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APPROACH TO STRUCTURING OF BUILDING COSTS FOR CONSTRUCTION AND OPERATION OF UTILITY TUNNELS

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ДО ПИТАННЯ ЩОДО ПРИНЦИПУ ФОРМУВАННЯ СТРУКТУРИ ВИТРАТ НА БУДІВНИЦТВО ТА ЕКСПЛУАТАЦІЮ МІСЬКИХ КОМУНІКАЦІЙНИХ ТУНЕЛІВ

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К ВОПРОСУ О ПРИНЦИПЕ ФОРМИРОВАНИЯ СТРУКТУРЫ ЗАТРАТ НА СТРОИТЕЛЬСТВО И ЭКСПЛУАТАЦИЮ ГОРОДСКИХ КОММУНИКАЦИОННЫХ ТОННЕЛЕЙ

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Infrastructure development of cities and effective operation of the modern municipal facilities are always connected with the active development of underground space, i.e. construction of tunnels of various application and especially utility galleries. This article envisages the issues relating to the expenditures for construction and operation of utility galleries, as well as performance evaluation of variants applied to their construction and operation.

Keywords: *utility gallery, water pipeline, costs, losses, expenditures, risks.*

Розвиток інфраструктури міст, ефективне функціонування сучасного міського господарства безперервно пов'язані з інтенсивним освоєнням підземного простору, зокрема, зі спорудженням тунелів різного призначення і в першу чергу комунальних комунікаційних тунелів. У цій статті розглянуто питання про витрати на спорудження й експлуатацію міських комунікаційних тунелів, оцінки ефективності застосовуваних варіантів їх будівництва й експлуатації.

Ключові слова: *комунікаційний тунель, водогін, витрати, збитки, ризики.*

Развитие инфраструктуры городов, эффективное функционирование современного городского хозяйства непрерывно связаны с интенсивным освоением подземного пространства, в частности, с сооружением тоннелей различного назначения и в первую очередь коммунальных коммуникационных тоннелей. В данной статье рассмотрены вопросы о затратах на сооружение и эксплуатацию городских коммуникационных тоннелей, оценки эффективности применяемых вариантов их строительства и эксплуатации.

Ключевые слова: *коммуникационный тоннель, водовод, затраты, ущерб, издержки, риски.*

Problem setting. Under current conditions, the ecological safety of construction and operation of utility galleries greatly contributes to the sustainable development of megalopolises. The major element of municipal utility system is utility

galleries, which are pass-through underground tunnels meant for joint laying of the following utility systems of various applications: heating services, water distribution networks, telecommunication cables, etc. The necessity to take into consideration the special features of municipal settings, the high density of overground housing system, presence of essential structures over the surface, dense network of underground utilities, determines the practical applying of innovative methods for construction of such utilities. This set of facts attaches conditions for the search of cost effective construction methods and operation of utility galleries.

Recent research and publications analysis. Tasks and problems considering theimprovement of service life of utility galleries and utility systems are examined to a great extend in works of G.K. Agadzhanov [1], D.F. Goncharenko [2,3], Zh.A.Frankevich [4], A.A. Sapukhin [5], V.M.Simanovich, [6], Ye.Ye.Yermolayev [6], Y.V.Shibaev [7] and many others.

The research objective consists in the consideration of the structure of building costs for construction and operation of utility galleries.

Key research findings. Today, numerous underground facilities of different application are fully or partially located under the main transport routes. Unsatisfactory condition of utility galleries and utility systems in most cities of Ukrainethat is caused by the high technical wear and deficient operation control, results in numerous damages of their particular sections. There are numerous utility galleries and passes in Kharkov city. Of particular interest is the utility gallery with the approximate length of 2 km, in which two lines of pressure water pipeline with diameter of DN 1200 mm and DN 600 mm are laid in parallel. It must be admitted that its useful lifetime, which is more than 40 years, exceeds the design life. In this regard, the issues, relating to the cost-effective and safe operation of utility galleries and their distribution systems, planning of recovery operation strategy as well as timely response to damages, are really actual ones [2].

