The cost to construct and operate a structure with many compartments will be more than for a structure with a shared compartment.

In some cases segregation is recommended or even required to provide a physical barrier between power cables and explosive or hazardous gases.

6.6. Allocation of Space

Requirements or recommendations specifying minimum separation distances between services (parallel or/and crossings) are enforced in some countries. Considerations leading to the choice of these distances are as follows:

- to allow for possible disturbances of some networks on the others (heating, EMF, water leakage).
- to conserve enough space in order to be able to modify one of the networks of the structure at a later time.
- to reserve space between the networks in order to be able to repair a network without damaging the others (during a welding operation for example).
- to reserve the space required for a visible route and a clear division of the networks

The space used by each of the occupants of the structure has to be defined at the beginning of the operation of the services in writing. If a modification occurs at a later time, the agreement has to be updated by all parties.

The agreement defines the responsibilities and the space available for each of the occupants, and also the sharing of investment and maintenance costs. Generally, costs are shared in proportion to the occupied space.

6.7. Operational Management and Maintenance

A unique management performing all current operation in the structure, monitoring the operations done under different services responsibility and keeping all documents, procedures and records required by the management committee or considered appropriate to perform its tasks should be in place. The responsibility of the manager has to be fixed in legal contracts.

The management should take part in board meetings (or the decision taking meetings). The management can be provided by the structure owner, by the most significant service owner, agreed amongst owners or given to a professional external service.

It is common practice to establish a central control room receiving information from the watching circuits in the structure and capable for quick reaction when safety is at risk.

Main functions covered by the management are:

- Maintain the safety in the structure. Intervene in operations that affect safety. Monitor the course of operations, with right to stop operation in case of risk or breakage of safety rules.
- Keep the operation of the central control station in accordance with rules established.
- Monitor the activities or works performed by different services. Assure that no damage to the structure or other services is produced, that good work procedures and housekeeping are maintained and safety rules are kept.
- Take active part in board meetings. Suggest improvements in the rules established to allow better and healthier work procedures. Deeply study new major works or installations and suggest improvements according with the experience gained. Suggest ways to solve disputes in a flexible way.
- Assure the correct maintenance and housekeeping of the structure and of services involved. Care is especially required for any ancillary service related with safety (fire alarms, close circuit TV watching, communication, entrance control, gases monitoring ...)
- The manager is responsible for the structure budget (own cost, repercussion to partners and external payments)

6.8. Structure Services

Commonly the structure is designed for frequent inspection, maintenance or repair work and occasional new service installation. Personnel will be present and has to be adequately protected. Accordingly the shared structure has to be provided with services in accordance with the situation, length, services requirements and local regulations and can comprise of the following.

6.8.1 Ventilation

Heat generated by cable losses may have to be removed. Natural ventilation generally is not enough for long tunnels and forced ventilation has to be provided. Ventilation has to be efficient in all the structure length, avoiding heat points and blind alleys at all times.

If forced ventilation is used to achieve cable ratings it is important that a ventilation failure event is planned for. Ventilation may not be N-1 secure, and a ventilation failure affects the cable rating leading to overheating within a number of hours. The cable owner may not be the tunnel or ventilation system operator. Mitigation measures must be planned for and implemented within that timeframe such as emergency ventilation or reducing cable loadings.

6.8.2 Fire System

Fire is a hazard to be considered in any structure. It is common to put in place a fire alarm system based on smoke detectors switching an alarm in the central control station. Heat detectors are scarcely used due to late activation. However, special optical fibre distributed sensing cables connected to a dedicated DTS system with a rapid response time is often specified for this application.

The use of a network of sprinklers / sprays activated by the detectors is relatively costly and increases the maintenance requirements. However some fire fighters may refuse to enter a tunnel in emergency conditions if there is no primary fire fighting system deployed.

Conventional sprinkler / spray systems may be effective in suppressing fire and cooling a tunnel but some systems require large amounts of water that may become contaminated resulting in time consuming and costly disposal.

High pressure clean water mist (spray) systems offer an alternative solution for suppression or extinction. Systems can be either dry or wet smaller diameter piping with a specifically designed array of spray heads fed from a high pressure pump unit by section valves. These systems require an adequate supply of clean water and a reliable power supply. Typical manufacturers tests show fire spread was prevented and tunnel temperatures reduced by this type of system.

Water sprinkler / spray systems can be readily retro fitted into installations.

6.8.3 Lighting

Some shared structures are equipped with lighting in all their length. The light is activated either automatically or manually in the zone where people are present. Some structures are provided with light only in the access zones, and in that case personnel have to be instructed and provided with hand lamps. Lighting has to allow at least safe displacement in case of accident.

6.8.4 Drainage

Water can be present in structures, especially in underground cable tunnels, and has to be removed. Water can penetrate through the walls, floor and ceiling in particular through joints in the civil work (seepage) or come into the structure by occasional flooding. The installation has to be designed to support water immersion during a short period. But the water can not be accepted permanently and has to be removed. A commonly used system is provide the structure with water troughs collecting water in adequate pits were is it removed by automatically activated pumps and disposed adequately.

6.8.5 Alarm System.

A general purpose alarm system should be provided in the structure ready to be activated by any person present in case of accident of any description (health, structural damages, services failures or malfunction, fire, flooding, sparks and shortcircuits, heavy overheating...). Alarm points are placed in the structure, easily noticeable (i.e. fluorescent paint) not far apart and at easy reach. The alarm should give advise to any person in the vicinity (light and sound combined is a most common option) and to the central station. Voice communication to the central station can complement the alarm and allow precise information of the accident be given. Actuation in case of accident is reserved to specialised brigades or trained personnel.

6.8.6 Communication.

In most cases the structure is provided with a communication system allowing contact with the central station through a telephone connector (the person in the tunnel should carry a telephone set). In some cases contact with the external network can be established directly or through the central station. The communication points (generally close to the alarm points) are located along the structure and not far apart.

6.8.7 Access, Escape and Rescue for Personnel.

Access points for personnel should be not too far apart. However, while 400 metres may be considered a reasonable distance for shallow tunnels, it is more likely to be 3,000 metres at shafts for a deep bored tunnel.

The entrance in the structure has to be closed and secured (with keys or padlocks) to avoid uncontrolled penetrations. It is common to provide the door entrance with magnetic card activated locks to improve the entrance control. The exit has to be outward opening and provided with panic bar. Access doors have to be capable for rescue of injured or incapacitated personnel. Access doors should be monitored by close TV circuits connected to the central station and kept free of obstructions at all times.

It is clear that for very short connections most of these services are not required. The selection and sophistication of the services to be installed depends of circumstances specific for any particular case.

The distance from and the direction to the nearest exit should be provided on a visible panels at adequate intervals along the tunnel.

As with high rise buildings, pressurised stairwells could improve the chances of escaping from a contaminated atmosphere.

6.9. Earthing

Metallic sheath or metallic screen of high voltage cables in tunnels or shared structures have to be earthed at the adequate intervals to reduce the induced voltage due to transmitted current or a consistent insulation of the screens and their connections has to be provided.

Joint and termination of both ends are normally selected as the earthing point. The necessity of earthing of metallic supporting structure of cable systems and in case of shared structure, metallic parts of other services, metallic piping, telecommunication cables and so on also have to be considered in the safety point of view and corrosion viewpoint.

High voltage cables in shared structures can be laid in close proximity or run parallel to other services and have the added hazard that people can come close to and touch the cables system. Hazards arising from HV cables in tunnels include earth potential rises, step and touch voltages and transferred voltages. The path for fault current flowing back to the source is by the cable sheaths or screen wires and the parallel earth return paths provided by metallic equipment, telecom cable sheaths, other power cable sheaths/screens, the structure and the general mass of earth.

Metallic cable support systems may not need to be earthed if the voltage induced into the support is negligible, although some countries it is mandatory for any metallic parts of the cable system (supports are part of the cable system) to be earthed. Exposed metalwork such as ladders which are longitudinally installed in parallel with power cable, especially in case of bulk power transmission line or high fault current system, stairs, metallic floors should be earthed for personnel safety by a suitably sized earth running along the structure,. The earthing should be suitably sized to limit step and touch voltages to suit the safety requirements in place

Cable screen earthing should not necessarily use the earthing of the structure.

It is preferable to apply electric corrosion proof system on metallic pipe in shared structure to avoid pipe electrolytic corrosion due to stray currents in earths.

6.10. Security

Security is a sensitive issue in countries subject to terror scares from militant cells are found or suspected to be operating. In such cases some utilities have conducted in-depth security reviews that have led to a "hardening" of assets to either deter intruders or to obstruct and delay militant attackers until special forces could be mobilized. The names on substations have been removed as have the identification of a substation's location on local maps. Information on infrastructure assets made available in a public forum could therefore be viewed as tending to compromise the security of such assets.

With the increased awareness of the vulnerability of essential services to damage by terrorist activity or vandalism, it is understandable that organisations with services in shared structure, particularly tunnels, were security conscious. In one case requiring police background checks

prior to entry.

Bridges are generally more visible and vulnerable targets not because of utility services installed This should be considered in the risk analysis for a shared structure along with secure access, segregation and protection from vandalism including from below

Where services are segregated they generally work on a two key or permit system from structure owner and service owner. Where common area the service owner gains permission from the structure owner's representative (eg security)

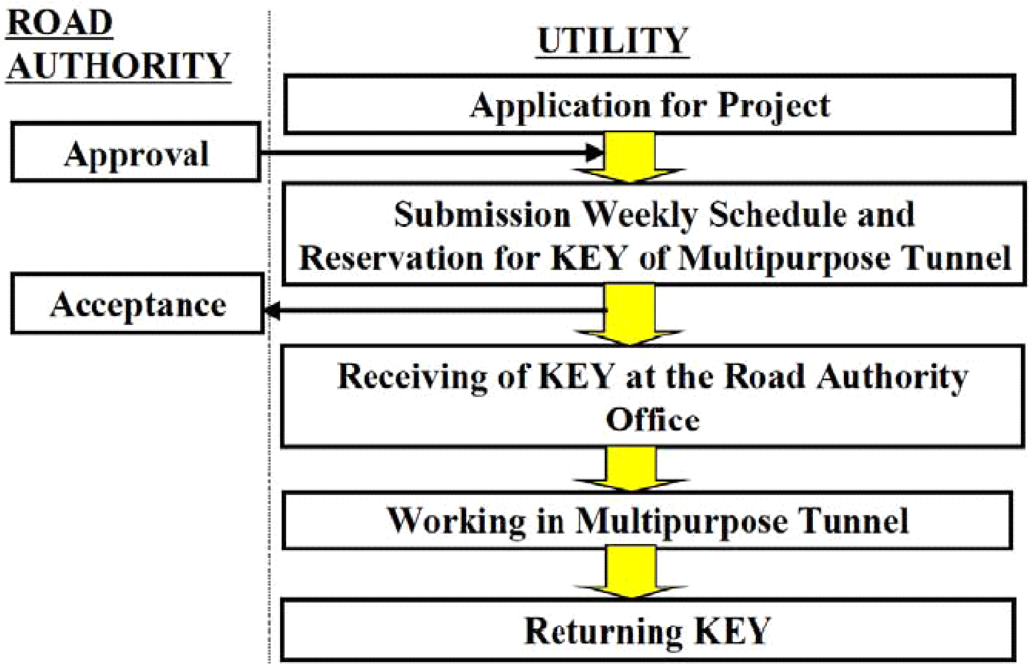


Figure 6.1. Typical procedure to access to multipurpose tunnel in Japan

7 ADMINISTRATIVE AND LEGAL ISSUES FOR SHARED STRUCTURES

A legal agreement covering the relationships, use, operation, and maintenance of the shared structure giving a clear understanding of the ownership, rights and responsibilities of occupancy by co-users is recommended. While any legal agreement would normally be made under the laws that apply in the local jurisdiction in which the asset is located, there are common elements that should be considered in an agreement. In reality the working group found little knowledge of the existence of such agreements, however, it recommends some common elements of agreements be considered when entering into a sharing arrangement if they are not already covered by regulatory controls.

The following are examples from agreements and are only intended to be used as a basis for consideration by parties intending to share a structure. They are not intended to be a comprehensive list.

7.1. The Shared Structure

Any agreement should include: a description of the shared structure and any acquisition interests associated with the structure, for example, easements or rights of way. An acknowledgement on how a new shared structure was constructed or an existing one acquired. What warranties or liabilities apply to the shared structure. Assurance that users of the structure have access to as-built plans and other relevant documentation.

7.2. Title

Under what ownership the structure was constructed and owned. What are the rights and obligations of the owners and users of a shared structure. The considerations under which parties acknowledge incurring obligations and rights for consideration received consideration from other parties.

7.3. Ownership

Issues of ownership covered by an agreement should include: who owns or how much each own of the structure and related acquisition interests and how they can be varied. That any specific interests in a shared structure will be made available for the purposes for which it was legally intended. It may include the portions of the shared structure that parties to an agreement have no interest and how any reasonable variation is consented to and the time frames that should apply.

7.4. Duration

The duration of any legally binding agreement should be clear and how it can be terminated or renewed.

7.5. Scope of Relationship between Joint Owners

The scope of a relationship between joint owners and structure users should be covered including any limitations on the joint owners' relationships.

7.6. Defects and Damage to the Shared Structure

There should be agreement to recovery of compensation in respect to any defect or damage to the structure. How any recovered monies are to be allocated and spent. Also, how any shortfall should be funded. What the limitations on the agreement liabilities are, for example it may not cover operating losses of co-owners.

7.7. Maintenance Agreement

A clear understanding of who is responsible for the maintenance and repairs and the limitations of liabilities of partners in the shared structure. This should include the methods and timeframes by which maintenance and repairs will be paid and to whom. Also how any disputes in relation to payments of maintenance costs shall be resolved.

7.8. Access and Safety

7.8.1 Physical Access

Owners and users should agree on how the shared structure will be accessed and any notification protocols that will apply for normal use and in case of an emergency. This may vary considerably depending on the complexity of the structure ranging from a simple bridge to a deep tunnel shared with hazardous substances.

In the case of an emergency, it should be possible for to notify the controller and the control rooms of other users of an intended entry into the shared structure and must comply with any reasonable requirements of the controller and other users. If the user is unable to notify the controller prior to entry in an emergency then it should give the notice as soon as possible after entry.

The agreements should also cover what rights of access a user may have to other sections of the shared structure and areas controlled by any other users.

7.8.2 Shared Occupational Health & Safety (OHS) Obligations

The shared structure should have a Safety Management Plan from which users should draw up their own specific safety plans. There should be an acknowledgement that in addition to their usual obligations as employers under applicable legislation, the joint owners have obligations as controllers of premises to assess and control risk, including risks to anyone who is given access to the shared structure. What the joint owners should do to assist one another and the users of the structure to comply with their joint and separate obligations.

7.8.3 Access and Safety Protocol

The Access and Safety Protocol should be in place for the operation of the shared structure and any obligations ensuring each owner or users' employees and representatives entering on its behalf comply with that protocol.

It is desirable that owners and users work together to ensure that they adopt a consistent approach to the qualifications and training that will be required for employees and non-employees permitted to access the structure. That any access agreement with a contractor or other third parties contains an acknowledgment that any access on their behalf must comply with the Access and Safety Protocol and any direction given by the shared structure's management.

Any resolution procedure including timeframes for disputes regarding access that has appropriate remedial measures through the controlling hierarchy using alternative dispute resolution methods, with the understanding that the outcomes all agree to accept.

7.9. Security

Any agreement should include a clear definition of responsibility for the physical security of the shared structure and the services using it. This should include any sharing of costs for security.

7.10. Accounting and Valuations

There must be agreement that a consistent accounting for their interests and the costs of the shared structure. How a valuation of the asset or its interest might be obtained by a joint owner without interference with the rights of other interested parties in that valuation.

7.11. Dealings with Interests

An agreement between sharing owners may include restrictions on how an owner or joint owner deals with its interest and any covenants that need to be given by other owners or even users. This could include a prohibition on mortgaging without the consent of other owners and any consents required and deeds to be provided on dealings.

The agreement may consider consents required of other owners and may place an obligation on owners not to unreasonably withhold agreement on dealings by co-owners. For example during the fulfilment of the obligations of a transferring joint owner and the other joint owners in the execution of a transfer of ownership.

It may also consider consents required and documents agreed to be provided to other owners for controlled mortgages and not to unreasonably withhold consent to a controlled mortgage.

It is essential that an agreement ensures that: a joint owner may not do anything that may result in the partition of the shared structure. That joint owners agree and acknowledge that a Mortgage or Dealing with an Interest in accordance with Dealings and Interests clauses or authorising use of the structure will not result in such a partition.

The joint owners should also ensure that: future owners of Interests are bound by the agreement that applies, they are each benefited by their respective rights and obligations under this deed and the restrictions on Dealing with and Mortgaging their Interests are for their mutual benefit.

Consideration should be given to what transfers are permitted by joint owners and users.

7.12. Pre emptive Rights

What pre-emptive rights the other joint owners may have on any intention of an owner to sell its interest in the structure making allowance for the timeframe and conditions of acceptance of an offer and completion of a contract.

7.13. Shared Structure, cables, communications, ventilation, drainage and maintenance vehicle

The joint owners and users rights and obligations should be defined with respect to:

- use of sections of the structure.
- responsibility, care, and repair of damage
- communication, ventilation, and drainage systems
- fire systems or other safety systems
- any other operating and maintenance equipment

7.14. Insurance

Shared structures and contained services can be expensive infrastructure so agreements should cover insurances that relate to:

- material damage insurance against physical loss or destruction or damage to any work; and for the full reinstatement or replacement value of any work;

- public and third party insurance covering legal liability in respect of: damage to any real or personal property of any third party; and the injury to, or death of, any person, arising out of the construction and use of the shared structure and its performance of its obligations and with any limits that apply.
- professional indemnity insurance covering legal liability in connection with the provision of any professional services by owners or their subcontractors in designing and constructing the shared structure and performing their obligations under any agreement with any limits on the amounts that shall apply.
- any requirements on each party to effect and maintain workers compensation insurance in accordance with the requirements of the relevant legislation.
- how insurances are funded and any conditions that may apply to owners who want to self insure.

7.15. Dispute Resolution

As with any partnership sharing structures should have agreed mechanisms for dispute resolution for:

- issues not covered by legislation
- an issue which cannot be resolved by a management committee after being voted on an agreed number of times by that committee; or
- a dispute between joint owners relating to their deed or the shared structure.
- how by serving notices in writing upon the other parties, a dispute can be referred through the managing hierarchy for resolution.

7.16. Undertakings

There should be general undertakings on how owners and users undertake to notify other interested parties of any event and steps taken or proposed to remedy that event.

7.17. Release, Indemnity, and Recovery of Insurance Monies

Owners must acknowledge that their liabilities in relation to the structure and its operation are both joint and separate. The extent to which joint owners will release other owners from any liability loss or claim that may arise from actions of their employees or other representatives acting within their authority in managing, maintaining or using a shared structure. Also the extent to which joint owners hold others liable for damage, expense, loss from fraud or negligence and failure to maintain agreed conditions such as insurances. It should also include any indemnities that might apply.

7.18. Confidentiality

It should include to what extent information may be disclosed by joint owners with or without prior agreement from other owners or users.

7.19. Notices

Consideration should be given to what form notices, certificates, consent approvals, directions and other communications in connection with the shared structure should take. Who will sign communications, how they should be delivered and when they come into effect.

7.20. Taxes

The obligations of joint owners in the payment of taxes related to the acquisition, operation, and disposal of the structure.

7.21. Interest

What interest is payable on monies owed to other joint owners, when it is due, and how it is calculated

7.22. General

Other issues that may include: what discretion a party has in exercising its rights.

Any liability for loss caused by the exercise or attempted exercise of, failure, or delay in exercising a right or remedy.

How promptly a joint owner agrees to perform an obligation.

To what extent joint owners comply with the conditions in any consent, another party gives in connection with the structure.

By giving its approval or consent a party does not make or give any warranty or representation as to any circumstance relating to the subject matter of the consent or approval.

How the rights and remedies provided in agreement affect other rights and remedies given by law independent of those provided.

How any provision, or a right created under it, may or may not be waived or varied except in writing, signed by the parties to be bound.

To what extent indemnities are continuing obligations, independent from the other obligations of the parties under this deed and continue after this deed ends. It may not be necessary for a party to incur expense or make payment before enforcing a right of indemnity under this deed.

Agreement of joint owners expenses in relation to anything that another joint owner reasonably asks in relation to: reaching an agreement, giving effect to the intentions and transactions of the joint owners, the execution and delivery of documents and other instruments and to use their best endeavours to cause relevant third parties to do likewise.

