Proceedings of the 15th European Conference on Soil Mechanics and Geotechnical Engineering
A. Anagnostopoulos et al. (Eds.)
IOS Press, 2011

doi:10.3233/978-1-60750-801-4-1739

Multi-utility tunnels (MUT) in Frankfurt am Main technical challenges and innovative perspectives

Tunnels multi-utilite (MUT) à Francfort sur le main defis techniques et perspectives innovatrices

M. Thaher[1]
Prof. Dr.-Ing. Mahmud Thaher TIS-TEC Engineering Consulting Office, 64331 Weiterstadt, Germany

W. Siedentopf
NRM Netzdienste Rhein-Main GmbH, 60486 Frankfurt, Germany

J. Becker, T. Lindemann
Mainova AG, 60486 Frankfurt, Germany

ABSTRACT

In huge cities as Frankfurt (Main) a considerable part of the underground supply infrastructure is becoming continuously more and more in need of modernization. Additionally, long term planning has to consider an expected extension of supply systems. This and the consecutively necessary restructuring of the existing supply systems lead in the future to area-wide constructions within the urban area of Frankfurt. Therefore concrete possibilities for realization of accessible Multi-Utility Tunnels MUT with attractive cost saving potential due to synergy potentials are expected. Despite high launching costs, man accessible MUT represent an economical alternative due to considerably lower lifetime consequential costs. In addition man accessible MUT are environmentally preferable compared to conventional piping in form of Single-Utility Tunnels SUT respectively conventional Single-Utility Installations (SUI). The city administration of Frankfurt and the public supply company Mainova AG are cooperating on future oriented Utility Tunnel (UT) projects to cope with these challenging conditions. In this contribution the future chances and challenges as well as actual difficulties concerning technical, economical and ecological efficiency are discussed in comparison. It is much more effective to concentrate as many utilities as possible in as few tunnels as possible.

RÉSUMÉ

Dans les villes énorme comme Francfort (Main) une partie considérable de l'infrastructure souterraine d'approvisionnement devient sans interruption de plus en plus nécessitant la modernisation. En outre, la planification à long terme doit considérer une extension prévue des circuits d'alimentation. Ceci et la restructuration consécutivement nécessaire des circuits d'alimentation existants mènent à l'avenir aux constructions de la taille du secteur dans la zone urbaine de Francfort. Par conséquent les possibilités concrètes pour la réalisation des accès multi-services MUT tunnels à coût attractif potentiel d'économie en raison de potentiels de synergie sont attendus. En dépit des coûts de lancement élevés, équipez MUT accessible représentent une alternative économique due aux coûts consécutifs de vie considérablement inférieure. En outre l'homme MUT accessible sont ambiant préférable comparé à la tuyauterie conventionnelle sous la forme d'installations conventionnelles de Simple-Utilité des tunnels SUT de Simple-Utilité respectivement (SUI). L'administration de la ville de Francfort et le public d'approvisionnement de compagnie Mainova AG coopèrent sur l'avenir de tunnel utilitaire orienté (UT) des projets visant à faire face à ces conditions difficiles. Dans cette contribution, les chances et les défis futurs réels et les difficultés liées à l'efficacité technique, économique et écologique sont discutés en comparaison. Il est beaucoup plus efficace de concentrer les services publics que possible dans les tunnels peu que possible.

Keywords: Frankfurt am Main, Leipzig Charter, Mainova AG, Maintenance Principle, Multi-Utility Tunnels MUT, NRM, Optimisation, Repair Principle, Single-Utility Installations SUI, Single-Utility Tunnels SUT, Supply Infrastructure, Supply Lines, TIS-TEC, Underground Infrastructure, Utility Tunnels UT

[1] Corresponding Author.

1 INTRODUCTION

Ensuring mobility, power and water supply is the main challenge of sustained urban development. To achieve this goal, a combined effort of politics, administration, citizen and particularly of science and engineering is needed. The European Union defined 2007 the idea of an European City and committed to modernizing infrastructure, increasing energy efficiency and protecting natural resources. Utility tunnels (UT) and especially Multi-Utility Tunnels (MUT) will surely contribute to reach these aims. Considering the rising concentration of urban areas and the continuously changing requirements on a sustained, future oriented infrastructure, the technical, ecological and not least economical advantages of infrastructure tunnels will encourage future implementations of MUT systems.