The main feature of underground utility systems is aneed for technical-economic and social-economic performance evaluation of variants applied for their construction and repair during operation [1].

The overall value of construction and operation of utility galleries must consider the following charges:

–design and survey work;

–establishing and development of building site;

–capital expenditure for laying of galleries, mines and chambers intended for assembling and disassembling of excavating equipment; water drainage; ventilation of mine openings; materials supply and issuance; people descending; pipelines laying etc.;

–involved (indirect)costs incurred in the cut-and-cover laying of galleries and re-laying of existing underground utilities. Moreover, the involved costs, arisen during perambulating of the building site (route elongation), are also incurred when constructing the cut-and-cover galleries in an urban setting;

–losses from possible accidents caused by the increased traffic volume on other streets;

–losses of enterprises and government offices from the late delivery of passengers and cargoes;

–losses from confiscation of land plots for the period of construction;

–extra expenditures of municipal services for liquidation of streets dirtying and loading of rain water system;

–expenditures connected with the repair of roadway paving after subsidence, appeared in 1-2 years after the trenches backfilling.

Additionally, it is necessary to take into consideration the operation cost incidental to expenditures, which are connected withstate control of utility galleries during operation, as well as their current and full repairs when in service. During construction and operation of utility galleries under uncertainty, the extra

expenditures (losses), which are united into specific group – risk losses [8] are possible to arise.

Risk losses (expenditures) may develop during construction and operation of utility systems. In the period of construction, the risk losses include:

–Possible influence of changes in geotechnical conditions which arise during construction, when the designed construction methods do not correspond to actual conditions. The practice of underground development shows that the abandoned collecting canals, construction waste as well as various utility systems, which are not specified in the construction documentation, may often crop up along the digging way.

–Occurrence of flooded soil and high level of underground water. In this case the projected technology of roadway construction does not produce the necessary effect resulting in expenditures for management of additional works such as chemical injection, ground freezing and dewatering, etc.

During operation of utility galleries, which maintenance-free service life is projected for more than 50 years, there is a probability of partial or full coming out of immediate support within the particular sections of the route. Such coming outs are causedby the external geologic, hydrogeologic and technical impacts, as well asinconformity of support parametersto these impacts. In this case, the possible expenditures for liquidation of damages within route sections will embrace the costs for repair of utility gallery, building of the temporary utility line diagram within the fault section and possible ecological damage caused by the breakage.

Thus, the structure of costs, intended to construction and operation of utility galleries, may be divided into four groups:

1) Direct (initial) expenses;
2) Indirect costs;
3) Operation expenses;
4) Risk losses.

Initial direct expenses include mainly the costs for design of utility systems. Moreover, the initial direct expenses contain the expenditures for permission documentation and approvals, as well as capital expenditures for carrying-out of construction operations.

The group of indirect costs includes expenditures for establishing of working site, shift and re-laying of underground utility systems, losses of city transport caused by the change of transport scheme, repair of roadway paving after subsidence, expenses involved in confiscation of land plots etc. Operation expenses include costs for controlling the route during operation, as well as costs for current and full repairs [9].

From the standpoint of impact on the whole service life of underground structure, the construction risks are predominant during building. Such risks may be divided into the following types [8]:

– errors and mismatches of design choices to the actual building conditions;

– risks associated with failures to comply with quality requirements of construction operations;

– risks associated with failures to comply with requirements as to construction period;

– risks as to security of the qualitative construction materials;

– risks connected with the safe usage of equipment;

– technological risks caused by the inconformity of equipment to geologic and hydrogeologic conditions.

Risk losses are possible to arise not only in the period of utility galleries construction, but during the whole service life of underground facility [7]. Service life of underground facility means the time from design development to the moment, when utility galleries are fully out of service. It is interesting method of determining the vulnerable areas of communication tunnels based on the principle set out in the work [10].