That in preparing, executing and completing an agreement owners and users agree to pay their own legal and other costs.

The approvals required for press or other announcements or releases relating the shared structure and any transactions, unless the announcement or release is required to be made by law or by a stock exchange.

A commitment to negotiate in good faith on any matters requested by any of the parties to this deed

That the agreement is governed by the law in force in the local jurisdiction, and the parties submit to the jurisdiction of the courts of that place.

7.23. Definitions and Interpretation

The definition and interpretation of specific wording is usually included in an agreement.

7.24. Management of the Shared Structure

7.24.1 The Manager

Agreement on who manages the shared structure and:

- how they are appointed,
- who the manager is responsible to, the mechanisms and timeframes for reporting.
- the delegated powers and levels of responsibility,
- preparation of maintenance budgets and who approves any maintenance or repair contract above a certain value.
- what applicable Occupational Health and Safety (OHS) requirements may apply for the shared structure.
- who controls access and work in or on the structure including control of 3rd party access issues
- any issue which is likely to have a material effect on the physical or operational safety of the structure.
- keeping all books, accountants and other records relating to the management, operation and maintenance of the shared structure.
- responsibility for any overall safety management plan for the shared structure.

7.24.2 A Management Committee

An agreement between owners sharing a structure should include the responsibility and mechanism for appointment of a Management Committee, its composition, and its powers. The procedures for and frequency of meetings

The responsibility of the management committee should define its authority to review and decide on issues relating to the shared structure. It is recommended they include:

- any proposals and recommendations from a shared structure manager
- budgets for operation, maintenance, repairs, and other costs (taking into account any amounts receivable from third parties in connection with the structure)
- The proper keeping of records regarding the maintenance and costs of the shared structure, decisions of the Management Committee, executive management, and determinations of any agreements with third parties;
- whether rights to use the structure should be granted to any third party
- the purchase of additional land or acquisitions by the owners in connection with ownership of the shared structure.
- capital expenditure and variations relating to the ongoing management and maintenance of the shared structure.
- a decision to reinstate the structure if it is damaged or destroyed and became unfit for occupation.
- litigation in connection with the structure unless that litigation is fully covered by insurance and is not of a nature that might reasonably be expected to adversely affect the reputation of the structure owners;
- any decision of any manager appointed by the shared structure owners the committee considers will have a significant impact on the ownership arrangements;

- approval of the maintenance budget of the shared structure, including rights of approval in respect of any maintenance contract for a sum exceeding a certain amount;
- the policy for access to the shared structure by third parties;
- occupational health and safety policy affecting employees and contractors of the users, owners, and third parties. This should include approval of the safety management plan for the shared structure.
- development and approval of any Access and Safety Protocol for the shared structure and any subsequent variations to this. This should include procedures for safe entry and work, environmental permits, and emergency procedures.
- whether any of these issues require internal approval from the respective organisations that own the structure.
- any other matter that an owner considers important.

7.24.3 Conduct of the Meetings of a Management Committee

The owners of a shared structure should have a mechanism for the appointment of any management committee and how a chairperson is chosen. This may include the rights of a joint owner to elect a member of the management committee, remove, or replace them and notifications required.

Other issues involving a management committee for a shared structure may include:

- membership voting rights, joint
- the notifications required for a committee member to call a meeting and conditions under which they are waived.
- what constitutes a quorum and procedures that apply to a meeting if a quorum is not present.
- the place and times any ownership committee will meet at and failing agreement, at the place the chairperson determines.
- the regulation of the conduct of proceedings at meetings.
- the vote required for acceptance on resolutions and the extent to which they are binding on joint owners.
- owners rights have to invite other persons to committee meetings.
- that an invitee has no voting rights; and may only be present during the consideration of business in which that invitee has an interest.

Also worth considering is agreement on what records should be kept, the specified time in which the proceedings and resolutions of a meeting and any resolutions passed must be recorded and provided.

8 REVIEW OF INTERNATIONAL EXPERIENCE OF HV CABLES IN MULTIPURPOSE OR SHARED STRUCTURES

8.1. Discussion on Survey Results

The Working group received responses from 12 countries to its survey. The results were divided into tunnels, bridges and other structures and are tabulated in the Appendices.

8.1.1 Tunnels

The survey results showed Japan to be the leader in the installation and use of shared tunnels which is understandable given the urban congestion and the protection offered by tunnels from seismic activity.

The longest shared tunnel in the survey results was in Switzerland.

High voltage cables commonly share tunnels with other high and medium voltage cables, telecom cables and water pipes.

Most common fire protection for cables in shared tunnels is a flame retardant treatment applied to the cable as a serving, tape or troughing. With the exception of ventilation control no fire protection systems were reported to be installed in the shared tunnels. Where Distributed Temperature Sensing (DTS) was installed it monitored cable performance and not tunnel conditions.

Although tunnel ventilation was widely reported most users did not report any fire protection in the tunnels. The majority of the tunnels had lighting installed in them.

The most common method of installing power cables was by pulling in then mounting them on metal brackets or cable trays attached to the tunnel sides. In some instances cables were buried in the tunnel floor, popular with oil filled cables to reduce the fire hazard. Cables on racks were either horizontally or vertically snaked. In most cases the metalwork was earthed.

Most respondents avoided joints in the shared tunnels. However, it was reported that space was allowed for joint assembly in Japan. No special precautions were reported other than multiple clamping of the cables at each side of the joint.

Sheath voltages varied between 50 - 400 volts under normal operating conditions and up to 20kV under through fault conditions.

Only special precaution reported for induce and transferred voltages other than earthing metalwork was “distance”.

Apart from design to select optimal arrangements, no particular precautions were reported by respondents to limit electric and magnetic fields (emf) of the energised cables. The emf is intrinsically low for 3 core and pipe type cables.

Most structures were designed and owned by a government agency or the principal (or original) user and built for them on contract.

The most common way of sharing construction and operating costs was in proportion to the space occupied by each tunnel user with each user installing and maintaining their own infrastructure. For shared tunnels owned by a Japanese government agency the costs are shared by the ratio of the estimated cost for each user to independently construct a tunnel. The tunnel common infrastructure was normally managed and maintained by the owner with the operating costs shared in proportion to the space occupied. It was reported that in Belgium there was a fixed installation cost and annual rental charge for shared structures.

The structure owner controlled access and managed any emergency response to an incident in the shared structure.

The design life of shared tunnels ranged from 25 -100 years with the majority of respondents between 70 -100 years. Privately owned tunnels were reported to have lower design lives than government owned tunnels, for example in Japan government owned tunnels had a design life of 75 years and private 25 years (but given the 1963 Shared Structures Act this may have been and misunderstanding of the question)

No special protection was reported for cables installed in shared structures other than covers or fibre reinforced plastic (FRP) barriers in tight locations. Oil-filled cables are normally installed to horizontal snaking in FRP protecting trough or buried in the tunnel floor. An anomaly is that in tunnels visited the joints for buried cables were exposed. XLPE cables are normally installed to horizontal or vertical snaking supported by brackets and without troughing. In special cases for efficient cooling purpose, even XLPE cables are installed in FRP trough.

Apart from installing support structures no other modifications were reportedly made to existing tunnels to install cables.

Although many respondents intended to use shared structures for future installations most were not obliged to do so. The reported exception being Switzerland where the government requires existing structures built for sharing to be used. Singapore reported they would not consider sharing a tunnel with gas mains.

Reported advantages and disadvantages for sharing tunnels are listed in Table 8.1 below.

Advantages	**Disadvantages**
Easier acquisition of a cable route. Avoids multiple excavations by utilities. Shorter construction times and cost savings particularly with existing structures. Less space occupied by services. Less long term public disruption and better accessibility. Ease of replacing cables in the tunnel. Better protection against third party and natural damage. Efficient use of the ground space. Easy accessibility and less public disruption in case of maintenance and repair.	Require longer planning times. Large investment before economic return. Potential for high maintenance costs particularly if wrong structure selected for geotechnical conditions. Sharing a highly regulated and controlled environment with limited capacity to upgrade and decisions made to benefit the group. An ongoing commitment to the other parties. Potential risk of an adverse effect on or by other services. Mutual impact between different systems. Complicated organizational structure. High costs. Can expose the cables to risk of fire not present for direct or duct laid cable. Future legislative or organisation changes resulting in unforeseen risks.

Table 8.1 Reported advantages and disadvantages for sharing tunnels

To summarise: encourage others to share their tunnels but discourage them from sharing yours.

8.1.2 Bridges

Bridges are the most common form of shared structure. Japan reported 1547km of cable circuits shared with road, rail, telecommunications, gas, water and sewerage.

The most common method of installation was pulling cables in to troughing, ducts or onto racks. Flame retardant serving or application was popular. The majority earthed cable support structures with the exception of Japan. The Japanese also prefer to horizontally snake cables if the space and installation method will allow. Cables were not usually cross bonded on bridges however, Japan reported the use of single point bonding as there was no earth on the bridge.

Nobody responding to the survey reported any special measures to reduce emf.

Road bridges were generally publicly owned, planned, designed and constructed by a government agency or its contractor.

Bridges generally built for transport. In Japan the additional construction costs are allocated by addition of weight required to install the service on the bridge. In one particular country installing cables inside bridges has been forbidden for several years.

Advantages and disadvantages similar to tunnel with added risks of exposure to weather and structural failure.

8.1.3 Other Structures

USA reported some cables installed in pipelines.

France reported some cables installed in an underground car park

8.2. Spain.

The urban development in Spain, with cities densely populated, obliges power transport and distribution to go underground. Municipal authorities make every effort to reduce the burden of new construction on the urban surface, and forces new circuits to be installed, when possible, in existing tunnels. Some shared tunnels are described as examples of this type of constructions in the following sections.

8.2.1 Shared Tunnels in Spain

8.2.1.1 Madrid

The water distribution is achieved by pipes installed inside of tunnels, some of them more than 100 years old. The size of the tunnels (≈2.0 m wide x 2.5m high) allows the installation of cables in addition to the water pipes (typically of 300mm or 500mm diameter). During the life of these tunnels, power, communication and optical fibre cables have been laid in the space not occupied by the water pipes (figs. 8.2.1 and 8.2.2).

As can be seen in Figs 8.2.4 and 8.2.5 tunnels can become overcrowded with:

- Water pipes, valves, and distribution outlets.
- Plastic conduits to hold optical fibre communication cables.
- Oil filled and mass impregnated paper cable with impregnated jute outer sheath
- Mass impregnated paper cables with PVC sheath.
- Dry insulated 15kV distribution cables with either PVC sheath or PE sheath
- Dry insulated 45kV, 66kV and 132kV distribution cables (as required by different distribution areas) and lately
- Dry insulated 220kV power transport cables.

8.2.1.1.1 Tunnel Services:

Tunnels are continuously monitored through CCTV systems. Entrance into these tunnels is restricted and authorized personnel are provided with smart identification cards.

Fire alarm is provided through smoke detectors linked through an optical fibre circuit to a central unit. SOS posts are provided at regular intervals along the tunnel, with telephone connections (fig 8.2.3).

No forced ventilation is provided.

The tunnels belong to the municipality that allocates space for new installations. The municipality also manages and maintains the tunnels.

Figure 8.2.1
Power cables and communication cables in a Madrid tunnel (Courtesy of Iberdrola Ingenieria y Construcciones and Union Fenosa)

Figure 8.2.2
View of a Madrid tunnel showing water pipes on the tu nnel floo r. (Courtesy of Iber drola In genieria y Construcciones and Union Fenosa)

Figure 8.2.3
A SOS bo x i n Ma drid tu nnel. Als o pipes extended into the tunnel. (Courtesy o f Iberdrola Ingenieria y Cons trucciones an d Unio n Fenosa)

Figure 8.2.4
High V oltage power cable and joint in Madrid tunnel. Water main on floor opposite. (Courtesy of Ib erdrola In genieria y Cons trucciones an d Unio n Fenosa)

Figure 8.2.5
Water main (with valve) and power cables in Madrid tunnel. (Courtesy of Iberdrola Ingenieria y Construcciones and Union Fenosa)

Figure 8.2.6
Section of a Madrid tunnel showing a water main at floor level with power and communication cables on the walls. (Courtesy of Iberdrola Ingenieria y Construcciones and Union Fenosa)

8.2.1.2 Barcelona

A total of 22km of shared cable tunnels were constructed in 1990 and 1991 prior to the Barcelona 1992 Olympic Games. The majority of these tunnels are of rectangular cross section approx. 2m wide and 2.5 m high. The tunnels contain:

- Communication cables (mostly optical fibre),
- Signal and data cable for municipal purposes (traffic light and miscellaneous).
- Dry insulated MV distribution cables.
- Dry insulated HV power transport cables (220kV)
- Occasionally water pipes for particular services.

Some sections of the tunnel are overcrowded.

8.2.1.2.1 Tunnel Services

The tunnels are continuously monitored and entry is restricted to authorised personnel provided with smart magnetic cards.

At regular distances along the tunnel connecting boxes are provided with light switches, telephone lines, and smoke and gas alarm detectors all linked to a central management system.

Fireproof doors are provided, isolating the tunnel into sections every 400m. Each section has its own independent temperature and ventilation control.

Forced ventilation is provided keeping the inner temperature of the tunnels within designed values.

Space is allocated to utilities (power distribution, municipal services, communication etc) who share the ownership of the tunnels. The tunnel management, monitoring, and maintenance are provided by an independent company.

Figure 8.2.7
220 k V H V Cables (with joints) on w all brackets in a Barc elona tun nel. Th e r ed conduits above left are for optical fibre communications. (Courtesy of Fecsa-Endesa)

Figure 8.2.8
A section of Barcelona tunnel where HV cables are mounted below MV distribution and service cables are treated with a white flame retardant coating. (Courtesy of Fecsa-Endesa).

8.2.1.3 Fire Incidents

Fires have occured in both Madrid and Barcelona tunnels. The cause of the fires was attributed to: electrical (joint) failure, human error or unknown. In some cases the damage was very substantial. In all cases the fire was propagated through the MV cables but they were not the cause of the fires.

8.3. Japan.

8.3.1 Shared Bridges in Japan

A classic application in Japan can be found in the famous "Honshu-Shikoku interconnecting link" where 500kV oil-filled, 187kV and 77kV XLPE cable systems were installed on long suspension bridges. 77kV XLPE cable system on bridge A, 187kV XLPE system on bridge B and 500kV OF on bridge C. The bridges were designed as “multi-purpose structures” for: highways, shinkansen high speed trains (bullet trains), telecommunication cables, power cables and other services. At the time of writing the shinkansen high speed train line had not yet been installed. The space for the cable installations and the influence of cable weights on each bridge structure had to be considered at the design stage of bridges. Various innovative technologies were developed and adopted to install power cables to long suspension bridges, adapt them to the behaviour of bridge, minimize mutual interference with other services and protect the environment.

The vibration caused by the passage of cars and trains was relieved by making the supporting interval of cable optimum considering the resonant frequency of cable and structure.

For environmental protection the oil filled cables were installed in fibre reinforced plastic (FRP) type troughs with a pressure relieving mechanism. The electro-magnetic induced voltage on communication lines was reduced below permissible values by transposing the cables.

Refer to reference1 in Section 10 for a study on the installation of power cables on these bridges.

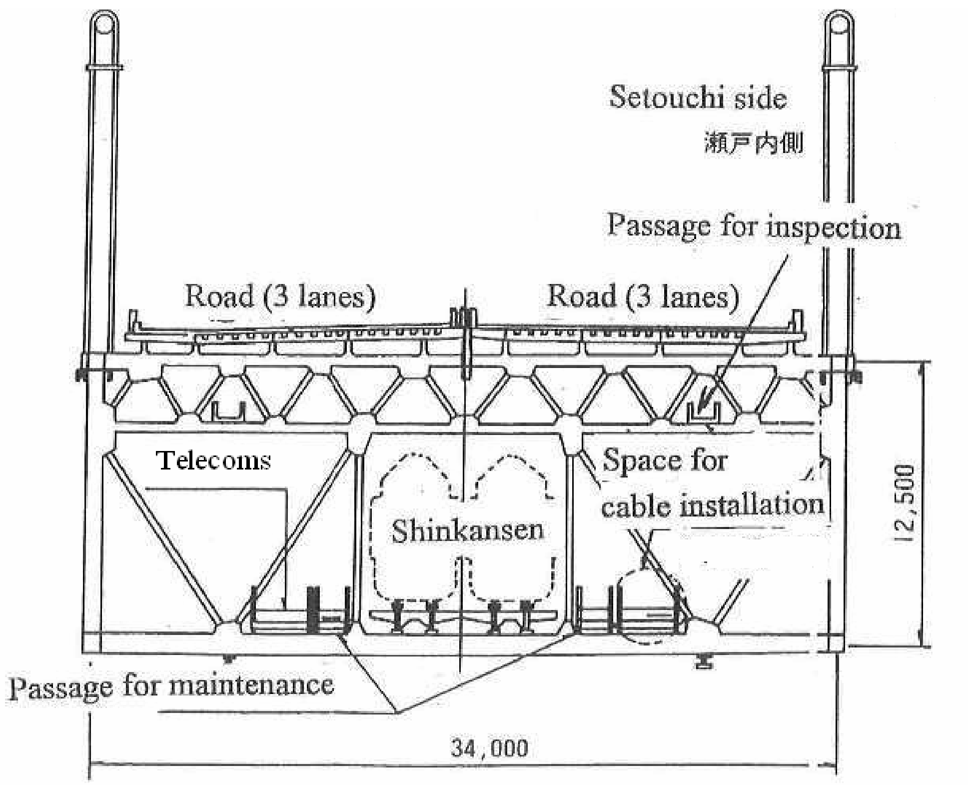


Figure 8.3.1 Typical Cross Section of a suspension bridge in Kansai

Figure 8.3.2 Location of the HV power cables on one
of the suspension bridges (highlighted in red)

Figure 8.3.3
Cables in the structure of the
giant pantograph on the bridge

8.3.2 Shared Tunnels in Japan

The Act for Multipurpose Tunnels enacted in 1963 requires Japanese utilities to participate in the use of multipurpose tunnels with up to 75 year planning horizons. Its intention was to control the repeated excavation in metropolitan areas, establish a strong road structure including underground and achieve a smooth traffic flow. A multipurpose tunnel (MPT) is an underground structure that is constructed under the road to install the public use facilities such as electricity, telecommunication, gas, water, sewage and other distributed services. The relevant road authority selects and designates the road as a "Road for possible MPT" whose repeated excavation can strongly affect on the road traffic condition in the future. The authority collects the opinions of related public utilities and MPT will be constructed if more than 2 utilities participate. Other utilities cannot own the space of that MPT and are barred by the legislation from excavating and laying services in the roads along the tunnel route.

The term common tunnel is used when utilities voluntarily cooperate to share a tunnel for the installation of various service lines.

Typically only 1% of HV and EHV underground cables in urban areas are direct buried.

