Multi-utility tunnels
Old-fashioned or Necessary?

an element of the wider

Analysis of Environmental Engineering Factors that create the Potential for Improving the Technical State of the Underground Infrastructure of Urban Areas,

which is the area of my interest.

1. INTRODUCTION

In 2000, the urban population of the planet exceeded 50% - see Figure 4.

Figure 5 presents the effects of such a large displacement of people from villages to cities.

It is considered that the number of people living in cities will rise, which is in line with the observations of the last decade. Hence it is said that the twenty-first century will be a period of the dynamic and unpredictable development of cities.

This will result in a greater than ever need to use the underground space in urban areas because of the need to not only put in such space the network infrastructure, but also the structures of communication and all kinds of technical objects – see Figure 6.

The effects of such development of cities in the future may look like the fantasy presented in - Figure 7.

Question? – Figure 8.

Today one of the main obstacles when implementing new investments are the elements of underground pipeline infrastructure.

Their poor technical condition and location makes the construction of underground tunnels, pedestrian crossings and underground garages difficult or even impossible – see Figure 9.

The next question? – Figure 10.

The first multi-utility tunnels were built in the late nineteenth century in London, Paris and Madrid – Figure11. In those cities, water pipes, electric cables and other networks were laid in large sewage collectors.

Later, multi-utility tunnels were used in this part of Europe in the 1960s and 1970s. A lot of multi-utility tunnels were built in Germany, the Czech Republic and Russia at this time. In Poland, the first multi-utility tunnel was built in 1978 in Wrocław. At that time most of the tunnels were built in open trenches as monolithic or prefabricated reinforced concrete structures and usually had a rectangular cross-section – see Figure 12. The construction of multi-utility tunnels in trenches caused very large communication obstacles, which were the biggest obstacle to their widespread use.

The development of trenchless technology and its dissemination have created new possibilities for building multi-utility tunnels. This is in order to meet the increasing demand for underground space in urban areas. In addition to the traditional approach of laying a network within multi-utility tunnels, there are advantages of using the tunnels for crossing rivers and other obstacles, as well as in the case of rebuilding the network infrastructure for the preparation of underground space for other functions (e.g., underground garages) – see Figure13.

The above considerations raise the need for a new approach to the problem of the widespread use of multi-utility tunnels in cities in order to expand their underground multi-functional infrastructure.

2. GENERAL REMARKS ON MULTI-UTILITY TUNNELS

The cross-section of multi-utility tunnels can be any shape. In the case of trenchless technology, the cross-sectional shape of the tunnel is the same as the cross-sectional shape of the boring machine, and is usually a circular cross-section - Figures 14 and 15.

Inside multi-utility tunnels all kinds of pipes and cables can be laid, i.e. water pipes, district heating pipes, sewer channels, power cables and telecommunication networks. The placing of gas pipes in multi-utility tunnels may not be permitted in every country.

Selected benefits resulting from the use of multi-utility tunnels are presented in Figure 16.

As you have seen - one of the most important advantages of multi-utility tunnels is the ability to control the technical condition of the networks, as well as the possibility to replace damaged elements without making excavations in streets.

This lowers the social costs of the cities, which in the event of a disruption of communication reach very high levels. Figure 17 shows a graph illustrating the levels of such costs for the biggest cities in Poland.

These costs are very high and rapidly increase with any additional difficulty in communication. Hence, technical solutions that to the largest extent reduce any inconvenience in transportation should be preferred. The solution to this is undoubtedly multi-utility tunnels.

The next very important problem are network failures and their consequences. In the case of networks lying directly in the ground, failure of sewage, gas or water pipes may cause extensive damage to the environment around the network that is often not possible to control. For example, a leak of a gas pipeline lying in the soil can result in a gas explosion in a nearby building due to gas penetrating into the ground without control (such an accident occurred in Warsaw in the 1970s). In the case of leakage of a gas pipeline lying in a multi-utility tunnel, failure is immediately signalled by sensors measuring the concentration of gas in the atmosphere inside the tunnel, and the pipeline is automatically closed.

Damage of a water pipe lying in the ground usually results in hydration of the land under a building or roadway, as occurred for example in Wroclaw (Poland), where such a failure resulted in the collapse of a road under the weight of a moving car – see Figure 18.

In the case of a water pipe failure in a multi-utility tunnel, leaking water is discharged to the internal drainage system and does not cause damage to the outside of the tunnel.