Taking into consideration all operational cycles, the service life of underground facility, which is possible to be determined in accordance with the formula, will be [4]:

$$T_{sl} = t_{pr} + t_c + t_o + t_d, \qquad (1)$$

where T_{sl} – service life of underground facility, years;

t_{pr} –period of underground facility projecting, years;

t_c – construction period, years;

t_o– operational period of utility galleries, years.

t_d – period of decommissioning and disassembling of utility galleries, years.

During operation of utility galleries, the risks are presented in the form of partial or complete breakdowns of system or its constituent elements. Theirrepair needs extra expenditures, which lead to the direct production losses. The extent of ensuing losses depends on the necessary volume of extra expenditures raised for performance restoration of utility galleries. Based on experience of operation of utility galleries with the aim of combined laying of pressurized water supply networks, major failures and recommendations, necessary for activities on restoration of their operational safety, are highlighted (Table 1) [6].

Thus, the result of economic appraisal of activities relating to construction and operation of utility galleries [S] may be determined as follows:

$$S = -\sum_{i=1}^{k_i}\left(k_{ds} + k_c + k_i\right) + \sum_{i=1}^{T_i}\left(A + P_r - E_c - E_f\right) - P\left(C_l^d + C_l^i\right), \qquad (2)$$

where k_{ds}, k_c, k_i – cost value of design and survey work, direct expenses for project construction, indirect costs, c.u.;

A – depreciation amount by basic funds used during the operational phase of object service, c.u.;

Pr – profit from transportation of introduced or used resources through galleries, c.u.;

E_c, E_f – expenditures for current and full repairs of utility galleries, c.u.;

P – probability of system failures (risks) during its construction and operation, fr.unit;

C^d_l, C^i_l – extend of expecteddirect and indirect losses, c.u.;

It must be admitted that the cost value of utility gallery operation may exceed the amount of moneys received for its construction. In this case, the index [S] will possess the negative quantity.

In **conclusion**, it should be admitted that in contrast to the aboveground facilities, the construction of utility galleries is connected with the necessity to excavate and remove the considerable soil volumes, as well as build up the cut-and-cover structures, requiring serious financial investments. The performance of these works needs the constant control at all stages of excavating and building processes, which are usually conducted under difficult engineering-geological and hydrogeologic conditions. Moreover, the control must be maintained at the narrow work front, as well as under conditions, when the space of utility gallery is blocked up with supportsand various excavating and transport equipment. Therefore, in order to forecast the total investments for construction, it is necessary to take into consideration the unscheduled expenditures connected with possible risks.

In summary, it is important to mention that the main economical aspect of effective operation of utility galleries consists in the detailed study of structuring of costs, which are intended for their building and operation. The article envisages the questions relating to the costs structuring and performance evaluation of construction and operation of utility galleries. The special attention is given to estimation of possible galleries damages and ways of their solving. In future, the economical estimation of risk factors, which are connected with damage of utility galleries, as well as the economic assessment of construction and repair methods of utility galleries are of special interest.