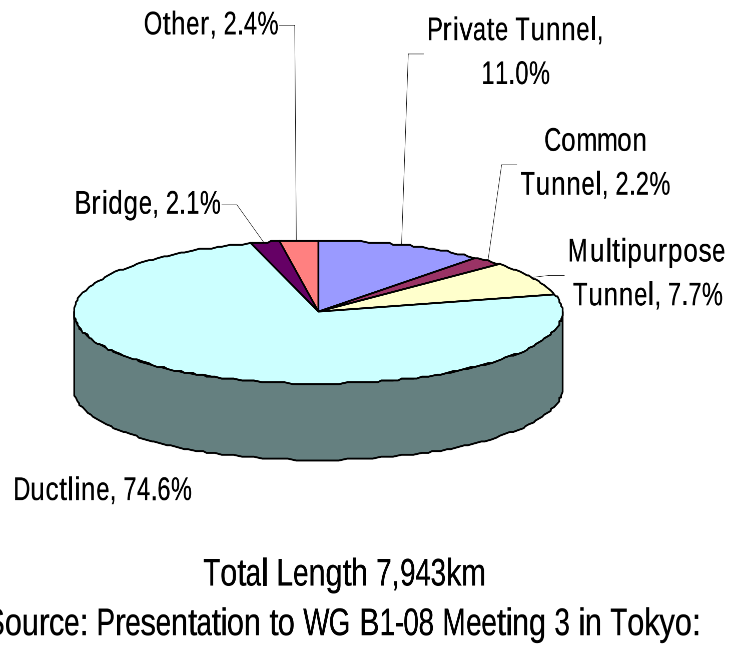
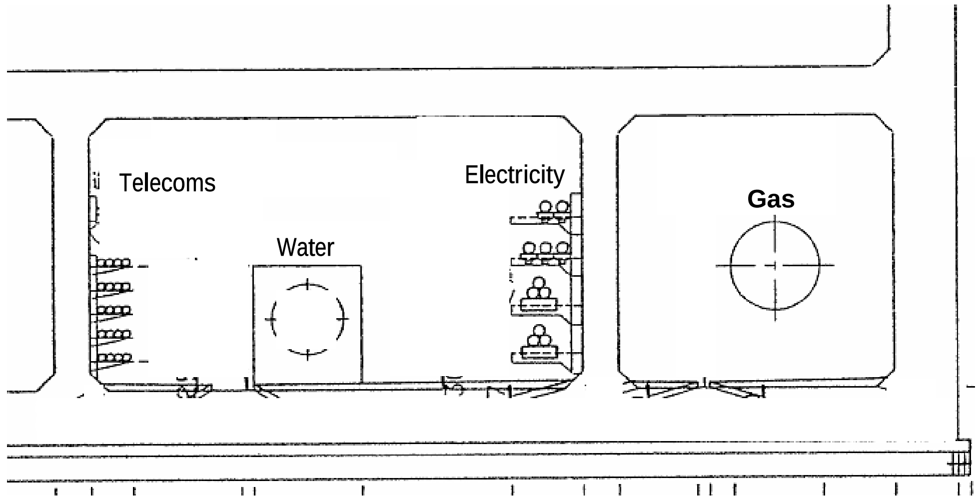


Figure 8.3.4 Typical example of the proportion of a Japanese Electricity Company's cables occupying shared structures.



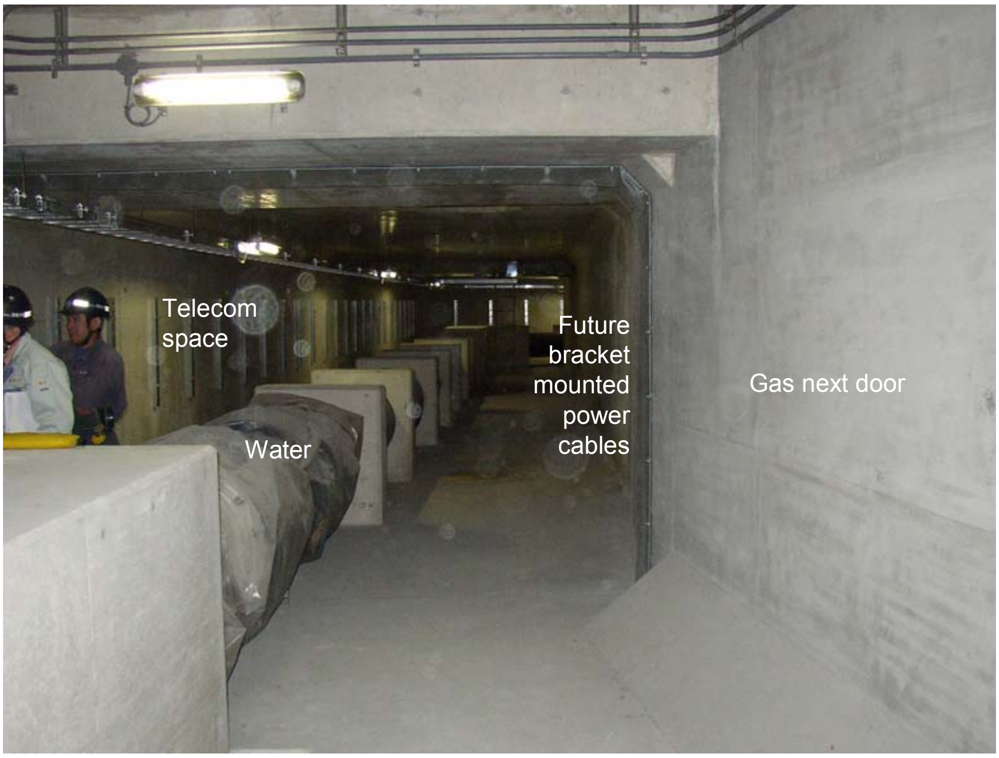


Figure 8.3.5 Example of a Multi Purpose Tunnel with the gas main in a separate compartment in the tunnel

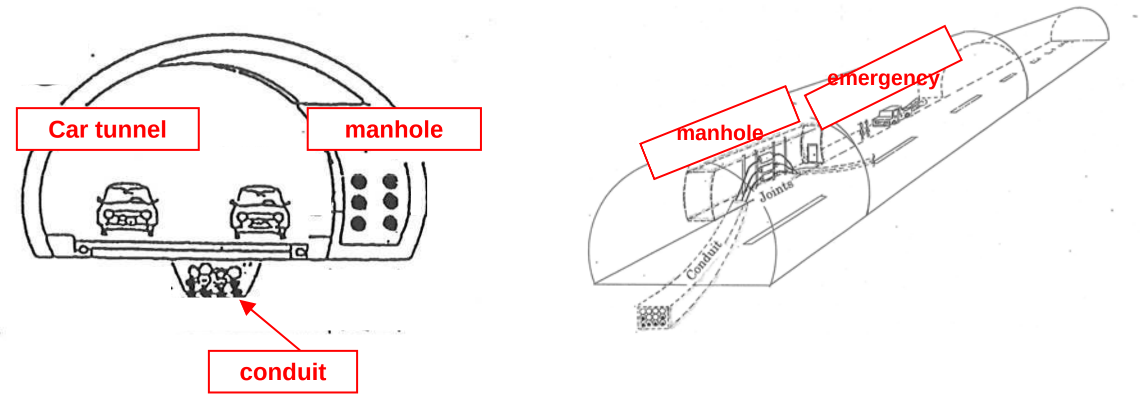


Figure 8.3.6 Sketches of the Sannomiya Road Tunnel designed to minimise traffic disturbance when shared with transmission cables. Installing the cables in the tunnel reduced the underground transmission line costs

In Japan the term common tunnel is used to describe a tunnel used by cables of various voltages and telecom cables.

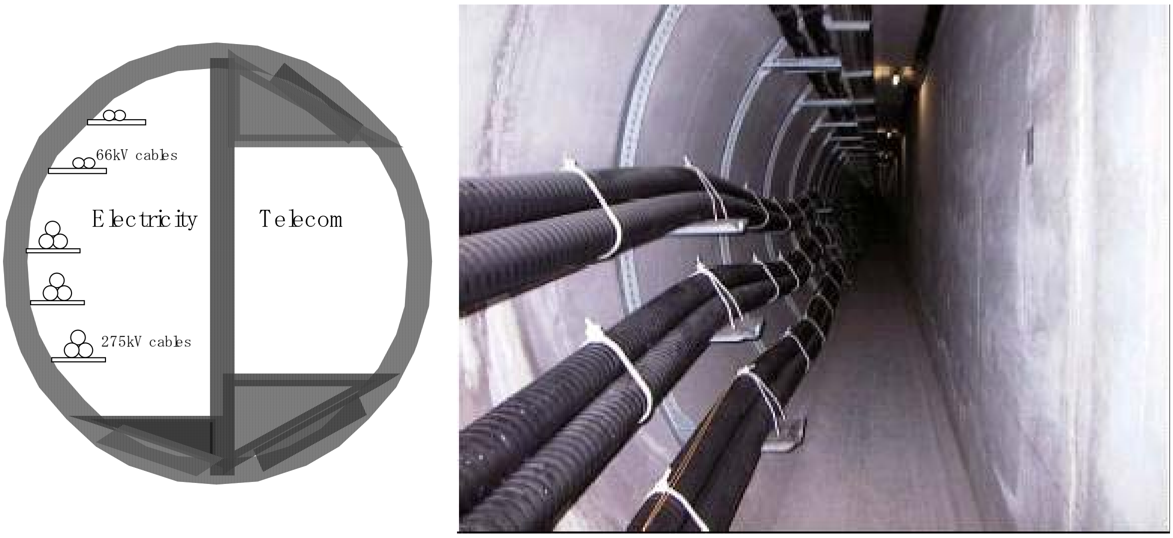


Figure 8.3.7 An example of power cables installed in a compartmentalised common tunnel.

8.4. China.

In China both bridges and tunnels are used as shared structures.

8.4.1 Shared Bridges in China

8.4.1.1 Changsha River Bridge

Figure 8.4.1 A general view of the Changsha River Bridge

One of the first bridges in China to have 110 KV XLPE cable installed on it was with the concrete 'box-beam' bridge across the Changsha River. Because of the long length and distinctive bridge reinforcement, specially designed cable and dilation equipment had to be developed to ensure that no stresses were imposed on the cable at dilation points where the bridge could expand and contract due to thermal changes.

The overall length of the bridge is approximately 1 km and a single length of corrugated stainless steel sheathed cable was installed in 1990. The way the bridge had been constructed made it particularly difficult for the application of conventional dilitation equipment. A 'bow spring' device was specially designed so that it could be fixed on one side and made to move on the other section.

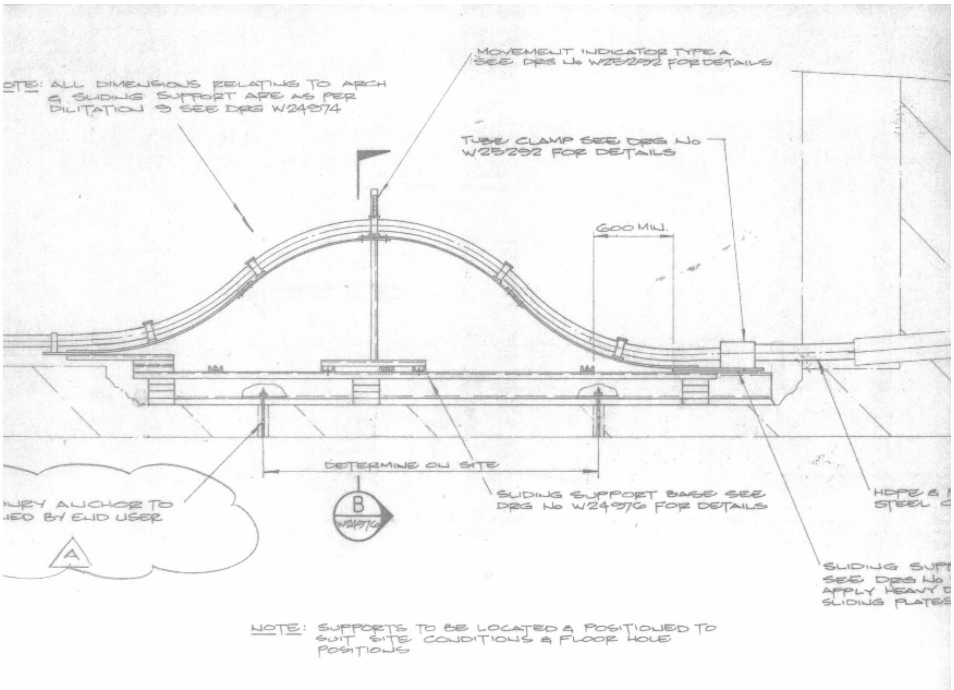


Figure 8.4.2 Bow Spring Expansion Arrangement

8.4.1.2 Tianjin Nanjiang Bridge

110kV cables were installed on this bridge and in this case it was possible to use a different system to compensate for the bridge movement. Cables were installed on framework in a concrete trough that formed part of the bridge structure. At each thermal expansion point the cables were snaked to allow for the expansion and contraction of the bridge

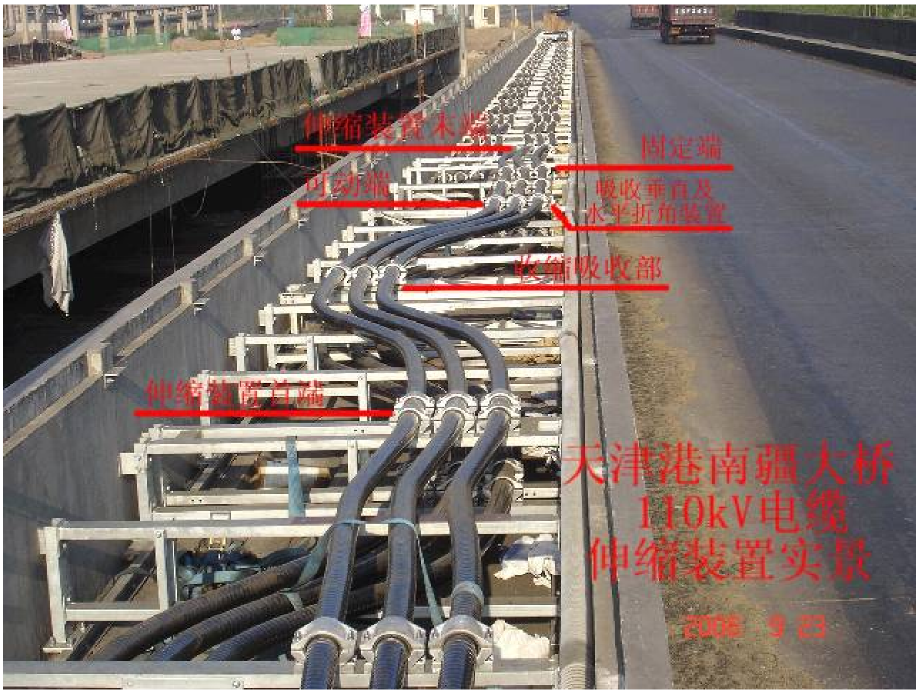


Figure 8.4.3 A typical snaking arrangement for cables to allow for movement on the Tianjin Nanjiang Bridge

8.4.2 Shared Tunnels in China

In most cities in China cable tunnels are now used for multiple transmission cables and such tunnels could be used for other services.

In established city centres such as Beijing the tunnels have been constructed deep under existing roads and buildings. However, when new roads are being constructed tunnels are now often built beneath the road at the time of the road construction. Such tunnels are well designed and very cost effective. The use of these tunnels for cable services means that lower cost XLPE cables with Corrugated Aluminium sheaths can be adopted without concerns about third party damage and corrosion.

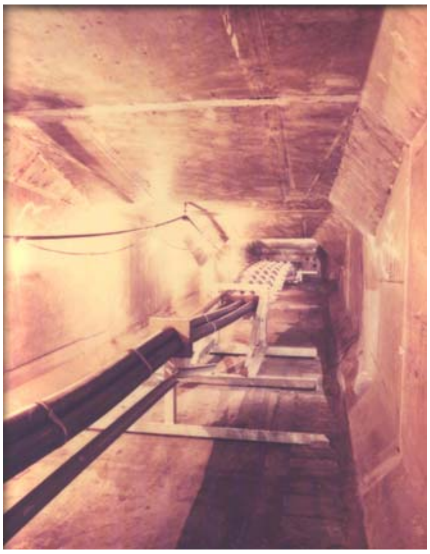
8.5. Australia and New Zealand.

There are few structures in this region but the number is increasing due to the need to reduce costs for the supply of services.

8.5.1 Shared Bridges in Australia and New Zealand

8.5.1.1 Victoria Road Bridge (Tennyson Circuit), Brisbane (Queensland)

In 1989 a 400mm^2 110kV XLPE corrugated Aluminium sheathed cable was installed within the concrete structure of a "box beam" type road bridge over the Brisbane River. In this case a special bow spring arrangement was designed and positioned within the bridge structure at the three Dilation points on the bridge. The circuit was clamped in trefoil, vertically snaked at 3 metre centres and the snaked cables secured at 1 metre intervals. This device was similar to that used on bridges in the U.K. to avoid any localised stress being put on cable at the points where the bridge moves due to thermal expansion and contraction of the bridge. At the time XLPE was chosen over Oil Filled to minimise the risk of fire. This circuit was the first jointed XLPE installation in Australia.



8.5.1.2 Sydney Watermain Bridge, Sydney (New South Wales)

In 2003 a 330kV fluid filled PPL cable was required to be installed on a bridge that had been specially constructed to carry a water supply pipe line across a waterway in Sydney. A special steel Gantry was constructed to carry the cable but in this case no special dilation arrangement was required. Cables were installed in troughing in the mesh enclosed gantry that was protected from vandalism from below. Access to the cables is from the walkway above.

Figure 8.5.1
A 330 kV cable circuit installed in a mesh enclosure between water mains on a shared river crossing

8.5.1.3 Captain Cook Bridge, Brisbane (Queensland)

In 2007 an 110kV single core 1660mm^2 corrugated sheathed XLPE cable system was installed on a specially constructed steel gantry attached to the underside of the bridge.

The circuit was clamped in trefoil and horizontally snaked. More complex bow structures were required to be installed on the bridge at the bridge movement points. This structure was specially designed and tested before installation to ensure that the system would perform and not provide undue stress on the cable at these points.

Figure 8.5.2 The steel structure for the cables that was retrofitted to the underside of the bridge and examples of the complex bow structure to prevent damage to the cables from bridge movement

8.5.1.4 Windan Bridge Graham Farmer Freeway, Perth (Western Australia)

To free riverside land for residential development a dual circuit 132kV tower line crossing the Swan River was replaced by 2 circuits of 132kV single core copper sheathed XLPE cables installed in the enclosed concrete box sections of a 406 metre 6 lane concrete bridge across the Swan River.

The supply authority was not permitted to penetrate the concrete structure and the installation was cemented in place. Each circuit was laid in a separate enclosed section and enclosed in mesh for mechanical protection. To satisfy a requirement of the road authority to mitigate emf the cables were enclosed in copper shielding at each end where they diverge from trefoil to exit the bridge.

Figure 8.5.4 Cables inside the bridge structure were horizontally snaked enclosed in mesh

Figure 8.5.5 EMF shielding at exit points from the bridge where cables are no longer in trefoil

8.5.2 Shared Tunnels in Australia and New Zealand

8.5.2.1 Auckland CBD (New Zealand)

As the soil conditions in Auckland are volcanic and it is difficult to obtain optimum ratings for cables installed directly in the ground it was decided to construct a cable tunnel to allow Transmission and Distribution cables to be more easily installed within the city. Vector identified the urgent need to provide sub-transmission from Penrose substation into the Auckland Central Business District (CBD) and proposed to construct an underground tunnel to house the power cable circuits.

A 9km tunnel was constructed from Penrose substation to Hobson St., Terminal Station and self supporting 110kV corrugated stainless steel XLPE cable. 22kV and 11kV power cables were also installed within this tunnel in 1998. The tunnel has a drainage chase down the centre of the floor, a ceiling mounted sprinkler system and leaky co-axial cable for communications in the tunnel.

Figure 8.5.6 A general view of the Auckland Tunnel. Leaky co-axial communications cable and sprinkler system pipe installed on the ceiling. A drain is installed along the floor.

In this installation provision has been made to allow for more circuits and it was planned to include the transmission service provider's HV cables along with other services. During installation special hydraulic cable handling equipment was developed to lift each cable into position on the brackets after being pulled into the tunnel from drums lowered into the access shafts. Use of this type of equipment in a tunnel that already contains other services may be impractical.

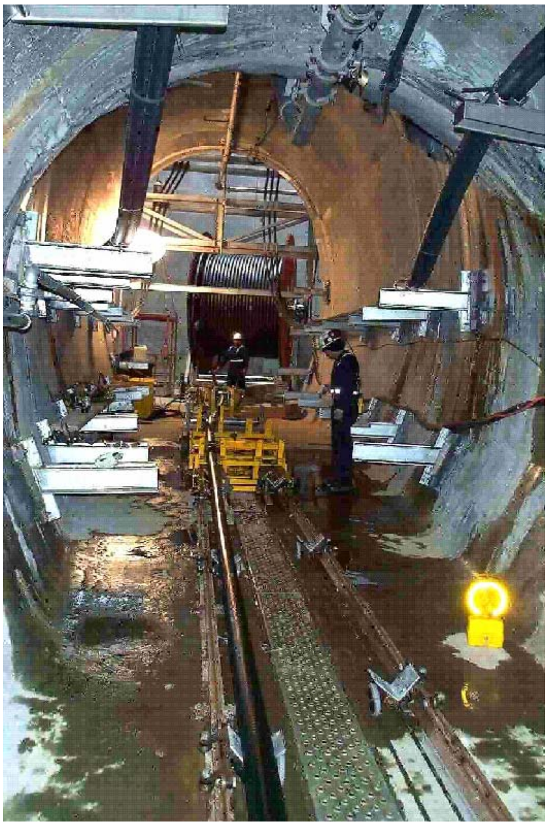


Figure 8.5.7
110kV single core XLPE cables pulled into the tunnel from drum located at the bottom of a shaft.