The city administration of Frankfurt and the public supply company Mainova AG are cooperating on future oriented utility tunnels projects. Planning and construction of UT within an existing cramped underground infrastructure, without serious affecting its function while (re-) constructing, implies especially in the case of SUT complex technical challenges. Therefore MUT will have to be taken into account to cope with these challenging conditions. Beside Frankfurt this also applies basically to other urban areas.

MUT are closed, accessible underground infrastructure tunnels for bundled and accessible hauling as well as for operation of different supply and disposal pipelines. Using huge sections for those utilities seems to be one of the most promising approaches to solve the corresponding problems. The serviceable section area of MUT could be increased up to ca. 80% against ca. 40% using SUT. The use of MUT does have 2 main advantages: supply lines can be reached much easier for service purposes and much fewer MUT have to be constructed and maintained instead of many SUT with smaller sections. It should be the main aim to concentrate as many utilities as possible in as few tunnels as possible. Of course the necessary changes can be realised only step by step, therefore they have to be started as soon as possible and by every chance presenting itself economical reasonable in any infrastructure project.

2 HISTORICAL REVIEW

There are infrastructure channels as SUT since time immemorial; the first were already in old Rome. In modern times and during the industrialization of Europe isolated cases with first approaches were realized for the regular bundling of utility systems in channels in the sense of MUT. First known European examples of MUT approximately go back to the middle of the 19th Century, see figure 1.

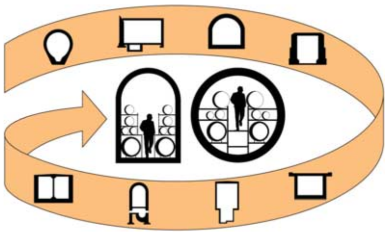


Figure 1. Examples of MUT-Sections from the 19th century up to now

MUT did not yet become generally accepted in the public communal street space. In contrast particularly economic advantages of systematic line bundling in accessible tunnels were recognized and realized punctually e.g. by fair companies, airport operators, universities and hospitals where all utilities are owned and operated by a single company or a small group of investors.

In comparison to the life cycle of buildings soil buried line systems must be repaired and/or renewed several times at high expenditure which can be reduced significantly by the use of MUT. Nevertheless supply and disposal lines are being installed up to now predominantly in the subsoil separated from each other in the street space, pretty often without comprehensible system and predominantly situation-dependent according to the respective spatial possibilities. In densely settled areas this leads inevitably to increasing challenges in the underground town construction:

- increasing expenditure for renewing and increasing new installations of medium

routes in ever more scarcely becoming public space,
- located politically and socio-politically in the everyday life relatively invisible and regardless in the underground,
- increasing need of technical adjustments and coordination of the involved parties in renewal and/or extension measures,
- increasing variety and unfavorable mutual influence of subsoil buried line systems as well as impairment of the environment and public traffic by increasing renewing activities,
- a substantial economical damage arises caused by remedial actions of supply lines and of subsequent damages.

Thus in the city area of Frankfurt already many years ago supply lines in channels and tunnels have been installed, so far predominantly in the case of district heat supply, partially also in combination with cable routes for electricity supply (figure 2). These hardly known cases are mostly located in areas with particularly high density of existing supply infrastructure or beneath existing railway tracks of the German Rail.

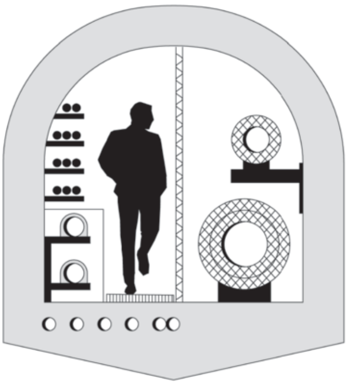


Figure 2. MUT-Section with installed district heating pipes and high voltage cables, based on [3]

Figure 2 shows an example of a MUT cross section with installed cable and district heat pipelines, 3 to 4 meters underneath the track apron of Frankfurt main station. This approx. 270 m long MUT has been built in the 80's and has internal dimensions of 2,20 m x 2,20 m (height x breadth) to be accessible.