In contrast, failures of sewage systems located directly in the ground are not immediately noticed. Sewage leaking from the channel over a long period of time can sap neighbouring objects, causing damage to their structure. In the case of infiltration, drainage of the area occurs, which leads to excessive subsidence of buildings, roads, etc. When the sewer network lies in multi-utility tunnels it is possible to control the current state of the network and remove technical defects.

3. CASE STUDY OF MULTI-UTILITY TUNNELS

Multi-utility tunnel under the Vistula river in Warsaw

The tunnel under the Vistula river is an element of a siphon, which was built in order to transport sewage, and consists of the following elements - Figure 19:

- an input chamber located in the area of left-bank Warsaw,

- a multi-utility tunnel with an internal diameter of 4.5m placed under the Vistula river,
- two sewer pipes with a diameter of 1.6m placed inside the multi-utility tunnel,
- an output chamber located in the area of right-bank Warsaw, including a slide chamber, decompression chamber and coupling chamber.

From a hydraulic point of view, the basic element of a siphon is a system of two ducts made of steel pipes and pipes made of Glass Reinforced Plastic (GRP). From the starting chamber (beginning of the siphon) up to the entrance of sewers into the tunnel, the sewers are made of steel pipes. Further, i.e. inside the tunnel along a section of approx. 1.3 km, they are made of GRP pipes.

The tunnel is built under the Vistula River within an area covering two geomorphological units, i.e. an area of a denuded erosive and accumulative terrace and the Vistula Valley. Soil and water conditions alongside the route of the tunnel are not very changeable. The structure of the tunnel was made of reinforced concrete tubings using TBM technology– see Figure 20.

Figure 21 shows the view of the starting chamber during its preparation for making the tunnel, and Figure 22 shows the assembly works in the exit chamber.

3.2. The biggest multi-utility tunnel in the World – Figure 23

The main objective of this tunnel is to solve the problem of flash floods in Kuala Lumpur and also to reduce traffic jams.

Construction works started in November 2003 and were completed in January 2007. The total cost of the construction was 515.6 mil US $. The tunnel was constructed by 2 TBMs – Figure 24.

There are two components of this tunnel – Figure 25:

- the storm-water tunnel (length 9.7 km; diameter 13.2 m);
- and a motorway double deck structure tunnel (length 4 km; length of ingress and egress are 1.5 km). The tunnel is suitable for light vehicles only - motorcycles and heavy vehicles are not allowed.

There are three modes of operation – Figure 26:

- in the first mode, under normal conditions where there is no storm, no flood water will be diverted into the system.
- when the second mode is active, flood water is diverted into the bypass tunnel underneath the motorway tunnel. The motorway section is still open to traffic at this stage.
- when the third mode is in operation, the motorway will be closed to all traffic. After making sure all vehicles have exited the motorway, automated water-tight gates will be opened to allow flood water to pass through.

After the flood has ended, the tunnel is emptied of water and cleaned via pressure-washing, and the motorway will be reopened to traffic - within 48 hours.

In 2011, the Smart Tunnel received UN Habitat Scroll of Honour Awards for its innovative and unique management of storm water.

4. CONCLUSIONS

The dynamic development of urban areas and the resulting demand for underground space leads to a broad analysis of the possibilities of building multi-utility tunnels using the latest trenchless technology.

The use of multi-utility tunnels creates greater opportunities for the use of underground space in cities for other purposes – mainly for the construction of underground transport facilities (tunnels, garages, etc).

In addition, placing the network in multi-utility tunnels increases the reliability of its operation and allows for the repair of pipes without trenches and the obstruction of traffic. As a result, considering the lower costs of a network's operation and the lower social costs of cities resulting from the lack of communication obstacles for investments, more expensive multi-utility tunnels are technically and economically viable when taking into account their lifetime.

Furthermore, the extensive development of tunneling technology and the application of the advanced material solutions used in the construction of tunnels encourages a wider usage of multi-utility tunnels. This is especially true for TBM technology (tunnel boring machine) and microtunnelling, and also for materials such as High Performance Concrete and Glass Reinforced Plastic. Wide access to these technologies and materials results in lower costs of their application and enables greater possibility for their usage, even in harsh conditions.

And finally there is the last question – Figure 27

Someone will ask: What is the role of this car on this small island?

Answer: It is the beginning of future problems.

REFERENCES – Figure 28