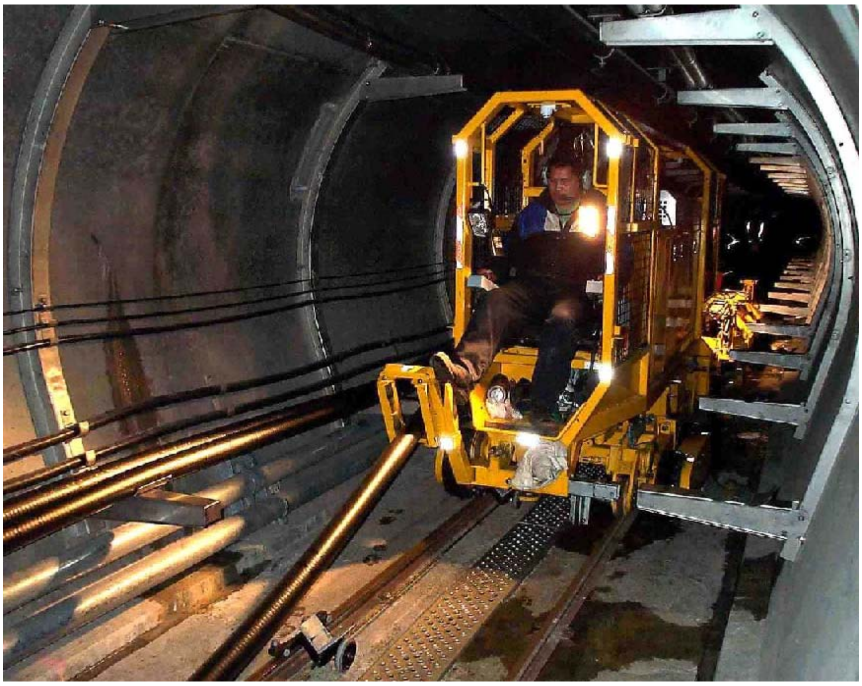


Figure 8.5.8 A special machine on guide rails was used
to mount cables on wall bracketed cable cleats

8.5.2.2 Haymarket, Sydney CBD (New South Wales)

In recent years several tunnels have been constructed in the Sydney Central Business District mainly for use by both transmission and distribution cables. In one case a 330kV fluid filled PPL cable has been installed in a 3.8 m diam tunnel, 3.5km long with the last 600m into the substation shared with four 132kV XLPE cable circuits. For fire protection and other reasons the 330kV cable has been buried in the floor of the tunnel (bottom left).

Figure 8.5.9 Tunnel shared by TCO and Distributor for HV Feeders in the Sydney CBD
The bracket mounted 132kV cables are single point bonded.

The 132kV stainless steel sheathed XLPE cables were horizontally snaked on cable brackets with support clamps every 3m. The circuits were singlepoint bonded. The 132kV cables had flame retardant polyethylene outer sheath and no fire system was installed in the shared tunnel. Pilot and control cables were installed on cable trays. The tunnel had a leaky co-axial cable installed on the ceiling for hand held communication within the tunnel. An adaption of the cable handling machine used in Auckland was used to place the 132kV cables after the 330kV cable had been installed.

8.6. Sweden. Cables in Shared Structures

8.6.1 Shared Tunnels in Sweden

8.6.1.1 Stockholm

High and medium voltage cables are installed in tunnels that were originally built for large diameter hot water pipes that provide district heating to buildings in Stockholm. These large diameter tunnels contain other services, have vehicle entry, are dry and fully lit.

Figure 8.6.1 Typical Multipurpose Tunnel in Stockholm
(shared with water pipes and communications)

A semi rural community built a tunnel to underground several high voltage overhead transmission lines that passed over the community. Now other services passing through the community will have access to the tunnel and will be required to use it.

8.7. The Netherlands.

8.7.1 Shared Tunnels in the Netherlands

Shared structures including HV cables are still rare in the Netherlands. However, two shared tunnels have been realised in recent years. The major reason for these tunnels was the lack of underground space in developed areas combined with cost sharing between different utilities. As an example, one of the Dutch multi purpose tunnels is described briefly in this section.

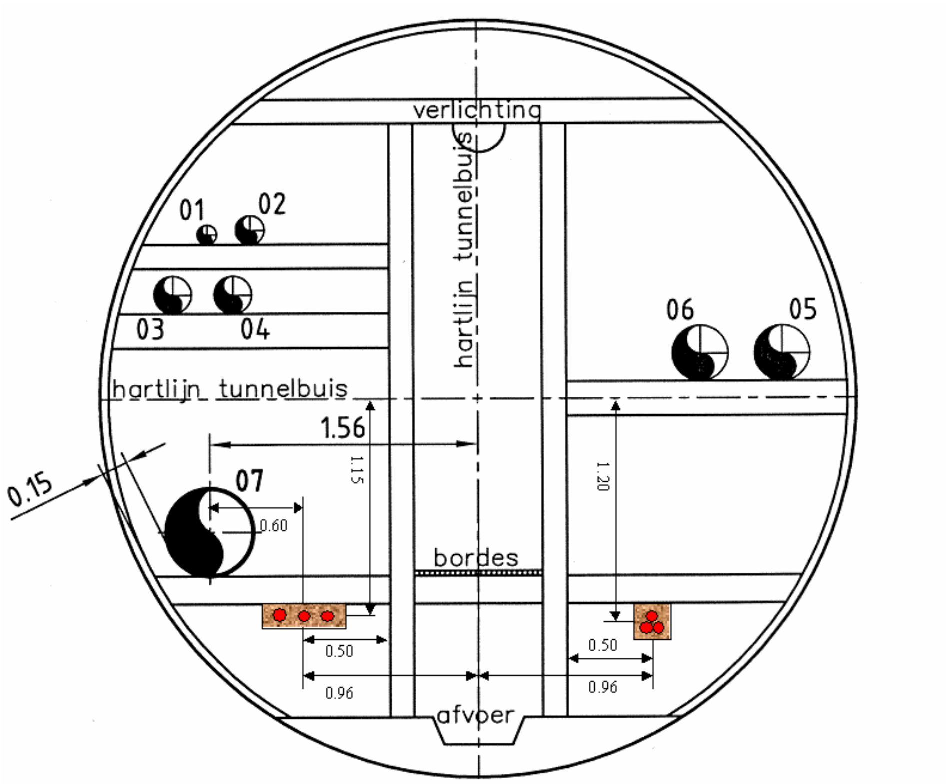


Figure 8.7.1 A cross section of the multi purpose tunnel multi-purpose tunnel in the Netherlands during the HV cable design stage. Section shows HV cables (in red) and other services. The personnel walkway is in the central rectangular section

In Fig. 8.7.1 shows the cross section of a Dutch multi purpose tunnel. This was an existing 20 metres deep tunnel, 4.2 metres in diameter and 340 metres long with no joints. Interest from utilities in using the tunnel has increased and one utility has been asked to install a double cable circuit in the tunnel. When designed sufficient space was allowed for services to be installed. This called for forward thinking during the tunnel design stage and when considering requests to install services in the tunnel. Each utility may have its boundary conditions which should not be violated by another infrastructure. In the case of a multi purpose tunnel, space considerations and considerations regarding the tunnel temperature are the most important. The cables installed in the tunnel are 150 kV XLPE, 1200 mm2 Cu cables with a maximum current of 500A. The cables are protected from accidental damage from falling objects during works in the tunnel by strong netting fixed above the cables. The existing monitoring and control system in the tunnel for temperature control, leakage control and smoke detection were modernised when the cables were installed.

From these considerations, the following points of attention emerge for all infrastructures in the tunnel:

1. Temperature and movement of the air. The air will be heated by the cables. The air may be ventilated in a certain way and the utilities in the tunnel will pose upper and lower limits on the allowable temperature range (think of avoiding legionella in a water mains when the water does not flow, think of chemicals solidising below a certain temperature). Furthermore, the detection of gases or fire will be influenced by flowing or non-flowing air.

2. Positioning of the cables. Refer to section 5.1 on magnetic field considerations.

3. Effect of short circuits or failures of other infrastructures.

HV cables have a very special position in multi purpose tunnels as cables directly influence their environment (they increase the temperature of the surroundings, and produce magnetic fields) while other infrastructures usually are only passive elements. This calls for special attention when HV cables are present in multi purpose tunnels.

Regarding the first consideration mentioned above, in this situation it was possible to meet all temperature limitations and gas/fire detection needs with using periodic, low speed ventilation. Think of not ventilating during daytime and ventilating during night time when the ambient air temperature outside the tunnel is lower. As can be seen in figure 8.7 2, by using such periodic ventilation regimes on clever settings the temperature inside the tunnel can be kept within very strict limitations while very accurate gas and fire detection is still possible.

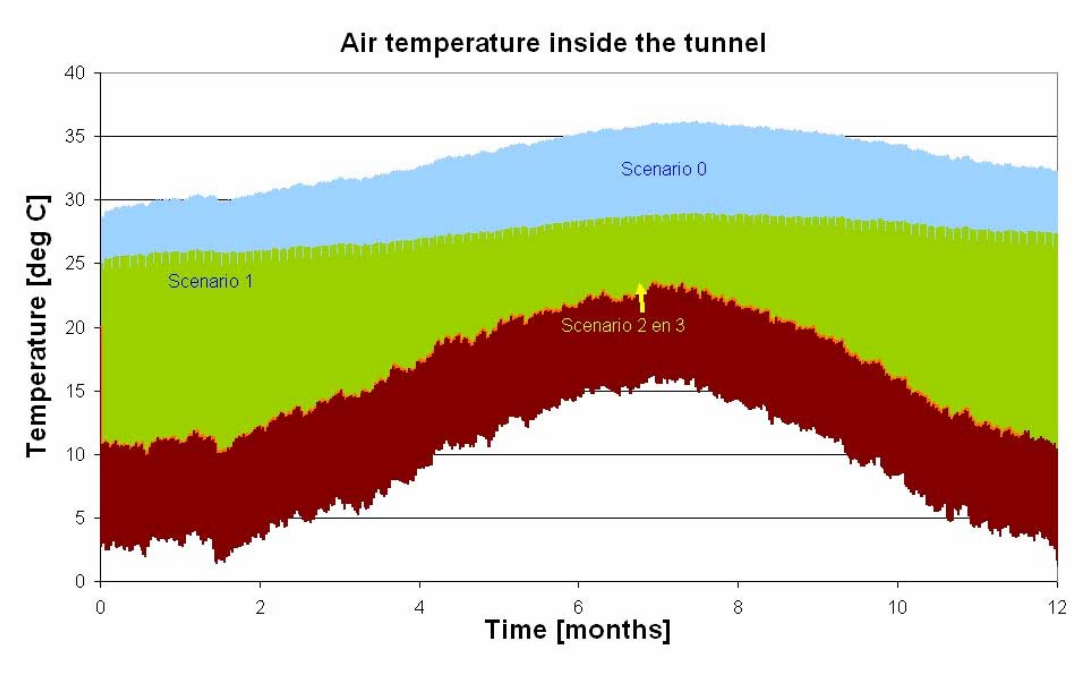


Figure 8.7.2: The air temperature inside the tunnel for different periodic ventilation regimes (during the daytime different than during the night).

Engineering the temperature in tunnels as above calls for a dedicated thermal model able to model both short and long time depended temperature effects. Heat will leave the tunnel partly radially via the tunnel walls and partly axially via the moving air. The models which have been made are used to engineer both the short term thermal behaviour (on a day to day basis) and the long term behaviour (which leads to a slowly increasing tunnel temperature over the years due to ventilating a deep tunnel with ambient air). The calculations show that a ventilation failure would cause an immediate temperature rise in the tunnel. Back-up ventilation and possibly an emergency power supply are needed to counter this temperature rise or the cable loadings would need to be reduced.

The cable positioning has a lot to do with the magnetic fields and subsequently with the induced voltages within the tunnel structure. This is discussed for the situation described above in section 5.1. The cable failure behaviour is also described elsewhere in the report.

There is a well established emergency action plan and safety procedures in place for visiting and working in the tunnel.

8.8. France

With the increasing development of the city centres and more generally substructure projects planned by public authorities' leads more and more to the use of underground structures.

During the project phase the opportunity to build a shared structure between different services is studied.

Despite a more complicated structure ownership and management, an existing or a future structure is often an opportunity to reduce installation costs.

Shared structures are almost always owned by the government or a public authority. Construction and operating costs for the different services are in general shared in proportion to the occupied space.

8.8.1 Shared Bridges in France

Bridges are located at places where crossings are difficult (sea channel, river, railway, etc) but necessary for transport or communication purposes. In order to minimise distances, transmission underground cables needs often to use a route located in the same area and facing the same crossing difficulties.

The cost of a proprietary structure is in general very expensive and solutions allowing the share of costs are particularly interesting. The installation of cables in bridges is probably the main field of application of HV cables installed in shared structures.

When possible, joints are avoided in bridges

Figure 8.8.1 An example of cables installed in troughing under a bridge in France

8.8.2 Shared Tunnels in France

The main applications where power cables are installed in a tunnel are encountered in the city centres. Voltage levels are in general medium and low voltage.

Location of HV cables in tunnels is not a very common situation in France. An exception is where the services sharing the tunnel are only electrical services (all voltage levels).

This is mainly due to historical reasons and to the fully integrated structure of the transmission and distribution company.

In terms of safety, minimum clearance distances between services are prescribed. Fault containment may be also prescribed when the structure is opened to people other than electrical utility employees.

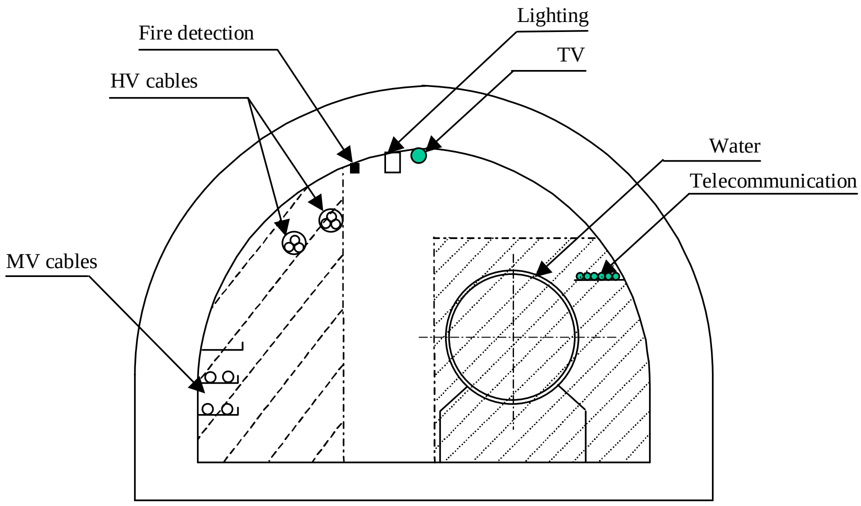


Figure 8.8.2 Cross section of shared tunnel in "La Defense" business area of Paris

The section of tunnel shown in figure 8.8.2 is a part of a tunnel area that belongs to a public authority in charge of the development of the “La Défense” business centre.

Operating services provided are:

- control access
- following of operations in the tunnel
- main equipment maintenance
- maintenance of the safety conditions

Safety equipment installed in the tunnel includes:

- entrance detectors
- telephone stations
- fire detectors
- lighting (normal and emergency)
- ground water pumps
- emergency exits
- safety signalling
- communication of safety equipment to a continuously manned central station.

In collaboration with the fire department, improvements of procedures for obtaining a more efficient smoke extraction have been achieved.

8.9. Singapore.

8.9.1 Shared Tunnels in Singapore

Singapore has many tunnels containing power cables at mixed voltages but as yet none in tunnels shared with other services. However, the Common Services Tunnel is a development that will contain HV power lines, telecom cables, water pipes. It will also provide for the installation of pneumatic refuse collection pipes. The 1.4-km stage one of the tunnel has been constructed at an estimated cost of about US$51 million. The 1.6-km second stage, currently under construction, is planned for completion in 2009 at an estimated cost of about US$86 million.

It is also proposed to construct a District Cooling Plant be that will supply chilled water through pipes in the tunnel to air-condition buildings in the Marina Bay area. The Singapore government is building the infrastructural base for Marina Bay, which includes the Marina Barrage, a Rapid Transit System and a new waterfront promenade and bridge.

8.10. South Korea.

8.10.1 Shared Bridges in South Korea

A special power cable system at 154 kV was installed in the long Yeong-Jong bridge in order to supply the electric power to Incheon International Airport. The length of cable in the bridge is 4.3km. The XLPE cable system was laid in the extension and contraction configuration in order to prevent cable damage from movement of the bridge.

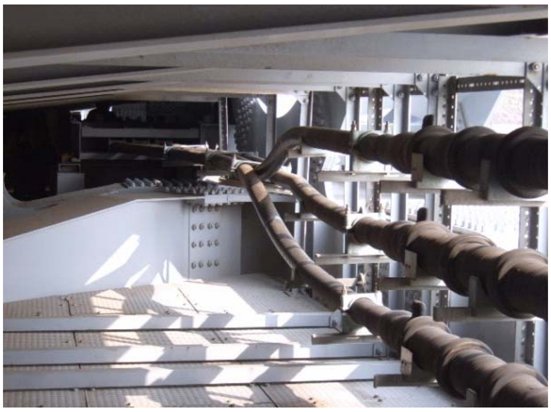


Figure 8.11.1 154kV power cables installed on Yeong-Jong bridge showing the snaking arrangement for bridge movement, joint installation and cable snaking in general.

8.10.2 Shared Tunnels in South Korea

In Korea, underground lines were constructed around the densely populated metropolitan areas because there would be a great deal of difficulty in constructing transmission lines. Shared tunnels have been mainly constructed in large-scaled new towns for the beauty of the city and the maintenance of roads.

In shared tunnels following facilities are usually included:

- Water supply and drainage pipes
- Air-conditioning and heating pipes
- Communication cables and optical fiber cables
- 22.9kV distribution cables
- 154kV and 345kV transmission cables

8.10.2.1 Yeouido Shared Tunnel, Seoul

Yeouido Shared Tunnel, which was built in 1978, is the concrete tunnel with 5 m width and 2.5 m height under the ground layer of 1.5 m depth. The partition was constructed in the middle of the tunnel to separate communication cables and power cables. It has a length of 6 km and an area of 35,000 square metres. Entrances for maintenance were established at 20 spots as a pathway.

At the upper side of the tunnel wall, communication cables including optical fibre cables were installed and power cables were located at the lower side of the wall. On the floor, water pipes and heat pipes go through. Also, there is a passage for the maintenance in the middle of the tunnel.

Figure 8.11.2 Examples of power cables and other services installed in Yeouido Shared Tunnel

8.10.2.2 Jungdong Multipurpose Tunnel, Incheon

Incheon is a metropolitan city with a high population density so the rate of underground cables is approximately 49 percent. The length of the tunnel is totally 53km and its shape is almost square box type (49km). The tunnel size differs according to the number of power cable lines.

Jungdong shared tunnel in Incheon has a length of 5.3 kilometres and each facility is isolated to minimise damage from fire. The cross section for the power cable allocation in this shared tunnel is a 2.1 m width and 2 m height.

Figure 8.11.3 Examples of power cables installed in Jungdong Shared Tunnel

The General Control System has been installed in tunnels for the safety, the economical comprehensive surveillance and the facility controls.

The following items are usually included in the General Control System;

- DTS (Distributed Temperature Sensor) System
- Fire detection and fire-extinguishing system
- Observation of not-allowed persons
- Remote control system of doors
- Surveillance of water level
- Control system for draining pump and ventilation
- Observation of oil pressure in OF cables

Fire detection and fire-extinguishing system are installed in these tunnels. Automatic fire detection lines are installed on top of the tunnel. The tunnel with OF cables has the special fire-extinguishing system and a firewall in the vicinity of all cable joints.

9 FUTURE TRENDS

With the increasing need for high capacity and long cable installations, there are many projects that present possibilities for cable installations in multi purpose structures. Examples include railway tunnels connecting Italy to France and Italy to Austria, EHV tunnels under urban areas or bridges over large expanses of water as in Japan.