3 STATUS QUO IN FRANKFURT

Frankfurt with approx. 690.000 inhabitants and a total area of approx. 250 km² is the fifth largest town of Germany and one of the most important traffic interchanges of Europe. The land utilisation of the Frankfurt city illustrates the following chart.

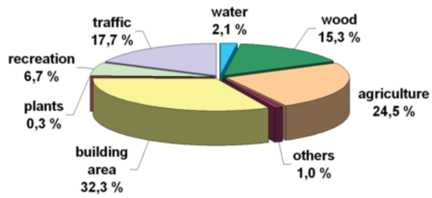


Figure 3. Land utilisation of the Frankfurt city, based on [1]

Frankfurt is a "European town", a finance centre as well as a fair and a commercial city of international significance. It is an important telecommunication node in the Internet traffic and services, shown by e.g. a more than 4.000 km-long fibreglass net, approx. 3.000 IT enterprises and the second-highest computer centre density in Europe.

Frankfurt shows a high density of high rises. The European tower (television tower) with 337.5 m is the cities highest construction. All together approx. 100 buildings higher than 50 m exist already; further high rises are continuously in the planning. This concentration of high rises leads to a relatively high demand for energy and communication.

Both, overground and subterranean traffic (road and railway) limit the available space for the necessary supply infrastructure underneath the ground level and its accessibility.

Table 1 conveys an idea to the extent of the Frankfurt infrastructure.

Table 1. Frankfurt infrastructure, based mainly on [1] and [2]

electricity	7.000 km *)	road network	1.200 km
fibreglass	4.000 km	city railroad	65 km
gas	3.000 km *)	suburban railway network (region)	300 km
sewerage system	1.600 km	suburban railway network (tunnel)	15 km

water	1.500 km [*)]	district heating	200 km [*)]

[*)] without private connections

The above mentioned conditions and the example in figure 4, with a confusing grown supply infrastructure make the need of optimisation of the space for supply lines evident. MUTs have to be considered as most promising in terms of long-range economical and logistical advantages first of all in streets and junctions with an exceptional density of infrastructure.

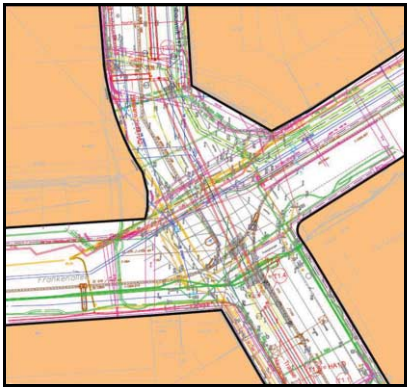


Figure 4. Traffic junction point Güterplatz with cramped supply infrastructure (situation with SUI)

Possibilities for a suitable reallocation and system conversion arise, e.g. after close-down of existing tunnels. This opens up new vistas as the existing space can be further used with relatively low expenditure, as proved by the use of closed railway tunnels for supply purposes.

In the city centre of Frankfurt a new district heating pipeline has been moved in this manner with relatively elementary constructional measures; that means without extensive tunnel or other underground construction works and without appreciable interference of the environment. The tunnel cross section offers favourable options for the installation of further supply pipes.

While there is need for action, there are also several future-oriented opportunities that only have to be captured.

4 PERSPECTIVES AND CHALLENGES

Figure 5 shows the junction point of figure 4 as an effective alternative by means of MUT, with a low lying transport level and a supply level near to the surface which serves in particular the supply of the adjoining buildings. This shows a contemporary and sustainable solution.

Certainly the transformation of the SUI state according to figure 4 to the MUT state according to figure 5 is a complex long term matter which only can be realised step by step. Each arising possibility for a partial transformation has to be used, e.g. in the course of street renewal measures or construction of new infrastructural facilities. In case of particularly cramped conditions the MUT offers the only remaining solution.