Table 1

List of major failures within utility galleries

Ser. No.	Physical damages within utility galleries	Possible consequent effects of arisen failures	Necessary activities on renewal of utility galleries operation
1	Severe corrosion of load carrying structures of immediate support (lining)	Reduction of load-carrying ability of immediate support, deformation and destruction of mine roadway	Complete overhaul of utility gallery including the removal of worked-out support, cutting of road trenches and backfill
2	Disturbed support of underground structure, breaking/shearing of bolted connections	Leakages, returns, deformations, subsidence, gabarites mismatch, reduction of working safety of mine roadways	Partial overhaul of deformed sections of immediate support
3	Removal of enclosing rocks adjacent to immediate supports of mine roadways	Deformation of immediate support, reduction of load-carrying ability of immediate support, separation of troughing block, gabarites mismatch	Partial overhaul of immediate support and cement grouting of soils adjacent to mine roadways
4	Disturbed water resistance of utility galleries with water entry on electrical facilities, heating main pipes etc.	Possible soil discharging, emergency situations	Cement grouting and stabilization of soil adjacent to mine roadway, waterproofing of immediate support, cement covering
5	Silting of open and closed drains systems	Structure submergence	Partial overhaul with cement grouting of supported space, local drainage
6	Maximum allowed sagging of ceiling beams and boards	Cracks of tension zones, disturbed waterproofing, leakages, reinforcement corrosion, destructions	Partial or complete overhaul of utility galleries
7	Maximum allowed ellipticity of support rings	Gabarites mismatch, reduction of load-carrying ability of immediate support	Partial or complete overhaul
8	Cracks in reinforced-concrete support blocks of round shapes (tension zones)	Leakages, reinforcement corrosion, reduction of load-carrying ability of immediate support	Partial overhaul of utility galleries
9	Metal ware deformation	Sagging, breaking of joint welds, leakages, returns, support deformation of underground structures, corrosive defects	Partial overhaul of utility galleries
10	Structure failure of utility gallery caused by the pipe breakages (breaching of pressurized water supply mains etc.)	Reduction of load-carrying ability of immediate support, deformation anddestruction of mine roadway	Damage control of pipelines, partial or complete overhaul of utility gallery according to magnitude of accident
11	Occurrence of hidden leakages within water pipelines laid in utility galleries	Destruction of gallery lining, development of corrosion processes	Elimination of point damages within water pipelines, local drainage, operating repair of utility gallery

References

1. Агаджанов, Г. К. Економіка водопровідно-каналізаційних підприємств [Текст]: навч. посібник / Г.К. Агаджанов. – Харків: ХНАМГ, 2010. – 392 с.

2. Гончаренко, Д. Ф. Эксплуатация, ремонт и восстановление трубопроводов водоснабжения [Текст] / Д. Ф. Гончаренко, А. И. Алейникова, Х. Вевелер. – Харьков: Раритеты Украины, 2015. – 280 с.

3. Гончаренко, Д. Ф. Организационно-технологические решения ремонта и восстановления канализационных коллекторов Харькова [Текст] / Д. Ф. Гончаренко, Ю. В. Булгаков, О. В. Старкова // Вода и экология. Проблемы и решения. – СПб.: ЗАО «Водопроект-Гипрокоммунводоканал», 2014. – Вып. 1 (57). – С. 62-70.

4. Франкевич, Ж. А. Экономико-математическая модель оценки эффективности проектов строительства коллекторных тоннелей [Текст] / Ж.А. Франкевич // Сб. науч. тр. ЦНИЭИУголь. – М, 2008. – №21. – С. 70-74

5. Сапухин, А. А. Анализ эффективности применяемых технологий при выборе подходов к организации строительства и ремонта трубопроводов [Текст] / А.А. Сапухин, В.А. Курочкина, С.О. Новиков // Вестник МГСУ. – 2013. – Вып. 7. – С. 96 – 103.

6. Симанович, В. М. Особенности определения затрат в составе сводного сметного расчета стоимости строительства[Текст]: практ. пособие / В.М. Симанович, Е.Е. Ермолаев. – М.: Москва, 2010. – 280 с.

7. Шибаев, Е. В. Оценка экономических и технических рисков и взаимосвязь по эксплуатации горных выработок [Текст]: научные труды / Е. В. Шибаев, Ж. А. Франкевич. – М.: ОАО ЦНИЭИ уголь, 2011. – №26. – 6 с.

8. Пикфорд, Д. Управление рисками [Текст]: пер. с англ. / Д. Пикфорд. – М.: ООО «Вершина», 2004. – 352 с.

9. Друри, К. Введение в управленческий и производственный учет [Текст] / К. Друри. – М.: Аудит, 1998. – 774 с.

10. Старкова, О. В. Разработка автоматизированной информационной системы определения приоритетных объектов реновации трубопроводов водоснабжения [Текст] / О. В. Старкова, Л. А. Гнучих, Е. А. Шаповалова, Д. А. Бондаренко // Коммунальное хозяйство городов: науч.-техн. сб. – К.: Техника, 2011. – Вып. 99. – С. 312–316.

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