For tunnels there is likely to be more installed in high density urban areas where commercial activity is dependant on free flowing traffic and roads and other traditional routes are already full of underground services. EHV cables in congested urban areas tend to be installed in special purpose tunnels. The trend is also towards installing HV cables and GIL in tunnels in areas of congestion. In Japan and South Korea this is already standard practice. In some communities this has progressed to organisations using sharing structures to install services. To get services through congested urban areas the preferred choice is horizontal directional drilling (HDD) for single services or tunnels with minimal or no impact on the urban environment. The choice of HDD is limited by length, bending radius and the ground conditions. A tunnel being a structure also offer a higher level of physical protection compared with burying cables. Changes to Occupational Health and Safety (OH&S) legislation in some countries has increased the expense of tunnel usage as controls have to be built into the structure or provided to workers entering what maybe classified as a confined space.

For bridges it is an opportunity for cable installation cost savings, particularly as construction and operation costs increase. Somebody else's bridges have always provided an attractive option for crossing a physical obstacle such as waterways provided the bridge has the strength to carry the additional weight. To cross waterways they can provide an environment that is less threatening or less unsightly than alternatives such as submarine cables or overhead installations although the alternative consideration is likely to be HDD

Other shared or multi purpose structures tend to be purpose specific limited to their own unique opportunities and constraints. Consideration has been given by some to installing HV cables in pipelines and drains or sewers. The issues involved have not been specifically covered in this document

We may build shared or multipurpose structures to last up to one hundred years but the organisations that manage and maintain those structures can change. It is therefore essential that we have systems in place to protect the ongoing use of and the access to these structures and the assets they protect.

By way of an example: in 1956 single core 33kV Armoured Aluminium Sheathed IP Gas Cables were installed in a tunnel with sewer pipes and a water pipe. The multiple services and tunnel were at the time owned by one government organisation. The cables were laid on the floor beside the water pipe. Some 25 years later the water main was removed and asbestos troughing containing telecommunications cables was installed. This trough pushed the cables against the support columns for the sewer and impeded the tunnel's drainage, which over the years allowed the armour wires to corrode and the cables deteriorated. The original owner of the tunnel and power cables had since been split into two separate organisations with the tunnel ownership going with the water utility. The access to the tunnel became difficult due to confined space entry requirements and the fact that the cables were pressurised was seen as a problem by the tunnel owner. The tunnel is in need of major refurbishment and after 51 years the cables were abandoned in 2007. However, they could not be removed from the tunnel until the asbestos cement telecommunications trough is removed. As the power cables remain in the tunnel the electricity utility may still be liable for their removal and tunnel refurbishment costs.

10 REFERENCES

1. K. Hirose et al "Development of Installation Techniques for a 500kV Oil Filled Cable on a Long Span Suspension Bridge", 80SM 557-9, IEEE PES Summer Meeting, Minneapolis, July 1980
2. R Benato, M Bernocchi, V Capgras, C Fourment, " Design of the Cables Inside LTF Tunnel", Report TENP2WP2.2. of Studies for a new Interconnection between France and Italy: Integration of Electricity and Rail Transport in the Lyon-Turin High Speed Railway French-Italian Tunnel Decision Reference: C(2006)2928 2005-E204/05-TREN/05/TEN-E – S07.59331.
3. R Benato, E M Carlini, C Di Mario, L Fellin, A Paolucci, R Turri, "Gas Insulated Transmission Lines in Railway Galleries", IEEE Trans. on Power Delivery, Vol. 20, Issue 2, April 2005, pp. 704-709.
4. R. Benato, et al, "Italy-Austria GIL In The New Planned Railway Galleries Fortezza-Innsbruck Under Brenner Pass", Proc. of CIGRÉ 2006, Paper B1-304, August-September 2006.
5. R. Benato, D. Capra, R. Conti, M. Gatto, A. Lorenzoni, M. Marazzi, G. Paris, F. Sala, "Methodologies to Assess the Interaction of Network, Environment and Territory in Planning Transmission Lines", Proc. of CIGRÉ 2006, Paper C2-208, August-September 2006.
6. R. Benato, M. Del Brenna, C. Di Mario, A. Lorenzoni, E. Zaccone, " A New Procedure to Compare the Social Costs of EHV-HV Overhead Lines and Underground XLPE Cables", Proc. of CIGRÉ 2006, Paper B1-301, August-September 2006.
7. W. Boone, F. De Wild, "HV power cables installed in multi purpose tunnels, a challengeable option!", '07 JICABLE, PAPER A2.6, pp. 66-70.
8. R. Benato, "EHV XLPE cable lines: calculation of EMF", Document name: TENP2WP2.2 Part b), in the framework of the Ten-Energy Programme, Contract Reference: TREN/2002/5.7100/Z/02-006, Contract Title, Studies for a new 380 kV transmission line between Italy and Austria through the Brenner Pass: Integration of Electricity and Rail Transport in Tunnel.
9. C.G. Henningsen, K.B. Müller, K. Polster, R.G. Schroth, "New 400 kV XLPE Long Distance Systems, Their First Application for the Power Supply of Berlin", Cigré 1998, Paper 21-109.
10. R Granadino, M Portillo, J Planas, F Schell, "Undergrounding the First 400kV Transmission Line in Spain using 2500mm² XLPE Cables in a Ventilated Tunnel: The Madrid "Barajas" Airport Project" Jicable 2003 Page 9
11. S. Sadler, et al, "1600 MW Electrical Power Transmission with an EHV XLPE cable system in the underground of London", Proc. of CIGRÉ 2004, Paper B1-108, August-September 2004.
12. R. Benato, "Multiconductor Cell Analysis Of Power Cable Steady State", Proc. of JICABLE 2007, Paper N° C.5.2.9., pp. 707-712, Versailles, France, 24-28 June
13. A. Bolza, F. Donazzi, P. Maioli, "Campi elettrici e magnetici: possibilità offerte dagli elettrodotti in cavo", Proc. of "ELETTRODOTTI e TERRITORIO", AEI CONFERENCE, Padova 22/12/2000 (in Italian).

14. P. Maioli, E. Zaccone, "Passive Loops technique for electromagnetic fields mitigation: applications and theoretical considerations", '07 JICABLE, PAPER A8.4, pp. 231-236.
15. R. Benato, "Electromagnetic interference and compatibility between the railway supply system and the transmission system HVDC: computation of static magnetic fields generated by HVDC system", Report TENP2WP2.3. of Studies for a new Interconnection between France and Italy: Integration of Electricity and Rail Transport in the Lyon-Turin High Speed Railway French-Italian Tunnel Decision Reference: C(2006)2928 2005-E204/05-TREN/05/TEN-E – S07.59331.
16. CCITT, "Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines". 1989, Geneva.
17. P. Van Hees and J. Axelsson, SP Sweden, S. J. Grayson and A. M. Green, H Breulet, U Vercellotti, "Assessing the fire performance of electric cables (FIPEC)", 2000.
18. R. Benato, M. Bernocchi, A. Dallago, V. Capgras, " Fire assessment of HVDC cables inside the Turin-Lyon gallery", Report TENP2WP2.5. of Studies for a new Interconnection between France and Italy: Integration of Electricity and Rail Transport in the Lyon-Turin High Speed Railway French-Italian Tunnel Decision Reference: C(2006)2928 2005-E204/05-TREN/05/TEN-E – S07.59331.
19. R. Benato, A. Dallago, "Survey on high pressure vessels international standards and fire assessment of transmission line in pilot tunnel", Report TENP3WP3.5, in the framework of the Ten-Energy Programme, Contract Reference: TREN/2002/5.7100/Z/02-006, TITLE "Studies for a new 380 kV transmission line between Italy and Austria through the Brenner pass: Integration of Electricity and Rail Transport in Tunnel", 2003-2005.
20. C. Philippczyk, et al,"Fire Hazard of MV/HV cables installed in tunnels", '07 JICABLE, PAPER N° A6.4, pp. 174-179.
21. D. Dhupil, et al, "Choices of flame retardant materials for cables with improved behaviour in fire", '07 JICABLE, PAPER N° B3.5, pp. 377-382.
22. F Donazzi, R Gaspari, B A Cauzillo, L Lagostena,O Bosotti, W Mosca, "Research on the performance of 400 kV extruded cable system under short circuit conditions", CIGRÉ 1996, Paper 21-205, Paris 1996.
23. R Benato, A Paolucci, “Operating Capability of Long AC EHV Transmission Cables”, Electric Power Systems Research, Vol. 75/1, July 2005, pp. 17-27.
24. R Benato, A Paolucci, "Operating capability of ac EHV mixed lines with overhead and cables links", Electric Power System Research/, Vol. 78/4, April 2008, pp. 584-594.
25. Cigré WG 21-8, 1992, "Calculation of temperatures in ventilated cable tunnels", Electra No. 143, August 1992, pp 39-59.
26. Cigré WG 21-8 1992, "Calculation of temperatures in ventilated cable tunnels, second part", Electra No. 144, October 1992, pp 97-105.
27. E Dorison, etal, "Current rating of cables installed in tunnels", Jicable 2003, paper C.8.1.6.
28. J M Mendez, J Monteys, “Design of Power and Communication Cable Installations to Minimize Interference in Tunnels”, Cables in Tunnels (Ref. No. 2000/070), IEE Seminar, 9 May 2000 Page(s):6/t-6/6

29. G Lucca, "Per Unit Length Parameters of a Multiconductor Line with Earth Return Inside a Tunnel", Electromagnetic Compatibility, IEEE Transactions on, Volume 42, Issue 1, Feb. 2000 Page(s):6 - 15
30. S M King, "Heat Transfer Calculation Methods for Cables in Tunnels", Cables in Tunnels (Ref. No. 2000/070), IEE Seminar, 9 May 2000 Page(s):1/4-1/19
31. D Lane; R Jefferies, "Tunnel Fires-Fire Precautions and Safety: a Discussion Paper" Cables in Tunnels (Ref. No. 2000/070), IEE Seminar, 9 May 2000 Page(s):3/1 -3/7
32. B Gregory, "Choices and Considerations for the Selection of Power Cables in Tunnel Installations", Cables in Tunnels (Ref. No. 2000/070), IEE Seminar, 9 May 2000 Page(s):8/1 -8/9
33. S White, G Williams, "Benefits and Experience of EHV Cables in Tunnels", Cables in Tunnels (Ref. No. 2000/070), IEE Seminar, 9 May 2000, Page(s):7/1-714
34. T Matsui, N Morimoto, H Suzuki, K Kumagai, Y Sakaguchi, H Higashi: "The Temperature Rising Characteristics of 275 kV Cables and GILs in Tunnels", Power Engineering Society Winter Meeting, 2002. IEEE, Volume 2, 27-31 Jan. 2002 Page(s):1354 -1359 vol.2
35. R Kadhim, D Kelsey, R Taylor, "Electromagnetic Compatibility between the Channel Tunnel Rail Link (CTRL) power supply and the highway agency (HA) communications system", EMC - It's Nearly Ail About the Cabling, IEE Seminar on (Digest No. 2003/10028), 22 Jan. 2003 Page(s):4/1 - 4/10
36. K L Cheok, "Electrical Installation in a 3 Km Long Cable Tunnel in Hong Kong" Installation Engineering Designing and Maintaining Successful Systems, 1988., Third International Conference on, 7-8 Jun1988 Page(s):8-12
37. S K Lee, S H Nam, J Y Hong, W K Park, H H Youn, "Real Time Ampacity Estimation System for 345 kV Transmission Cable Installed on Tunnel" Jicable 2003 Page 594
38. B Gregory, J Monteys, S Barris, J M Mendez, "Installation of 220 kV XLPE Cables in a Tunnel Installation whilst Minimising Electromagnetic Induction in Communication Cables" Jicable 1999 Page 148.
39. D Paulin, J L Legue, E Vasseur,J M Couquet, "550 kV Cables Laid in Tunnel for the Guangzhou Pumping Station" Jicable 1995 Page 22
40. A Friday, D G Roberts, A W Nichollls, "Development of Low Smoke and Fume Cables and Joints for the Channel Tunnel" Jicable 1991 Page 415
41. H R Bennett, J A M Gibbons, "275 kV XLPE Insulated Cables for Tunnel and Shaft Installations". Jicable 1987 Page 373.
42. Y Watanabe, K Yagisawa, S Hiyama, M Nishinoma, "Thermo-mechanical Behaviour of 275 kV XLPE Cable in Tunnel" Jicable 1987 Page 377.
43. J M Méndez, F R Grupo, B Gregory, J Monteys, "Influence of a Power Line on Weak Current Lines", Cigre 2000 36-202
44. Choog Chean Yin, "Undersea Cable Tunnel to Pulau Seraya", PUB Singapore, 7th CEPSI Conference, October 1988.
45. Gao Ping An, Zhang Yue-Xin, Lin Bang Jun, K Barber , R Horne, "Installation of 110kV XLPE Power Cable across the Xiang Jiang River Bridge", Cigre Regional Meeting October 1993.

46. V Rouillard, R Piechota, G Barnewall, K Barber, “Verification of Mechanical Support for Cables used on Bridge Structures at Dilation Points”, Jicable 2007.

47. EN 13501-1:2005 “Classification fire products and building elements - Part 1: Classification based on the results of tests of reaction to fire” Describes the classification procedure reaction to the fire of all construction products including products elements contained in the building.

48. M Fajdiga, K Barber, “Auckland CBD Crisis a Road to Recovery” D2000 Brisbane, Australia 1999.

49. N U Rahman, K Barber, “Auckland CBD Reinforcement Project” Cigre Paris, 2002.

50. N U Rahman, K Barber, “Challenge & Opportunities when installing HV cable in Australia and Sri Lanka”, Jicable 2007

51. Cigré TB 194 “Construction, Laying and Installation Techniques for Extruded and Self Contained Fluid Filled Cable Systems” WG21-17 October 2001

52. Cigré TB 104 “Magnetic Field in High Voltage Cable Systems” JTF 36-01/21, June 1996

53. Cigré TB 247 “Optimization of power transmission capability of underground cable systems using thermal monitoring”

54. Takashima, H.; Uenoya, T. “Cable Tunnel Management System” Japan Telecommunications Review, Oct. 1981, vol.23, no.4, pp. 347-55, Journal Paper.

55. Matsuura, F.; Sasaki, T.; Asao, T. “Study on Cable Tunnel Ventilation System” Review of the Electrical Communication Laboratories, Jan.-Feb. 1978, vol.26, no.1-2, pp. 222-32, Journal Paper

56. IEC 60287 “Electric cables - Calculation of the current rating” Parts 1-3

57. IEC/TS 60479. “Effects of current on human beings and livestock”, Parts 1-5

58. Cigré WG B1-26 “Earth potential rises in specially bonded screen systems”

59. Cigré TB 283 “Special Bonding of High Voltage Power Cables”

60. “Fire Test Summary #009/CT/JAN04, HI-FOG systems for cable tunnels”, 18 May 2004, Marioff Corporation Oy, Finland

61. Cigré WG21.08 “Calculation of Temperatures in Ventilated Cable Tunnels”, Part 1. Electra 143, August 1992 pp39-56 and Part 2 Electra, October 1992 pp96-105. Erratum : Calculation of temperatures in ventilated cable tunnels (Electra 144) Electra 209 p 47.

11 APPENDICES

11.1. TF B1-14 Shared Structures Report

Annual Report on CIGRE Task Force TF B1-14

CABLE SYSTEMS IN

MULTIPURPOSE OR SHARED STRUCTURES

24 July 2004

Task Force: Year of creation 2003 Expected year of disbanding 2004

In accordance with the decision at 2003 Mabula meeting, Task Force TF B1-14 was formed and members were appointed by national committees.

1. Membership

Susumu Sakuma (Convenor)	Japan
William Boone	The Netherlands
Yoshihisa Takahashi	Japan
Christophe Moreau	France
Colin Peacock (Secretary)	Australia

2. Scope of the Task Force

To report on whether a full Working Group (WG) on the Cable Systems in Multipurpose or Shared Structures is warranted. If justified: set up the terms of reference, scope of work, proposals for the structure, time schedule and deliverables for a full WG.

3. Working items of the Task Force Work Plan

3.1 Collect global information on trends toward underground cable systems in multipurpose tunnel or shared structures.

3.2 Collate global experience the installation of underground cable systems in multipurpose tunnel or shared structures.

3.3 Define the Terms of Reference for a future WG

3.4 Define the Scope of Activities for a future WG

3.5 Determine a Time Schedule, WG Structure

3.6 Define the expected Deliverables for a future WG

4. Task Force Activities

Task Force members exchanged and discussed information using e-mail. No meetings were held during the year.

5. Information on Cable Installations in Multipurpose or Shared Structures

TF members collected preliminary information on the tendencies toward and experience gained in the installation of cable systems in multipurpose or shared structures. A survey of member and neighboring countries was conducted using the questionnaire attached. The information received was summarized in the attached Table. The tabulated information was used to make recommendations for a future WG.

6. Conclusions of the Task Force

From the information received, the Task Force recommends the following for any future WG:

6.1 Terms of Reference for Working Group

6.1.1 Establish the appropriate terminology

6.1.2 Using a comprehensive questionnaire developed by the WG: collect comprehensive global information and experience on the use globally of multipurpose or shared structures for the installation of cable systems. The survey should not be limited to technical aspects such as type of cables, structure design, construction, installation, other infrastructure installed, mutual impacts, maintenance and operational constraints. It should also consider economical aspects, occupational health and safety aspects, administrative aspects, legal aspects and decision-making aspects.

6.1.3 Collate, summarise and review the information

6.1.4 Identify the issues that need to be considered when installing underground cable systems in multipurpose or shared structures.

6.1.5 Recommend guidelines for the practical application of for the installation of cables.

6.2 Scope of Work for Working Group

The Working Group should cover the following:

6.2.1 Medium, High and Extra High Voltage cable installations.

6.2.2 Solid (XLPE), fluid and gas insulated cable systems.

6.2.3 Multi-purpose tunnels and shared structures shared with piped services (water including hot or cooled, gas and sewage) and other utilities (other electricity services and tele-communications), Transport services (Roads, Rail and Subways).

6.3 Timeframe for the Working Group

Three (3) years from 2004 Paris meeting.

6.4 Structure of Working Group

It is recommended that the WG should include representatives from the following .

6.4.1 Power system utilities (Underground power cable utilities)

6.4.2 Providers of other services that are potential or existing users

6.4.3 Manufacturing

6.4.4 Consultants

6.4.5 Research and Academics

6.5 Deliverables

A final report submitted and discussed at 2007 SC B1 meeting.