The need for such contemporary, efficient and adaptable supply networks appropriate for maintenance, as they can be realised in MUT will further grow in future due to the continuously changing demands on supply infrastructure, e.g.:

- abolition of monopoly positions in the area of telecommunications and energy supply,
- changing requirements for materials, e.g. for water and energy supply,
- increasing extension of district heating converting oil, coal or gas heating systems,
- new development of inner-city areas and persistent high-rise constructions,
- increasing rainwater management and variable capacity utilisation of the canalisation,
- change of the consumer behaviour,
- availability of new technologies, e.g. geothermal energy, automated guided vehicle systems (CargoCap).

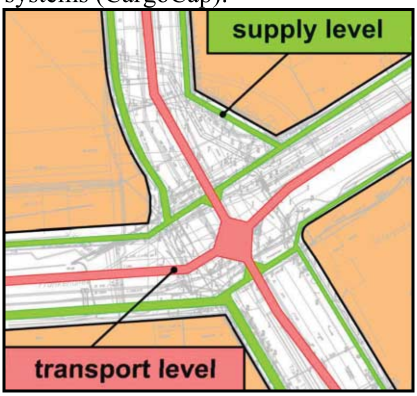


Figure 5. Traffic junction point Güterplatz with MUT as sustained alternative solution, schematic

The objectives and action strategies LEIPZIG CHARTER [4] to the lasting European town are supported by MUT. The main issue of the charter is the creation and protection of public spaces of high quality, e.g., through creation and protection of functioning infrastructures and taking into account cultural, economic, technical, social and ecological aspects. Also the modernisation of infrastructure networks and the increase of energy efficiency were approved as a significant aim in this context. In particular the timely improvement and adaptation of technical infrastructures according to required adjustments are aims that are considerably simplified by installations and collective duct laying in MUT.

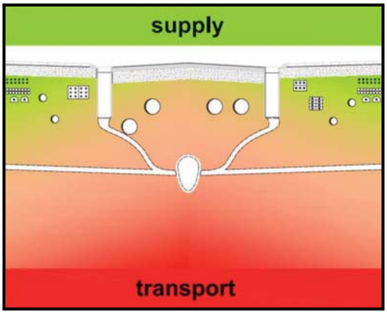
The construction of MUT is especially suitable within transformation measures e.g. of traffic arrangements, renewals of the supply infrastructure and new development areas. The advantages of MUT compared with SUT- or SUI-systems can be summarised as follows:

- supply lines are accessible at any time and can be checked and maintained regularly, maintenance principle instead of repair principle,
- adaptations, renewals and new installations of lines are possible with relatively low expenditure,
- better protection against humidity, water and other external environmental factors,
- lower sensitivity and in the case of hazardous incidents quicker and more favourable localisation and remedial action,
- optimisation of use of the underground construction space by concentrated line arrangement,
- protection of flora and fauna by less civil engineering works.

Figure 6 highlights the optimisation potential of the available subterranean space by means of MUT, compared with conventional buried line arrangements. Special attention is to be directed to the connections between the transport and the supply level with different requirements for the planning depending on the supply medium.

However, the realisation of MUT contains also technical challenges, especially under urban conditions. Within the scope of a development of new building areas the construction of MUT can be carried out in comparison to a conventional development with SUI, in the long term, absolutely reasonable. The demands for the planning and realisation comprehend no special difficulties. In contrast compulsions arise in inner-city areas due to the cramped subterranean construction spaces. These lead to higher demands concerning the planning and realisation of MUT-systems. Nevertheless, when these are realised in closed coverage type this difficulty is decisively compensated by the advantage to be able to realise new MUT below the existing supply infrastructure.

Thus the existing supply remains unaffected and is transferred bit by bit in the MUT. Operation interruptions and supply shortfalls are thereby minimised and the transformation can be carried out economically and environmentally passable. The higher beginning investments under difficult conditions on one hand and lower operational and renewal cost on the other hand have to be taken into account when comparing lifetime cost of MUT and conventional SUI. In all cases in which MUTs will amortise within lifetime they have to be the preferred alternative for future installations. The possibility for the exploitation of new utilisation, e.g. rainwater management or heat recovery, should not remain unmentioned in this context.