11.2. TF B1-14 Shared Structures Survey

Questionnaire for

CIGRE Task Force TF B1-14

CABLE SYSTEMS IN

MULTIPURPOSE OR SHARED STRUCTURE

TF B1-14

No.	Question	Answer		
Q1	Does your country have multi-purpose tunnel or shared structure for underground power cable systems?	Yes	No	
Q2	If no to Q1, is there any future plan or future demand for that kind of systems?	Yes	No	
Q3	If yes to Q1, how many kilometers does your country have of such kind of tunnel or structure, approximately? Please indicate voltage level (MV, HV)	<5km	<50km	<500km
Q4	Why does your country or utility apply or intend to apply in the future this kind of structure? (What is the purpose to apply this kind of structure for underground power cable system in your country?) What is the expected major advantage of MT? What is the expected major disadvantage?			
Q5	By what kind of utilities are the structures occupied together with power cable utilities? Please remark. If others, please write in	Telecom	Gas	Water
		Sewage	Heat/Cold	

CIGRE Task Force TF B1-14

CABLE SYSTEMS IN MULTIPURPOSE OR SHARED STRUCTURES

Question Country :	France	Italy	Germany	Netherlands
1 Does your country have multi-purpose tunnel or shared structure for underground power cable systems?	Yes	No Yes No		
2 If no to Q1, is there any future plan or future demand for that kind of systems?		No		Yes
3 If yes to Q1, how many kilometers does your country have of such kind of tunnel or structure, approximately? Please indicate voltage level (MV, HV)	<50km HV; <500km MV	<5km	HV	
4 Why does your country or utility apply or intend to apply in the future this kind of structure? (What is the purpose to apply this kind of structure for underground power cable system in your country?) What is the expected major advantage of MT? What is the expected major disadvantage?	No advantage for electrical utility to share a structure (the interest for MT is generally shown by the people in charge of town planning). Advantages: • to use an existing structure at lower cost Disadvantages: • operating and safety constraints, repairing costs	At the moment multipurpose structures are not adopted in Italy. In some cases, this is forbidden by the Italian regulations, for instance gas pipelines cannot coexist with cable systems.	In Germany exist only a few multi-purpose tunnel for short length (crossing of rivers or streets etc.). Shared structures were not used up to now may be there were some feasibility studies Disadvantages: • the risk that the different systems influence each other is too high.	Advantages: • Avoid excavation in case of repair or extension
5 By what kind of utilities are the structures occupied together with power cable utilities? Please remark. If others, please write in.	Telecom; Gas; Water Sewage; Heat/Cold; Rainwater Railway; Compressed Air (very few); Other liquids (very few)	Nil	Telecom To put telecom cable and power cable together in a tunnel or trench is not new.	Telecom; Gas; Water Sewage; Heat/Cold

Question Country :	Japan	South Korea	Singapore	Australia
1 Does your country have multi-purpose tunnel or shared structure for underground power cable systems?	Yes	Yes	Yes (in progress)	Yes
2 If no to Q1, is there any future plan or future demand for that kind of systems?				No
3 If yes to Q1, how many kilometers does your country have of such kind of tunnel or structure, approximately? Please indicate voltage level (MV, HV)	<500km Voltage levels to 500kV (HV and MV)	Total : 85 km • 40 km for 154kV and 22.9kV (HV and MV) • 45 km for 22.9kV (MV) only	<5km 230kV and 22 kV (HV and MV)	<5km HV and MV
4 Why does your country or utility apply or intend to apply in the future this kind of structure? (What is the purpose to apply this kind of structure for underground power cable system in your country?) What is the expected major advantage of MT ?What is the expected major disadvantage?	<u>Advantages:</u> • Reduce the construction cost of structure for underground power cable systems. • Obtaining cable routes is easy. <u>Disadvantages:</u> • Management of entering the structure is complicated. • It takes long time to modulate a lot of matters on construction of structure. • The modulation with other companies on the cable construction schedule is complicated. • It is difficult for electric companies to reduce the cost of maintenance because the proper authorities decide the method of maintenance. • The prior investment is needed. • The electric companies must judge whether they adopt the MT or not according to the far future plan.	<u>Advantages:</u> • minimise road excavations and for efficient management of the underground cable <u>Disadvantages:</u> • the heavy cost of installation and maintenance.	The key driver is land constraint, particularly so in built-up area. <u>Advantages:</u> • ease of access to cables and its future maintenance • anticipated longer cable service life • elimination of cable damage by excavation work. <u>Disadvantages:</u> • high cost, • difficulty in obtaining consensus on cost apportioning, maintenance, responsibility and management of tunnel for the users, and • risk of simultaneous damage to multi-utility services.	Airport Runways with Road, Telecom gas and water Sewage under Brisbane river. Electrical supply authorities on common route in CBD <u>Advantages:</u> • sharing of construction and operating costs • cheap option for relocating services for infrastructure development <u>Disadvantages</u>: • difficult access to services in road tunnels • sharing and transfer of risk • apportioning costs of construction, operation and maintenance • control of access and emergency procedures • maintenance practices influenced by others • damage of assets by other services. • impact of future works
5 By what kind of utilities are the structures occupied together with power cable utilities? Please remark. If others, please write in.	Telecom / Gas / Water Sewage / Heat/ Cold / Subway (Rail)	11.2 / Heat/ Cold / 11.2	Telecom / District Cooling / Water	Road / Telecom / Water Elect Utilities / Sewage

Question Country:	United Kingdom		UK (NGC)	EDF (UK)	Spain		
1 Does your country have multi-purpose tunnel or s hared s tructure for u nderground power cable systems?	Yes Yes			No	Yes		
2 If no to Q1, is there any future plan or future demand for that kind of systems?	Yes No			No			
3 If yes to Q1, how many kilometers does your country hav e of s uch k ind of tunn el o r structure, ap proximately? Please indic ate voltage level (MV, HV)	Unknown Approx		. 50km (HV)	Approx. 50km (HV and MV)	<50 kM 220 kV (HV)		
4 Why do es y our country or utility apply or intend t o app ly in the f uture this k ind of structure? (What is the purpose to apply this kind o f s tructure for underground p ower cable system in your c ountry?) W hat is the expected ma jor a dvantage of MT? What is the expected major disadvantage?	More interest in the future, particularly as the e lectricity trans mission company (NGC) an d th e gas company (Transco) have merged Advantages: • lower costs. Disadvantages: • ensuring safety of both people and equipment. • Access can also be difficult. There have been big problems in the UK with p ower c ables in s hared r oad tunnels. It is dif ficult to g et permission to close the road tunnel and ac cess is onl y lik ely for a few hours in the mi ddle of the night. The utility wants rapid access in the event of fa ults a nd a tra nsmission cable c annot be r epaired in a few hours between 0100 and 0430		Urban e nvironments where NGT would consider i f t hey a re fu lly in demnified fo r carrying out work: • no longer practicable alternative, • access to su rface s everely restricted/congested. • existing overhead li nes if re moved (undergrounded) off er i mproved development opportunities. If the preferred solution is a tunnel Advantages: • Unrestricted a ccess to ci rcuit for maintenance/ inspection/repair. • Space in place for ad ditional f uture circuits. Disadvantages: • Circuit des ign ma y derate or n ot o ffer required circuit ratings. • Size of tu nnel n eeds to be c arefully considered, s hould allow f or future technologies (GIL)	Comments: • We also have some subways owned by th e local a uthorities th at c ontain some 11kV a nd t ele. c ables, t hese subways are used by all utilities.	Advantages: • Reduce e nvironmental i mpact a nd improve the installation procedures in the cities. Disadvantages: • Cost. • Fire risk		
5 By what k ind of utilities are th e s tructures occupied together with power c able utilities? Please remark. If others, please write in.	Road Telec	om	(Not stated)	Telecom	Telecom	Traffic light signals	Water

11.3. WG-08 Survey, December 2005

WG-08 Cable Systems in Multipurpose or Shared Structures. Questionnaire

Introduction:

WG-08 is interested in collecting information on shared structures used for the installation of high voltage cables (50kV and above).

The American Public Works Association defines a shared structure as "Any continuous structure containing one or more utility services which permits the replacement, renewal, maintenance, repair or revision of the service without the necessity of making excavation. This implies the structure is traversable by people and in some cases by some sort of technology" (American Public Works Association).

Your cooperation in taking the time to complete and return this survey is greatly appreciated by the Working Group. In accordance with CIGRE policy, all information will be treated in confidence and no specific companies or individuals identified without prior authorisation.

Question		Yes / No	Quantity	Comments
1	Does your organisation have power cable systems (50kV and above) in a multi purpose structure?			
2	Has your organisation installed power cable systems (50kV or above) in a multi purpose structure for other organisations?			

IF YOU ANSWERED YES TO Qu. 1 OR 2 : PLEASE COMPLETE ALL QUESTIONS. IF YOU ANSWERED NO TO Qu. 1 OR 2: PLEASE GO TO Qu. 40

Question 3			Comments:				
Types of Shared Structure	Number of structures	Total length of structure [km]	Maximum length of structure [km]	Cable circuit length installed [km]	Maximum voltage level of cable [kV]		Services shared with(eg water, telecoms, cable < 50kV Sewage Heat / Cooling Road Rail)
Tunnels					XLPE		
					OF		
					GP		
					Others		
Bridges					XLPE		
					OF		
					GP		
					Others		
Pipelines					XLPE		
					OF		
					GP		
					Others		

WG08 Shared Structure Survey Dec 05.doc

Types of Shared Structure	Number of structures	Total length of structure [km]	Maximum length of structure [km]	Cable circuit length installed [km]	Maximum voltage level of cable [kV]		Services shared with(eg water, telecoms, cable < 50kV Sewage Heat / Cooling Road Rail)
Others (Please define)					XLPE		
					OF		
					GP		
					Others		

	Question	Yes / No	Response
4	Were special features selected for high voltage cables in shared structures *(eg flame retardant serving)*? Please describe.		
5	What methods were used to install the cables in the structure(s)?		
6	How were the cables arranged in the structure *(eg trefoil, flat)*? Please describe.		
7	Please describe how the cables were installed *(eg racks, direct buried)*? Please describe		
8	If not buried, what type of support structure was used?		
9	Are the cable support structures earthed?		
10	Are the cable snaked? If yes, please describe how.		
11	Was allowance made for the inclusion of cable joints in / on the structure? Please describe.		
12	Are any special precautions taken at joint locations? Please describe		
13	Are the cable circuits cross bonded? Please describe cross bonding method(s) used.		
14	What is the maximum sheath voltage allowed for within the structure?		

	Question	Yes / No	Response
15	What precautions are taken to prevent transferred and induced voltages on other services sharing the structure?		
16	Are the cable support structures earthed? Please describe how.		
17	Were measures taken to limit emf?		
18	How many are publicly owned structures? (number please)		
19	How many are privately owned by others? (number please)		
20	Who planned the structures (*eg other user, contractor engaged by you, owner, Govt etc*)?		
21	Who designed the structures(*eg other user, contractor engaged by you, owner, Govt etc*)?		
22	Who built the structures (*eg other user, contractor, contractor engage by you, owner, Govt etc*)?		
23	How were construction costs shared?		
24	How are the structures managed (*eg jointly, owner, one Govt.)*?		
25	How are the structures maintained(*eg by owner, shared service contract etc*)?		
26	How are operating costs shared?		
27	Who manages the emergency response plan?		
28	How is access controlled?		
29	What is the design life of the structures?		
30	Are barriers provided between services? Please describe		
31	What other protection against cable damage is provided?		
32	Are special measures are undertaken when people are working in proximity to the cable circuits(*eg protective barriers on cables, standby person provided, circuits de-energised)*? Please describe		

	Question	Yes / No	Response
33	Do you take any precautions to limit the impact of cable systems on people and other services? Please describe.		
34	Is Distributed Temp Sensing (DTS) used and for what purpose (eg cable rating, fire, cooling etc.)? Please describe		
35	Are fire protection systems provided?		
36	Are ventilation systems used?		
37	Is there lighting provided for tunnels?		
38	Did modifications have to be carried out to existing structures to use for cable installation? Please describe.		
39	Do you have a maintenance programme for the cable systems? Please describe and frequency *(eg 1 year)*		
40	Do you intend to use shared structures for future cable installations?	Maybe	*Reduced investment cost, reduced project time.*
41	Will you be obliged to use shared structures for future cable installations? Please indicate by who and reason	No	
42	What do you consider the advantages of shared structures?		*See q 40*
43	What do you consider the disadvantages of shared structures?		*Risk of common failure. More costly maintenance. Unclear responsibility*

11.4. WG B1.08 Survey Results

WG B1.08 Cable Systems in Multipurpose or Shared Structures. Responses for All Structures						
		Country 1	Country 2	Country 3	Country 4	Country 5
1	Length of power cable systems (50kV and above) in a multi purpose structures	1,547 km*cct	36T/L	Yes Ye	s Ye	s
2	Length of power cable systems (50kV or above) installed in a multi purpose structures for other organisations	No No		No No No		
3	Information on Cables installed					
	Tunnels					
	Number	Government owned: 294 Private participating corporation: 228	10		3	1
	Length of structure [km]	Government: 465 Corporation: 95	26		0,35	1,2
	Maximum length of structure [km]	Government: 16 Corporation: 8	5.2			1,2
	Cable circuit length installed [km]	Government: 947 Corporation: 273	89.252		2 x 0,40 in tunnel 2 x 5 in circuit	3,5
	XLPE	500 154			150 145	
	OF	275	154			
	GP		0			
	Others		0			
	Services shared with	Telecoms, Gas, Water, Sewage, Heat, Subway	No Response		Chloride, kerosene, nitrogen, CO2, sewage	Water and cable < 50 kV
	Bridges					
	Number	1091				4

	Country 1	Country 2	Country 3	Country 4	Country 5
Length of structure [km]	133				1,4
Maximum length of structure [km]	5				0,6
Cable circuit length installed [km]	315				15
XLPE	500				
OF	500				300
GP					
Others					
Services shared with	Telecoms, Gas, Water, Sewage, Rail, Expressway				Telecom and cable < 50 kV
Pipelines					
Number	0				
Length of structure [km]	0				
Maximum length of structure [km]	0				
Cable circuit length installed [km]	0				
XLPE	0				
OF	0				
GP	0				
Others	0				
Others Structures					
Number	1				
Length of structure [km]	4				
Maximum length of structur e [km]	4				

		Country 1	Country 2	Country 3	Country 4	Country 5
	Cable circu it le ngth in stalled [km]	12				
	XLPE	275		132		
	OF	0				
	GP	0				
	Others	0				
	Services shared with	Expressway		11kV and 33kV cables		
4	Special features selected for high voltage cables					
	Tunnels	Flame retardant serving or preventive tape against fire	Use the flame retardant cable in the shared structures	No No None		
	Bridges	Laying cables in ducts Laying cables in trough or cables with fire preventive tape space permits	N/C			None
	Pipelines	N/A	N/C			
	Others	None	N/C			
5	Methods used to install the cables					
	Tunnels	Hauling machine	Use the supports to install the cable	On trays	-Separate enclosure to other services. -Hanging from the steel construction provided in the tunnel.	The cables are laid on racks
	Bridges	Winch Winch and hauling machine if space permits	N/C			
	Pipelines		N/C			
	Others	Winch	N/C			
6	Cables arrangements in the structure					
	Tunnels	Trefoil (single cable)	Use the trefoil arrange	Trefoil	Trefoil	Trefoil

		Country 1	Country 2	Country 3	Country 4	Country 5
	Bridges	Single cable per a duct or three cables per duct Laying three cables flat in trough if wide space permits	N/C			
	Pipelines		N/C			
	Others	Single cable per a duct (Car tunnel)	N/C			
7	How the cables were installed					
	Tunnels	Direct buried	Use the hanger	Racks	Hanging from racks	The cables are laid on rack.
	Bridges	Ducts or troughing	N/C			The cables are either installed in the sidewalks or laid on an open shelf within the bridge construction itself.
	Pipelines	locations	N/C			
	Others	Direct buried in ducts	N/C			
8	If not buried, what type of support structure was used?					
	Tunnels	Metal supporter and trough for horizontal snaking Laying cables on wide surface supporter (cable tray?)	Use the angle and cylinder support	Cable trays	Steel construction	The cables are clamped to the rack.
	Bridges	Laying cables in trough if space permits	N/C			
	Pipelines	N/A	N/C			
	Others	N/A	N/C			
9	Cable support structures earthed	No No		No Yes		Yes
10	Were the cables snaked?					
	Tunnels	Horizontal Vertical for single cable	Cable diam every 6 metres	No	Yes	The cables were snaked when they were fixed to the rack.
	Bridges	Horizontal in trough (if space permits troughs)				
	Pipelines					
	Others					

		Country 1	Country 2	Country 3	Country 4	Country 5
11	Allowance made for the inclusion of cable joints in / on the structure					
	Tunnels	Space allowed for joint assembly	Yes	No joints as the cables are a short length only.	None None	
	Bridges	Space allowed for joint assembly				None
	Pipelines					
	Others	Space allowed for joint assembly				
12	Special precautions taken at joint locations	None	Widen the tunnel at joint locations	No	No need, there are no joints in the tunnel	N/A
13	Cable circuits cross bonding method					
	Tunnels	Cross bonded (single cable)	-Cross bond is used in a long-range transmission line to reduce sheath voltage. -3 phases are earthed after transposed	No None		None
	Bridges	Cross bonded (single cable), no earth in bridge				None
	Pipelines	N/A				
	Others	Cross bonded (single cable)				
14	Maximum sheath voltages allowed for within the structure					
	Tunnels	50V 100V		65V None		
	Bridges	50V				
	Pipelines	N/A				
	Others	50V				
15	Precautions are taken to prevent transferred and induced voltages on other services sharing the structure					
	Tunnels	Twisted at joints location	None	No precautions	Keeping distance from the other services	
	Bridges	Twisted at joints location				
	Pipelines	N/A				
	Others	Twisted at joints location				
16	Earthing of cable support structures					

		Country 1	Country 2	Country 3	Country 4	Country 5
	Tunnels	None None		None Yes		Connected to the earth conductor.
	Bridges	None None		None Yes		Connected to the earth conductor.
17	Measures taken to limit emf	None None		None None None		
18	Number of publicly owned structures					
	Tunnels	3 governments - National - Prefecture - City	All		2	5
	Bridges	5 - Government (National, Prefecture, City) - Expressway Company Limited - Public Corporation				
	Pipelines					
	Others	City government (1)		None		
19	How many are privately owned by others? (number please)	N/A 0		None	3	0
20	Who planned the structures					
	Tunnels	Owner - Government or Participating corporation	Government	Utility	Government owned company (Rotterdam Port Authority)	Owner
	Bridges	Government- Expressway Company Limited- Public Corporation				
	Pipelines	N/A				
	Others	Owner Government				
21	Who designed the structures					
	Tunnels	Owner - Government or Participating corporation	Government	Utility	The tunnel was designed by a contractor of the Rotterdam Port Authority . The cable infrastructure is designed by a contractor of ENECO	Owner
	Bridges	Government- Expressway Company Limited- Public Corporation				
	Pipelines	N/A				
	Others	Owner Government				
22	How the structures were built					

	Country 1	Country 2	Country 3	Country 4	Country 5
Tunnels	Owner - Government or Participating corporation	Government	Contractor	By contractor of the Rotterdam Port Authority The cable infrastructure was built by a contractor of ENECO	Owner
Bridges	Bridge by government (Duct by private corporation) Bridge by Expressway Company Limited or Public corporation (trough etc. by private corporation if width space permitted)				
Pipelines	N/A				
Others	Owner Government				
23 How construction costs are shared					
Tunnels	Government: share of total expense by the ratio of the cost for each to independently construct a tunnel Private: share at the ration of the space needed by each corporation.	Construction costs were shared at a occupancy rate of inside space in the shared structures	Utility	The cost of the tunnel are shared with a entrance fee per user, depending on the cross section of the service	
Bridges	Bridge by Government, Expressway Company Limited, Public Corporation (share of the additional cost of the structure by the addition of weight by ducts and cables etc. of each corporation). - Duct and trough etc. by private corporation				
Pipelines	N/A				
Others	Government (share of the cost by participating corporation with conference in advance)				
24 How the structures are managed					
Tunnels	Owner - Government or Participating corporation	Government	Utility	Rotterdam Port Authority manages the tunnel	Each owner is responsible for own installation.

		Country 1	Country 2	Country 3	Country 4	Country 5
	Bridges	Owner - Government, Expressway Company Limited or Public Corporation				
	Pipelines	N/A				
	Others	Each corporation				
25	How the structures maintenance is managed					
	Tunnels	Owner - Government or Participating corporation	Government	Utility	Port Authority maintains the tunnel	Owner
	Bridges	Owner - Government, Expressway Company Limited or Public Corporation				
	Pipelines	N/A				
	Others	Each corporation				
26	How operating costs are shared					
	Tunnels	Government: Government and participating corporation Private: Each corporation	Each operating division shares its costs.	Utility	Yearly fee	
	Bridges	Bridge by Government, Expressway Company Limited or Public Corporation (owner) and ducts troughs etc by private corporation.				
	Pipelines	N/A				
	Others	Each corporation				
27	Management of the emergency response plan					
	Tunnels	Government: Government Private: Each corporation	Government	None	Rotterdam Port Authority	
	Bridges	Government, Expressway Company Limited or Public Corporation				
	Pipelines	N/A				
	Others	By each corporation				
28	Control of access					

		Country 1	Country 2	Country 3	Country 4	Country 5
	Tunnels	Government: Government Private: Each corporation	Entrance procedure controlled by Shared Structure Administrator	No control	Rotterdam Port Authority	Personnel with permission to enter have key.
	Bridges	By each corporation				
	Pipelines	N/A				
	Others	Government				
29	Design life of the structures					
	Tunnels	Government: 75 years or above Private: 25 years or above	50 years	No design life	Unknown for the tunnel. The standard life span of a cable connection, 40 years	50 years
	Bridges	25 years or above				
	Pipelines	N/A				
	Others	25 years or above				
30	Type of barriers between services					
	Tunnels	Concrete	Yes	None	Yes, a full separation wall exists between the cables and the other services	None
	Bridges	None				
	Pipelines	N/A				
	Others	Concrete				
31	Other protection against cable damage provided					
	Tunnels	Some 110kV or above cables are protected	The cable is also installed at a separate space.	None None		
	Bridges	-Laying the cables in ducts which are installed on the bridge. -Laying cables in a trough covered by metal grating where space permits				
	Pipelines	N/A				
	Others	Duct laid				
32	Special measures are undertaken when people are working in proximity to the cable circuits					

	Country 1	Country 2	Country 3	Country 4	Country 5
Tunnels	None	Monitor provided at the site. (Standby person provided)	None	None	Standby person when the work starts. Later when necessary.
Bridges	None	Monitor provided at the site. (Standby person provided)	None	None	Standby person when the work starts. Later when necessary.
Others	None		None	None	Standby person when the work starts. Later when necessary.
33 Precautions taken to limit the impact of cable systems on people and other services					
Tunnels	Some 110kV or above cables are protected	The cable is also installed at a separate space.	None	None other than the separation wall	Personnel with permission to enter have key.
Bridges	-Laying the cables in ducts which are installed on the bridge. -Laying cables in a trough covered by metal grating where space permits				
Pipelines	N/A				
Others	Duct laid				
34 Use of Distributed Temp Sensing (DTS) and purpose	None	None	None	None	Distributed temp sensing for cable rating.
35 Fire protection systems provided					
Tunnels	By structure owner	The protection equipment of the spread of the fire. A fire detector, auto spread fire extinguish facility	None	A fire protection system is used in the tunnel. No extra systems are provided for the cable compartment	None
Bridges	None				
Pipelines	N/A				
Other	By owner structure				
36 Ventilation systems installed?					

		Country 1	Country 2	Country 3	Country 4	Country 5
	Tunnels	By structure owner	Yes	None	This system is used to cool the cable and prevent heating of the other services.	None
	Bridges	N/A				
	Pipelines	N/A				
	Others	By structure owner				
37	Lighting provided for tunnels?	By structure owner	Yes	None	Yes	None
38	Modifications have to be carried out to existing structures to use for cable installation?					
	Tunnels	Protection by mat etc. on the cables	No	None	The separation walls	
	Bridges	Protection by mat etc. on the cables if space permits				Modification of the sidewalk on two bridges.
	Pipelines	N/A				
	Others	N/A				
39	Maintenance programme for the cable systems?					
	Tunnels	Inspect all aspects of facilities every 3 to 6 years	The cable systems are maintained periodically by standard program of inspection	None	The ventilation is checked regularly, though the frequency is still to be determined. The cable itself is maintained as all other cables, i.e. a check of the condition at a planned shut down only.	Inspection once a year.
	Bridges	Inspect all aspects of facilities every 1 to 6 years				
	Pipelines	N/A				

		Country 1	Country 2	Country 3	Country 4	Country 5
	Others	Inspect all aspects of facilities every 6 years				
40	Intention to use shared structures for future cable installations					
	Tunnels	Yes	Yes	There will be a shared manhole for jointing 132kV , 33kV and 11kV cables soon	Only when there is no alternative solution	None
	Bridges	Yes				
	Pipelines	N/C				
	Others	Yes				
41	Obligation to use shared structures for future cable installations	None	Yes. in case of the same route	Depends on the local authority	By the port authority or municipal authorities at certain areas	Yes
42	Advantages of shared structures					
	Tunnels	-Acquisition for the cable route with ease. -Avoidance of many excavations on the same route by each utility	The economic benefit	No advantage to the utility, but it saves space for the local town planners	None	Share the routes for infrastructure.
	Bridges	Acquisition for the cable route with ease.				
	Pipelines	N/C				
	Others	Acquisition for the cable route with ease.				
43	Disadvantages of shared structures					

	Country 1	Country 2	Country 3	Country 4	Country 5
Tunnels	Government : -Procedure of access to Multipurpose tunnel to be owned by government with complicated. - Impossible permission to an urgent request of participating corporation due to adjust a construction of Multipurpose tunnel to be owned by government for a long time. - Difficulty of planning of cable routes ahead of 75 years.	Slightly inconvenient of access to the shared structures in relation to maintaining	The maintenance responsibility of the shared facility.	Fees, restrictions on infrastructure, lack of flexibility	Unequal needs for use and operation of the structures.
Bridges	Need for Expressway Company Limited or Public Corporation to accept in case of access to the bridge (if wide space like tunnel is permitted)				
Pipelines	N/C				
Others	Need for Government to accept in case of access to the tunnel				

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
1	Length of power cable systems (50kV and above) in a multi purpose structures	Many locations where services are installed within service corridors on road bridges. Length of each road bridge location is about 30metres.	Yes 6		2km	1
2	Length of power cable systems (50kV or above) installed in a multi purpose structures for other organisations	No Yes		No No No		
3	Information on Cables installed					
	Tunnels					
	Number	Nil. Proposed combined services tunnel		3 2 1		
	Length of structure [km]		150 kV 48.3 km total net-length 50 kV 43.5 km total net-length	7 1.8		0.062
	Maximum length of structure [km]		48.3 km	5.5		0.062
	Cable circuit length installed [km]			14	3	0.774
	XLPE				110	123
	OF		x	150		
	GP		x			
	Others			150 (EPR)		
	Services shared with			Telecom , water , gas	Water, cables < 50 kV	Not yet
	Bridges					
	Number	Many			2	
	Length of structure [km]	Many x 30			0.2	
	Maximum length of structure [km]	About 0.07km				
	Cable circuit length installed [km]				1.5	
	XLPE	230			110	

	Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
OF	400				
GP					
Others					
Services shared with	Gas pipe, water pipe, vehicular bridge, telecoms.			Water, telecom, cables < 50 kV	
Pipelines					
Number	Nil				
Length of structure [km]					
Maximum length of structure [km]					
Cable circuit length installed [km]					
XLPE					
OF					
GP					
Others					
Others Structures					
Number	Nil				
Length of structure [km]					
Maximum length of structure [km]					
Cable circuit length installed [km]					
XLPE					
OF					
GP					
Others					
Services shared with					

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
4	Special features selected for high voltage cables					
	Tunnels		HV-cables are normally layed in PE-ducts in concrete that are laid in the ground of the shared structure. Separate areas for the cable joints were built. For gas-pressure-cables gas sniffers were installed.	None	flame retardant system at joints and every 50 m on cables	Fire resistant covers
	Bridges	Generally, the cables sheath are either flame retardant taped or have flame retardant serving.				
	Pipelines					
	Others					
5	Methods used to install the cables					
	Tunnels		Pulling the cables in the ducts	Usual method	pulling	Manual
	Bridges	Direct /Bond pulling.				
	Pipelines					
	Others					
6	Cables arrangements in the structure					
	Tunnels		Trefoil in 2 on 2 combination	Flat on supports every 3.5m (o o o)	flat, vertically	Flat
	Bridges	Generally, in flat formation.				
	Pipelines					
	Others					
7	How the cables were installed					
	Tunnels		PE-Pipelines DN 163/150 per each cable	Direct buried	hot dip galvanized steel racks with short PE tubes	Racks
	Bridges	Laid direct or cleated on horizontal racks within the service corridor.				
	Pipelines					
	Others					

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
8	If not buried, what type of support structure was used?					
	Tunnels		PE-Pipelines DN 163/150		hot dip galvanized steel racks	Steel racks
	Bridges	With cable cleats on horizontal racks.				
	Pipelines					
	Others					
9	Cable support structures earthed	Yes. Yes.		Yes. Yes. Yes.		
10	Were the cables snaked?					
	Tunnels		No	Supports at 3.5m cable snaked 0.3m.	Yes fixed every 2.5 m	None
	Bridges	Generally they are not snaked.				
	Pipelines					
	Others					
11	Allowance made for the inclusion of cable joints in / on the structure					
	Tunnels	No joints.	No	No	Joint niches	There are no joints in tunnel
	Bridges					
	Pipelines					
	Others					
12	Special precautions taken at joint locations	N/A	Mechanical protection at the separate areas for the cable joints	No	Flame retardant system, fixation clamps	
13	Cable circuits cross bonding method					
	Tunnels		Yes/No -> It depends from the cable-plant. We have the system where the screen crossed out but also the system where the phases are crossed out.	Yes the usual	Cable sheath cross bonded at every 1/3 of circuit length	None
	Bridges	The cables are cross bonded but not on the bridges.				

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
	Pipelines					
	Others					
14	Maximum sheath voltages allowed for within the structure					
	Tunnels		10 kV	1kV	1kV	10 kV (testing)
	Bridges	Actual sheath voltage in operation is about 50V				
	Pipelines					
	Others					
15	Precautions are taken to prevent transferred and induced voltages on other services sharing the structure					
	Tunnels		The buildings of the shared structure have foundation groundings. All metallic things are grounded. The HV-Cables have an insulated jacket.	Earthing	distance	At this moment there are no other services sharing the structure
	Bridges	The power cable have aluminium sheath which are cross bonded and earthed. No cases of induce voltage interference were detected or reported.				
	Pipelines					
	Others					
16	Earthing of cable support structures					
	Tunnels		Yes	With earthing condoctor	By separate earth wire	With Cu wire
	Bridges	Metallic bridges are physically earthed via earth rods.	Yes	With earthing condoctor	By separate earth wire	With Cu wire
17	Measures taken to limit emf	Power cables are transposed in addition to X-bonding	None but we make calculations in the planning phase	None	Narrow arrangement, flat, trefoil	None
18	Number of publicly owned structures					
	Tunnels		Most	4 4		

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
	Bridges	Many locations. Generally all are publicly owned. One that is owned by SP PowerAssets, constructed across a canal (about 70metres long) has a gas pipeline install on it.				
	Pipelines					
	Others					
19	How many are privately owned by others? (number please)	1		0 0		
20	Who planned the structures					
	Tunnels		The Gov. with our support	Contractor engaged by us	Owner	Owner
	Bridges	Generally, the structures are planned by the user/ authorities.				
	Pipelines					
	Others					
21	Who designed the structures					
	Tunnels		The Gov. with our support	Contractor engaged by us	Owner	Contractor engaged by owner
	Bridges	Generally, the structures are designed by the user/ authorities.				
	Pipelines					
	Others					
22	How the structures were built					
	Tunnels		Contractor	Contractor engaged by us	Owner	Contractor engaged by owner
	Bridges	Generally, the structures are built by the authorities/user.				
	Pipelines					
	Others					

	Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
23 How construction costs are shared					
Tunnels		Used surface per user	By Space used	Costs participation depending on used space	N/A
Bridges	Generally no charges are levied, except in the planned building of an extensive combined services tunnel where SP PowerAssets are required to contribute towards the construction and maintenance cost. This cable tunnel has not been finalized.				
Pipelines					
Others					
24 How the structures are managed					
Tunnels		Government	Owner Owner Owner		
Bridges	User/authorities.				
Pipelines					
Others					
25 How the structures maintenance is managed					
Tunnels			Owner	Owner	Owner
Bridges	User/authorities.				
Pipelines					
Others					
26 How operating costs are shared					
Tunnels		Used surface per user	Usually no costs, if any, shared by owners	Owner	

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
	Bridges	Generally no charges are levied, except in the planned building of an extensive combined services tunnel where SP PowerAssets are required to contribute towards the construction and maintenance cost. This cable tunnel has not been finalized.				
	Pipelines					
	Others					
27	Management of the emergency response plan					
	Tunnels		Government	No emergency response plan	Owner	Owner
	Bridges	User/authorities.				
	Pipelines					
	Others					
28	Control of access					
	Tunnels		By Gov. (regristation by Handy is necessary)	By control operator	no public access	Owner
	Bridges	The cables installed within the service corridor of the vehicular bridge are protected by reinforced concrete slabs. No access controls. For cable installed on cable bridges, such bridges have barricades/fence to deter people from getting onto it.				
	Pipelines					
	Others					

	Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
29 Design life of the structures					
Tunnels		100 Years	No life design	100 years	50 years
Bridges	At least 99 years.				
Pipelines					
Others					
30 Type of barriers between services					
Tunnels		Each user has his assigned area. Every 200 m there is a barriers against fire.	None None None		
Bridges	Except for 18 whereby the cables are installed in trough like compartments.				
Pipelines					
Others					
31 Other protection against cable damage provided					
Tunnels			None	None	Thermic, distant
Bridges	Physical protections include covering with reinforced concrete slabs and / or cement bound sand. Legislation was passed to control works near HT cables/services.				
Pipelines					
Others					

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
32	Special measures are undertaken when people are working in proximity to the cable circuits	For HT cables installed on bridges, they are easily identified by the concrete slabs. Only manual means is allowed while working in the vicinity of HT cables. Legislatively, SP PowerAssets must be notified before works near HT cables may commence. SP PowerAssets thru its agent SP PowerGrid, would patrol the work sites involving HT cables.	None	Protective barriers on cables , circuits de-energised if required	Attention marks	Protective barriers, video control
	Tunnels					
	Bridges					
	Others					
33	Precautions taken to limit the impact of cable systems on people and other services					
	Tunnels		None	None	Access limited to service staff	Protective barriers, video control
	Bridges	N/A				
	Pipelines					
	Others					
34	Use of Distributed Temp Sensing (DTS) and purpose	DTS was installed on 230kV & 400kV cable from 1998 onwards to detect hot spots. There also initiatives to review the method of using these data for dynamic cable loading.	None	None	For test purposes	Cable rating
35	Fire protection systems provided					
	Tunnels		Yes	None	None	Yes.

	Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
Bridges	None				
Pipelines					
Other					
36 Ventilation systems installed?					
Tunnels		Yes	None	Natural ventilation	Yes.
Bridges	None				
Pipelines					
Others					
37 Lighting provided for tunnels?	N/A	Yes	Yes Yes Yes.		
38 Modifications have to be carried out to existing structures to use for cable installation?					
Tunnels		Cable trays	None	None	None
Bridges	None				
Pipelines					
Others					
39 Maintenance programme for the cable systems?					
Tunnels		Visual inspections, pressure-controls for the OF- and GP-cables	None	Every 6 months, visual check, dilatation	Twice a year
Bridges	DGA for oil filled cable – every 6 months or yearly (depends on results of DGA). Cable sheath test – every 2 years subject to network exigencies.				
Pipelines					
Others					

		Country 6	Country 7 (A)	Country 7 (B)	Country 7 (C)	Country 8
40	Intention to use shared structures for future cable installations					
	Tunnels	Yes but not with Gas.	Yes	Yes	Yes	Yes.
	Bridges	Yes but not with Gas.				
	Pipelines					
	Others					
41	Obligation to use shared structures for future cable installations	If service corridors on road bridges are available, it would save us cost to use them for cable installation.	If there is an shared structure the Gov. obligates all to use.	None	None	By public sector, less diggings
42	Advantages of shared structures					
	Tunnels	Shorter construction time, less disruption to traffic; no problem with cable easement	All the different mediums can be concentrated in a small area. The mediums are always accessible.	Cost reduction	Costs saving	Occupied less space, sometimes cheaper, prevent further diggings, easer cables replacements and maintenance
	Bridges					
	Pipelines					
	Others					
43	Disadvantages of shared structures					
	Tunnels	Requires pre-investment in structures & maintenance.	Price, cost of the Maintenance, limited place, the long planning and construction period	Restrictions due to property of the structures	No protection, possible interferences	Mutual influence (damage)
	Bridges					
	Pipelines					
	Others					

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
1	Length of power cable systems (50kV and above) in a multi purpose structures	More than 15 HPFF circuits in tunnel, and a few XPLE cables installed in PVC pipe.	7 4	(tunnels) Unknown bridges -	No About	50km
2	Length of power cable systems (50kV or above) installed in a multi purpose structures for other organisations	No No			No No	
3	Information on Cables installed					
	Tunnels					
	Number	3 1		4		
	Length of structure [km]		0.17	2.41		
	Maximum length of structure [km]		0.17	1.35		
	Cable circuit length installed [km]	It varies from a few hundred feet to few thousand feet	3 x 0.17 = 0.51 in tunnel. 3 x 0.6 = 1.8 total circuit length.	3.26		
	XLPE			150		63kV to 225 kV
	OF	115, 230 and 345kV (HPFF)				63kV to 225 kV
	GP					
	Others		Pipe Type 115 kV			HPOF
	Services shared with		Two other 115 kV pipe type cables (another electric utility), telecom	Water, telecom, LV and MV cables, fuel oil		Cable < 50kV
	Bridges					
	Number		3			
	Length of structure [km]		0.05 0.02 0.04 Total 0.11 km			
	Maximum length of structure [km]		0.05			
	Cable circuit length installed [km]		2 x 0.11 = 0.22 in bridges Total circuit length 2x 14.5= 29 km			
	XLPE			150		63kV to 225 kV

	Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
OF		115 kV			63kV to 225 kV
GP					63 kV
Others		Pipe Type 345 kV			HPOF
Services shared with		Electric distribution, gas, telecom, water	Water, telecom, LV and MV cables, …		Road, railway, telecom, gas, water, heating, rainwater
Pipelines					
Number	A few				
Length of structure [km]					
Maximum length of structure [km]					
Cable circuit length installed [km]					
XLPE	115KV and 138KV				
OF	115kV 230 and 345KV				
GP	138KV				
Others					
Others Structures					
Number		3			Underground Carpark
Length of structure [km]		0.03 0.05 0.03 0.11 Total			
Maximum length of structure [km]		0.05			
Cable circuit length installed [km]		2 x 0.11 = 0.22 km in casings 2x10.9 = 21.8 km total circuit length.			
XLPE					225 KV
OF					
GP					
Others		Pipe Type 345 kV			
Services shared with		Water			Water, sewage, cable < 50kV, gas

	Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
4 Special features selected for high voltage cables					
Tunnels		Not for the cables themselves.	Flame retardant serving for cables inside tunnels (study case per case)		Confining when the structure is opened to people (other than electrical utility employee)
Bridges		Not for the cables themselves.			
Pipelines					
Others					
5 Methods used to install the cables					
Tunnels		Pre-tensioned steel pipe on brackets for pipe type cable in tunnel,	Synchronize power drive rollers + winch		Laying on the ground and then put on the racks, pulling in HDPE ducts, pulling with rollers
Bridges		Ductlines suspended from bridge steel for bridges,			
Pipelines					
Others		Ductlines or steel pipe in pipejackings.			
6 Cables arrangements in the structure					
Tunnels	Trefoil and flat.	In steel pipe for pipe type, in conduit for SCFF cables.	Trefoil (sometimes, flat in vertical shafts)		Trefoil arrangement or flat arrangement in shafts
Bridges		In steel pipe for pipe type, in conduit for SCFF cables.			
Pipelines					
Others		In steel pipe for pipe type, in conduit for SCFF cables.			
7 How the cables were installed					
Tunnels	HPFF cables are installed in rack. All the XPLE cables are installed in PVC pipe or direct buried 4-6 feet below grade with concrete on the top of the duct bank	On racks supporting steel pipes in tunnel,	Racks (generally) or troughs		Racks, direct buried, troughs, cable cradles, brackets (and straps), cleats (in shafts)

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Bridges		On hanger brackets supporting fibreglass ducts for bridge crossings,			
	Pipelines					
	Others		In conduits through pipejackings (casing backfilled with sand or cement grout after conduits installed).			
8	If not buried, what type of support structure was used?					
	Tunnels	Racks supported by tunnel wall	Steel racks in tunnels,	Metal		Racks, metallic holder structure (brackets)
	Bridges		Hanger brackets on bridges,			
	Pipelines					
	Others		Steel racks in casings.			
9	Cable support structures earthed	Yes.	Yes	Yes		Yes when metal parts
10	Were the cables snaked?					
	Tunnels		Snaking occurs in conduits and manholes.	Horizontal or vertical		Horizontal and vertical snake but mostly vertical snake. Alternation of brackets-straps and straps)
	Bridges		Snaking occurs in conduits and manholes.			
	Pipelines					
	Others		Snaking occurs in conduits and manholes.			
11	Allowance made for the inclusion of cable joints in / on the structure					
	Tunnels	There were splice joints and trifurcated joints inside the tunnel. Manholes are used for long XPLE cables.	Short enough that splicing occurs at manholes outside shared structures.	None		Especially in tunnels, avoided if possible in bridges. Joints out of line with the others, cleats installed on both sides of the joint
	Bridges					

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Pipelines		Short enough that splicing occurs at manholes outside shared structures.			
	Others		N/A			
12	Special precautions taken at joint locations		N/A	Policy to avoid installing joints inside structures		None
13	Cable circuits cross bonding method					
	Tunnels	None	Pipe type circuits are multipoint bonded within the pipe. SCFF cables are single point bonded.	Direct cross-bonding (without SVLs)		Not inside the structure
	Bridges					
	Pipelines	None				
	Others					
14	Maximum sheath voltages allowed for within the structure					
	Tunnels		Unknown	8 kV		Same as external to the structure (400 V in normal operating conditions)
	Bridges		Unknown			
	Pipelines					
	Others					
15	Precautions are taken to prevent transferred and induced voltages on other services sharing the structure					
	Tunnels	Use linked ground boxes and surge arresters aw well as parallel conductor between the two points.	Unknown. Pipe type cable pipes are grounded on both ends through polarization cells.	Earthing of racks		Earthing and minimum clearance distance with telecommunication cables
	Bridges		Unknown. Pipe type cable pipes are grounded on both ends through polarization cells.			
	Pipelines					