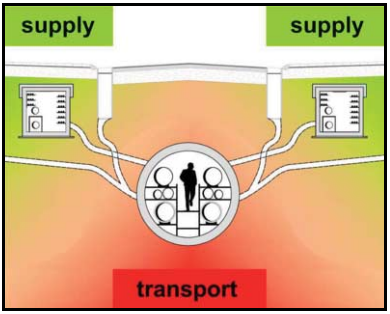


Figure 6. Conventional line arrangement SUI (above) and concentration in the sense of MUT (below)
transport level: mainly transmission pipes and high voltage; supply level: mainly connecting pipes and cables

Another challenge shows the heat development, e.g. because of district heating pipes. The thermal influence must be analysed and considered in connection with other supply pipes installed simultaneously. The most intelligent way to handle this, is to recover the excessive heat energy by heat exchanger and heat pumps and its specific use, e.g. to the heating of residential and office buildings. Of course it can also be remedied by single measures corresponding to the supply media, e.g. by isolation, mechanical heat dissipation and ventilation.

All in all there must be paid attention for the purpose of dependable operational safety to the fact that mutual interactions of the different MUT-media are analysed and switched off or minimised reliably by the planning and in the operating stage. Accordingly, metrological installations should provide by a continuous observation for the fact that malfunctions are recognised and repaired on time. Mutual interactions have to be treated as a part of the planning; dependably neutralising measures have to be fixed, taken and observed strictly enough and to be pursued metrologically. The operational safety must be guaranteed dependably and permanently.

In summary the conversion of SUI- into MUT-systems is a process of optimisation which has to be started as soon as possible. Optimisation in the field of civil engineering is a core area in the profession of the authors, see [5].

5 CONCLUSION

The supply infrastructure in bigger cities has to be sustainable. The surface urban development currently hurries far ahead of the subterranean city development. The earlier politics, economy and society start with possible developments, the better for the medium- and long-term supply safety.

Since growth and progress require fully functional lifelines, it is a matter of public agenda and in the interest of the supply companies to transfer the present, partly outdated underground supply systems methodically in more capable systems, especially in MUT-Systems.

Due to various difficulties and mutual interactions the realisation of MUT-solutions has to be analysed and decided in particular cases. Always returning combinations of MUT-media can be checked on the basis of single studies and corresponding standardised solutions can be derived. The authors already work on first relevant considerations and approaches. They would be glad if this in the long term indispensable system asserted itself for the purposes of human being and the environment.

ACKNOWLEDGEMENT

The presented contribution has been developed in cooperation with the city administration of Frankfurt. The authors appreciate very much the kind support and discussions, and thank in anticipation for the necessary support for further discussions and studies.

REFERENCES

[1] Statistisches Jahrbuch Frankfurt am Main, 2010
[2] Mainova AG, *Märkte bewegen. Unternehmen steuern. Zukunft gestalten.*, Geschäftsbericht, Frankfurt, 2009
[3] Mainova AG, *Kabel- und Fernheizkanal unterhalb des Hauptbahnhofsvorfeldes*, Vermerk, Frankfurt, 1990
[4] LEIPZIG CHARTA zur nachhaltigen europäischen Stadt, 2007
[5] www.TIS-TEC.de

Proceedings of the 15th European Conference on Soil Mechanics and Geotechnical Engineering

Geotechnics of Hard Soils – Weak Rocks

Comptes Rendus du 15ème Congrès Européen de Mécanique des Sols & de Géotechnique

La Géotechnique des Sols Indurés – Roches Tendres

Part 1, 2 and 3

Edited by

Andreas Anagnostopoulos

National Technical University of Athens

Michael Pachakis

OTM Consulting Engineers SA

and

Christos Tsatsanifos

PANGAEA Consulting Engineers LTD

IOS Press

Amsterdam • Berlin • Tokyo • Washington, DC

XV EUROPEAN CONFERENCE ON SOIL MECHANICS & GEOTECHNICAL ENGINEERING

ATHINA 2011

"Geotechnics of Hard Soils - Weak Rocks"

1st BULLETIN
OF THE XV ECSMGE

The Megaron Athens International Conference Center

12-15 September 2011

Athens, Greece

www.athens2011ecsmge.org

HELLENIC SOCIETY FOR SOIL MECHANICS & GEOTECHNICAL ENGINEERING