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Others		Unknown. Pipe type cable pipes are grounded on both ends through polarization cells.			
16	Earthing of cable support structures					
	Tunnels	Yes.	Support brackets attached to rebar structure in tunnel, and to ground rods.	Earthing between structure and concrete tunnel (each section of the racks separately)		Copper wire ground cable in parallel with the power cable. Each metallic support is connected to the copper wire cable
	Bridges		Support brackets in bridges are substantially made of fibreglass.			
	Pipelines	Yes				
17	Measures taken to limit emf		Not specifically to reduce EMF, but intrinsically EMF very low for pipe type, selected optimal phase arrangement for SCFF cables.	None		None
18	Number of publicly owned structures					
	Tunnels	0	All (1)	4		Majority (about 90%)
	Bridges		All (3)			
	Pipelines					
	Others					
19	How many are privately owned by others? (number please)	Many	3	0		Minority
20	Who planned the structures					
	Tunnels	HPFF Cable was installed in the 1960. XPLE cables were installed by cable contractor with the present of cable manufacturer representative.	Municipal Agency	Owner		Government or owner
	Bridges		State or Municipal transportation departments.			Government or owner

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Pipelines					
	Others		Cable Owner			Government or owner
21	Who designed the structures					
	Tunnels	Our Engineering Dept.	Municipal Agency	Contractor engaged by the owner		Government or contractor engaged by the owner
	Bridges		State or Municipal transportation departments			Government or contractor engaged by the owner
	Pipelines					
	Others		Pipejackings - Consulting Engineer retained by cable owner			Government or contractor engaged by the owner
22	How the structures were built					
	Tunnels	Contractors.	Municipal Agency	Contractor engaged by the owner		Government or contractor engaged by the owner
	Bridges		State or Municipal transportation departments			Government or contractor engaged by the owner
	Pipelines					
	Others		Pipejackings – Contractor retained by cable owner			Government or contractor engaged by the owner
23	How construction costs are shared					
	Tunnels	No.	Municipal Agency constructed tunnel, each utility installed their own facilities at their own cost.	Structures already built		Public funds or owner funds (depending who plans the structure)
	Bridges		State or Municipal transportation departments constructed bridges; each utility installed their own facilities at their own cost.	Structures already built		Public funds or owner funds (depending who plans the structure)
	Pipelines					

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Others		Pipejackings – Prorated among joint users based on approximate volume of installed facilities.			Public funds or owner funds (depending who plans the structure)
24	How the structures are managed					
	Tunnels		Municipal Agency manages tunnel.	Managed by the owner		The owner or contractor engaged by the owner
	Bridges		State or Municipal transportation departments manage bridges.	Managed by the owner		
	Pipelines					
	Others		Pipejackings: Owner manages.			The owner or contractor engaged by the owner
25	How the structures maintenance is managed					
	Tunnels	Owner and shared by other utilities.	Municipal Agency maintains tunnel, each utility maintains its own facilities.	Maintained by the owner		The owner or contractor engaged by the owner
	Bridges		State or Municipal transportation departments maintain bridges; each utility maintains their own facilities.	Maintained by the owner		
	Pipelines					
	Others		Pipejackings: Owner maintains casing, each utility maintains their own facilities.			The owner or contractor engaged by the owner
26	How operating costs are shared					
	Tunnels		Municipal agency controls access.	The utility has a key and warns the owner when he comes in/out the structure (or he has to ask the key to the owner)		Key, badge, recorded access authorization
	Bridges		State or Municipal transportation departments control access to bridges.			
	Pipelines					

	Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
Others		Pipejackings: Facilities are buried. Transportation Department or Railroad Owner controls access.			
27 Management of the emergency response plan					
Tunnels		Municipal agency controls access.	The utility has a key and warns the owner when he comes in/out the structure (or he has to ask the key to the owner)		Key, badge, recorded access authorization
Bridges		State or Municipal transportation departments control access to bridges.			
Pipelines					
Others		Pipejackings: Facilities are buried. Transportation Department or Railroad Owner controls access.			
28 Control of access					
Tunnels		Municipal agency controls access.	The utility has a key and warns the owner when he comes in/out the structure (or he has to ask the key to the owner)		Key, badge, recorded access authorization
Bridges		State or Municipal transportation departments control access to bridges.			
Pipelines					
Others		Pipejackings: Facilities are buried. Transportation Department or Railroad Owner controls access.			
29 Design life of the structures					
Tunnels	40 years	Nominal 40 years, but this is more for accounting purposes.	40 years		Between 70 to 100 years

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Bridges		Nominal 40 years, but this is more for accounting purposes.			Between 70 to 100 years
	Pipelines					
	Others		Nominal 40 years, but this is more for accounting purposes.			Between 70 to 100 years
30	Type of barriers between services					
	Tunnels		No barriers between facilities, but all are pipe type cable in steel pipe. Pipes are on opposite tunnel walls, by ownership.			Minimum clearance distances
	Bridges		Cables are in conduit. Bridge structural I-Beams between adjacent bays form de-facto barriers between utilities.			Minimum clearance distances
	Pipelines					
	Others		Pipejackings: Annulus between outer sleeve and utilities is filled with sand or concrete grout.			Minimum clearance distances
31	Other protection against cable damage provided					
	Tunnels	Alarm		Concrete slabs or metal cover or warning panels		Mechanical protection of cables (narrow passages, important links)
	Bridges					
	Pipelines					

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
	Others		Cathodic pr otection o n pipes within casings.			Mechanical protection of cables (n arrow pas sages, important links)
32	Special measures are undertaken when people are working in proximity to the cable circuits					
	Tunnels		Confined s pace en try procedures, standby person.	Presence of a supervisor from other utilities (only when cables are not protected)		Wooden made protective barriers, standby person
	Bridges		Cables are in conduit, so work is don e fro m adj oining manholes.			
	Others		Pipejackings – NA			Wooden made protective barriers, standby person
33	Precautions taken to limit the impact of cable systems on people and other services					
	Tunnels			Installation of c able c lamps (against short circuit), earthing cable, flame retardant serving		Minimum c learance dis tances Use of HDPE duc t ins tallation when c onfining is req uired (in order to minimize consequences of an i nsulation failure of the cable system)
	Bridges					
	Pipelines					
	Others					
34	Use of Distributed Temp Sensing (DTS) and purpose		None	Optical fibr es ins ide the cables but n ot u sed for the measurement of the temperature i n t he s tructure (only for det ection of hot spots)		None

	Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
35 Fire protection systems provided					
Tunnels		Ventilation controls.	None		Not in general (not dedicated to power cables)
Bridges		None			
Pipelines					
Other		N/A			
36 Ventilation systems installed?					
Tunnels	Yes . V entilation f ans are provided for the tunnels.	Yes	Yes		In gen eral n atural air movement
Bridges		No			
Pipelines					
Others		N/A			
37 Lighting provided for tunnels?	Yes. Yes.		Yes		Yes
38 Modifications have to be carried out to existing structures to use for cable installation?					
Tunnels			Yes - only the installation of racks		None
Bridges		Engineering review of effect of cable system on bridge rating, reinforce bridge structure if required, remove/modify existing bridge diaphragms, add hangers and conduits.			None
Pipelines					
Others					None

	Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
39 Maintenance programme for the cable systems?					
Tunnels	Perform r adiographic inspection. Perform dissolved gas a nalysis o n c able f luid yearly. Oil leak ed monitoring system on the terminations.	Varies by c able ty pe, but generally ins pect c able terminal equipment ev ery two months as par t o f s ubstation inspections, inspect manholes and c athodic protec tion systems annually.	Visual control once a year		None
Bridges					None
Pipelines					
Others					None
40 Intention to use shared structures for future cable installations					
Tunnels	No	Yes b ut no spe cifics a t th is time	No	No ac tual p lan, b ut no p olicy to avoid it	Depending on the opportunities al lowing to reduce cost installations
Bridges					
Pipelines					
Others					
41 Obligation to use shared structures for future cable installations	No	Possibly but no specifics at this time	Government or local authorities. Reasons: to bring together all the installations of the different utilities and to have less opening of public ways	In specific situations we might be obliged, but not in general. Only relevant in cities or in areas with beautiful scenery. Eg. bridges, tunnels.	No

		Country 9 (A)	Country 9 (B)	Country 10	Country 11	Country 12
42	Advantages of shared structures					
	Tunnels		May provide routing advantages (bridge for a water crossing, for example), economic advantages in some cases.	Shared costs, limit the length of the link (no link diversion)	Might be cheaper for the sum of systems. Only one excavation for more systems Easy extension and reinforcement of the utility system Better protection against third party damage	To use an existing structure at a lower cost
	Bridges					
	Pipelines					
	Others					
43	Disadvantages of shared structures					
	Tunnels		Maintenance of the shared structure could put the transmission facility at risk. Failure of a shared structure (bridge, tunnel) could result in extended outage. If the shared structure is maintained "by others", some loss of control in getting maintenance work done. Work practices/safety practices and commercial issues have to be agreed to by multiple parties.	Problems of maintenance, oversheath test (impossible without a conductive layer – graphite), dependant on the owner of the structure	Problems with failure situations: Possible not possible to get access to your own system; a break down of the structure can imply a multi utility break down. Problems with maintenance. Not on your own in planning maintenance, reparation or installation. Influence on and from other lines, pipes etc. (electrical influence, heat)	Operating, maintenance and safety constraints
	Bridges					
	Pipelines					
	Others					

WG B1.08 Cable Systems in Multipurpose or Shared Structures. Responses for All Structures

		Country13	Country 14	Country 15	Country 16	
1	Length of power cable systems (50kV and above) in a multi purpose structures	0.8km No		0.8km cct - tunnel 0.5km cct - bridge	>67km	
2	Length of power cable systems (50kV or above) installed in a multi purpose structures for other organisations	No No		No No		
3	Information on Cables installed					
	Tunnels					
	Number			5	37	
	Length of structure [km]			0.8 km	68	
	Maximum length of structure [km]				10	
	Cable circuit length installed [km]			4.5km	87	
	XLPE			132 kV	400 kV	
	OF	230kV		330 kV	220 kV	
	GP			0		
	Others			0		
	Services shared with	Telecom		Other HV Cables		
	Bridges					
	Number			1		
	Length of structure [km]			0.5 km		
	Maximum length of structure [km]			0.5 km		
	Cable circuit length installed [km]			0.5 km		
3	Information on Cables installed					
	Tunnels					
	Number			5	37	

	Country13	Country 14	Country 15	Country 16	
Length of structure [km]			0.8 km	68	
Maximum length of structure [km]				10	
XLPE					
OF			330 kV		
GP					
Others					
Services shared with			Water Main		
Pipelines					
Number					
Length of structure [km]					
Maximum length of structure [km]					
Cable circuit length installed [km]					
XLPE					
OF					
GP					
Others					
Others Structures					
Number					
Length of structure [km]					
Maximum length of structure [km]					
Cable circuit length installed [km]					
XLPE					
OF					
GP					
Others					

		Country13	Country 14	Country 15	Country 16	
	Services shared with					
4	Special features selected for high voltage cables					
	Tunnels	None		Bracket mounted 132kV XLPE cables have stainless steel sheaths with a flame retardant serving (oversheath)	Generally none but in ocasión cables have fire retardant serving and high screen area to improve EMC	None
	Bridges					
	Pipelines					
	Others					
5	Methods used to install the cables					
	Tunnels	Horizontally space and rack supported with wooden cable clamps		By conventional means and the use of a special hydraulic vehicle to install cables on wall mounted brackets	Hauling machine and pulley to push the cable into final position	
	Bridges			Conventional means		
	Pipelines					
	Others					
6	Cables arrangements in the structure					
	Tunnels	Horizontally spaced		Trefoil	Mostly trefoil except OF cables arranged in flat	
	Bridges			Trefoil		
	Pipelines					
	Others					
7	How the cables were installed					
	Tunnels	Racks		Direct buried and on wall brackets	Cables are laid on the tunnel floor and then lifted to final position	
	Bridges			Clamped in a self supporting steel mesh enclosure		
	Pipelines					
	Others					

		Country13	Country 14	Country 15	Country 16	
8	If not buried, what type of support structure was used?					
	Tunnels	Racks		Clamps on wall brackets	Generally metallic arms fixed to tunnel walls or suported on the floor.	
	Bridges			Clamps		
	Pipelines					
	Others					
9	Cable support structures earthed	Yes		Yes Yes		
10	Were the cables snaked?					
	Tunnels	Yes, approximately 3m between clamps with a 225mm offset		Horizontal with 3m between clamps and one cable diam. Offset	Generally strait but in some installations cables are snaked vertically if enough strait length is available.	
	Bridges			Horizontal		
	Pipelines					
	Others					
11	Allowance made for the inclusion of cable joints in / on the structure					
	Tunnels	Yes		Yes	Joint are made on places where space allows	
	Bridges			None		
	Pipelines					
	Others					

	Country13	Country 14	Country 15	Country 16	
12 Special precautions taken at joint locations	Special expansion clamps and fixed clamps were used. In the fixed clamp the cable clamps surrounds the cable while in the other type of clamp the hole is oval in shape and allows an opportunity for the cable to move (perpendicular to its axis) within the clamps.		None	In City B tunnels the HV joints are closed in anti explosion and anti fire box. Rest of joints are not protected.	
13 Cable circuits cross bonding method					
Tunnels	None		132kV - single point bonded (no joints in tunnel) 330kV - cross bonded (as part of longer circuits)	Yes. Either cross bonded or single point earthed (for short lengths). Cross bonding is done in a box provided with SVL's	
Bridges			Cross bonded		
Pipelines					
Others					
14 Maximum sheath voltages allowed for within the structure					
Tunnels	100V		150V Max	150V	
Bridges			150V		
Pipelines					
Others					
15 Precautions are taken to prevent transferred and induced voltages on other services sharing the structure					
Tunnels				No precautions except in some tunnels were the sheath has an increased area to reduce induced voltages on near metallic telephone wires	
Bridges					
Pipelines					

		Country13	Country 14	Country 15	Country 16	
	Others					
16	Earthing of cable support structures					
	Tunnels	#4/0 AWG PVC insulated 600V bonding cable runs from each end of the pothead for the cable ground		Yes	Every metallic arm is connected to the tunnel bare copper earth conductor provided. The earth conductor is grounded at discrete points along the tunnel	
	Bridges			Yes		
17	Measures taken to limit emf	None		Cables installed in trefoil	Cables are firmly cleated to the supporting arms	
18	Number of publicly owned structures					
	Tunnels	1		All	All are totally or partially municipality owned	
	Bridges			All		
	Pipelines					
	Others					
19	How many are privately owned by others? (number please)	0		none non	e	
20	Who planned the structures					
	Tunnels	State Hydro and Dept of Highways		TSO and Distributor	Owner	
	Bridges			Water Authority (existing structure).		
	Pipelines					
	Others					
21	Who designed the structures					
	Tunnels	State Hydro and Dept of Highways		TSO	Owner	
	Bridges			Water Authority with modifications by the TSO		
	Pipelines					
	Others					

	Country13	Country 14	Country 15	Country 16	
22 How the structures were built					
Tunnels	Dept of Highways		By the TSO's contractor	Owner	
Bridges			Water authority (existing structure) with modifications by TSO contractor.		
Pipelines					
Others					
23 How construction costs are shared					
Tunnels			Shared	In City M they used mostly already existing structures. In City B the consortium has shared cost according with volume used by each user.	
Bridges			Existing structure		
Pipelines					
Others					
24 How the structures are managed					
Tunnels			By an agreement	In City M the municipality, in City B a maintenance company was set up for that purpose.	
Bridges			By the Water Authority		
Pipelines					
Others					
25 How the structures maintenance is managed					
Tunnels			TSO	Manager is resposible	
Bridges			By Water Authority except for bits added by TSO		
Pipelines					
Others					

		Country13	Country 14	Country 15	Country 16	
26	How operating costs are shared					
	Tunnels			Shared	In City M the users pay a fee to the municipality that cover the operating costs. In City B that cost is shared among the user/owners	
	Bridges			Shared		
	Pipelines					
	Others					
27	Management of the emergency response plan					
	Tunnels			TSO	The owner or the management company	
	Bridges			Bridge owner		
	Pipelines					
	Others					
28	Control of access					
	Tunnels			Access controlled by the TSO and agreements with the Distributor sharing.	The management gives access. Entrance is monitored through CCTV. An electronic card and a key is required to get in.	
	Bridges			Secured separate access to area where cables are installed.		
	Pipelines					
	Others					
29	Design life of the structures					
	Tunnels			40 years		
	Bridges					
	Pipelines			40 years	Ignored	
	Others			Unknown		

	Country13	Country 14	Country 15	Country 16	
30 Type of barriers between services					
Tunnels	No		OFC buried in chases in the floor of the tunnel.	None	
Bridges			OFC installed in a specifically designed enclosure.		
Pipelines					
Others					
31 Other protection against cable damage provided					
Tunnels	None		Bracket mounted XLPE cables have a stainless steel sheath.	Fire proof paint or none	
Bridges			Cables in specifically designed enclosure with a metal barrier underneath (to protect against vandalism)and above.		
Pipelines					
Others					
32 Special measures are undertaken when people are working in proximity to the cable circuits					
Tunnels	The utility will demand they be notified and depending on the nature of the work will elect to either have a qualified Safety Personnel on site or de-energize circuit.		Use of standby person	Protections are provided if hard work are to be done in close proximity to the cables according to the opinion of the engineer in charge. Outages are programmed when the risk requires.	
Bridges			Cables segregated		
Others					

	Country13	Country 14	Country 15	Country 16	
33 Precautions taken to limit the impact of cable systems on people and other services					
Tunnels			EHV OFC buried in the floor of shared structure. Cable clamps and earthing on bracket mounted HV XPLE cables	None	
Bridges			EHV OFC installed in own segregated cage and clamped.		
Pipelines			N/A		
Others					
34 Use of Distributed Temp Sensing (DTS) and purpose	None		Yes optical fibres installed with all circuits. EHV cables continuously monitored for dynamic rating	DTS is provided in some circuits. There use depends of the circuit owner	
35 Fire protection systems provided					
Tunnels	No		DTS	Yes. Detection system is provided. No extinction system	
Bridges			None		
Pipelines					
Other					
36 Ventilation systems installed?					
Tunnels	Yes		Nil	In some tunnel forced ventilation and temperature control is used	
Bridges			Not required		
Pipelines					
Others					
37 Lighting provided for tunnels?	Yes		At entry ways only	Yes, emergency lighting provide as well	

		Country13	Country 14	Country 15	Country 16	
38	Modifications have to be carried out to existing structures to use for cable installation?					
	Tunnels	None		Tunnel designed for purpose.	Displace existing service to provide space when required	
	Bridges			Installation of a fabricated self supporting steel frame to secure and support the cables.		
	Pipelines					
	Others					
39	Maintenance programme for the cable systems?					
	Tunnels	Yes, jacket tests are done once every 5 years. The oil samples are taken every 3 years and verification of oil alarm tests are undertaken once every 3 months		Sheath testing every 10 years. The oil samples every 5 years and verification of oil alarm tests are undertaken once every 6 months	Visual inspection every half year or year	
	Bridges			As above		
	Pipelines					
	Others					
40	Intention to use shared structures for future cable installations					
	Tunnels	If required	No	If required or financially attractive.	Yes according with the news projects.	
	Bridges					
	Pipelines					
	Others					
41	Obligation to use shared structures for future cable installations	Will be dictated by public pressures and project economics	No	No obligation	Yes. The tunnel already exist and municipality obliges its use.	

	Country13	Country 14	Country 15	Country 16	
42 Advantages of shared structures					
Tunnels	Project Economics		Enabled access to site in CBD that was very difficult by conventional means. Greater protection from third party dig-ins. Capacity for future use.	No clear opinion comes out. Economic savings are the main advantage reported.	
Bridges			Enabled shorter and cheaper route with better profile for OF cables to be used at a reduced cost.		
Pipelines					
Others					
43 Disadvantages of shared structures					
Tunnels	Collateral damage and related consequences in the event of cable failure, and impact on priority of service restoration in emergencies		Risk of damage to bracket mounted cables by others working in the structure.	Any damage in cables will destroy other near cables. That is a serious burden if the damaged installation is strategic. Other disadvantages are fire risk, unclear responsibilities, damages risk, accessibility jeopardised etc	
Bridges			Reluctance of Water Authority to share the structure.		
Pipelines					
Others					