Встановлено основні фактори, що впливають на ефективність відновлення водопровідних мереж методом «Берстлайнинг» на основі узагальнених технічних і організаційно-технологічних характеристик ділянок. За допомогою методу експертних оцінок виділені фактори, що мають найбільший вплив на ефективність ремонтних робіт, такі як: фізико-механічні властивості ґрунту, технічний стан існуючого трубопроводу, поздовжній профіль ділянки відновлення. Детальне дослідження цих факторів дозволить поліпшити техніко-економічні показники відновлювальних робіт

Ключові слова: водопостачання, трубопровід, водопровідні мережі, безтраншейні технології, метод «Берстлайнинг»

Установлены основные факторы, влияющие на эффективность восстановления водопроводных сетей методом «Берстлайнинг» на основе обобщенных технических и организационно-технологических характеристик участков. С помощью метода экспертных оценок выделены факторы, оказывающее наибольшее влияние на эффективность ремонтных работ, такие как: физико-механические свойства грунта, техническое состояние существующего трубопровода, продольный профиль участка восстановления. Детальное исследование данных факторов позволит улучшить технико-экономические показатели восстановительных работ

Ключевые слова: водоснабжение, трубопровод, водопроводные сети,бестраншейные технологии, метод «Берстлайнинг»

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RESEARCH INTO THE FACTORS WHICH INFLUENCE EFFICIENCY OF THE WATER SUPPLY NETWORKS RECONSTRUCTION BY THE «BERSTLINING» TECHNOLOGY

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1. Introduction

Under current conditions, operational enterprises of the water utilities in the Ukrainian cities fulfill their social and economic commitments at the limit of technical and organizational capacities, which is evidenced by:

1. Technical constituent: technical condition and the wear of the main assets, in particular, water supply networks (a structure of the water utilities networks in Ukraine by technical constituents is presented in Fig. 1–4) [1].

2. Economic constituent: unstable economic situation in the country and the sector's dependence on subsidies.

3. Organizational-administrative constituent: an obsolete management system, which requires reformation.

An increase in the volumes of renovation operations at the underground engineering communications of water utilities, stricter requirements to the ecological safety of conducting construction works when repairing and laying of distribution networks under conditions of tight existing urban development necessitate using such technical equipment that provides for conducting the earthworks at the minimum volume and impact on the surrounding array.

England, Germany, France, Italy, Denmark, the USA and other countries gained significant experience in the reconstruction of underground pipelines by the trenchless techniques. They make it possible to substantially reduce duration of construction operations, to exclude digging the territories by 80–90 %, to achieve large savings as compared to the traditional trench method. They include: broaching polymeric pipes through the existing pipeline with and without the destruction of the existing pipe, lining the internal surface of pipelines by the seamless woven hoses made of the polyester and nylon threads, etc. [2].

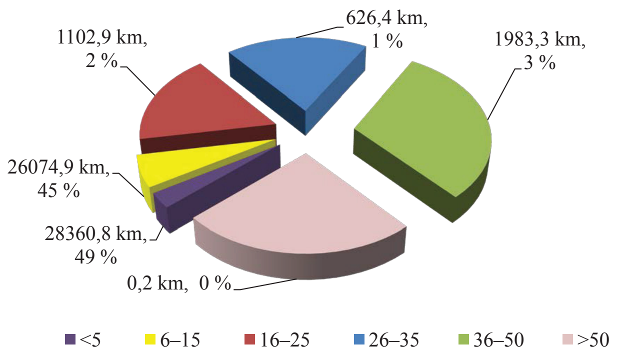

Fig. 1. Structure of the water utilities networks in Ukraine by the period of operation (years)

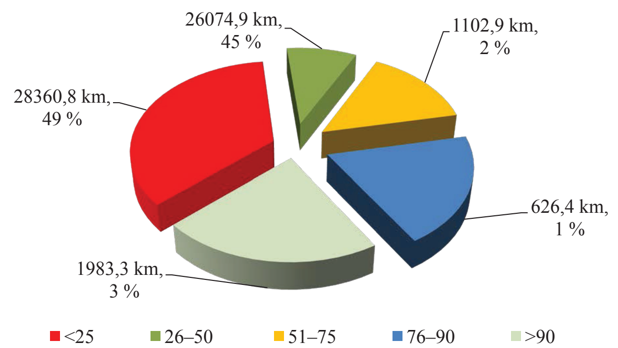

Fig. 2. Structure of the water utilities networks in Ukraine according to the coefficient of wear (%)

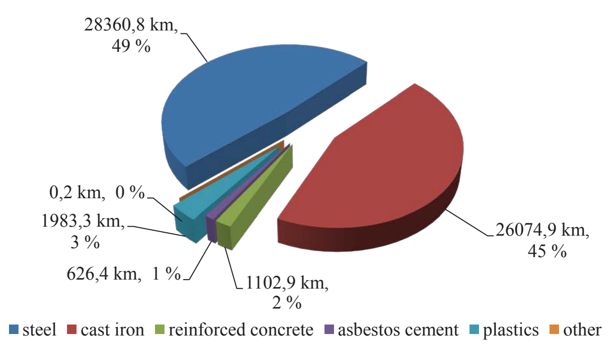

Fig. 3. Structure of the water utilities networks in Ukraine by the material

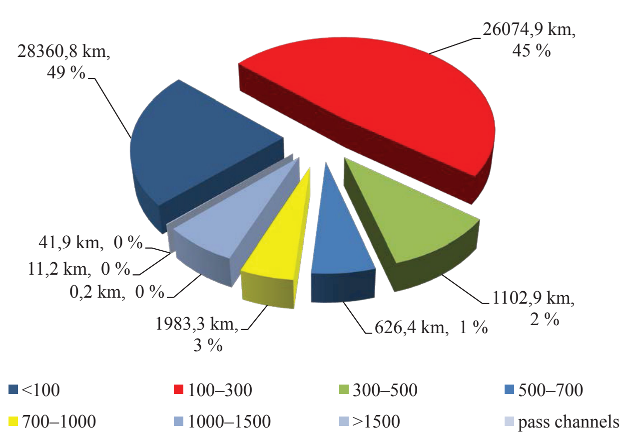

Fig. 4. Structure of the water utilities networks in Ukraine by diameter

The experience of the operating enterprises over recent years has attested to the fact that in Ukraine more and more attention has been paid to the issues of using trenchless techniques that are known in the world as NO-DIG or TRENCHLESS TECHNOLOGIES. In this connection, it is necessary to highlight the renovation of water utilities networks by the berstlining method. Due to significant technical wear of the water utilities networks in Ukraine and, as a result, to an increase in the volumes of repairing works by the given method, it appears interesting to improve the effectiveness of their conducting. The study of the factors that influence the efficiency of restoration of the water utilities networks is by all means relevant. The hypothesis of present scientific work is in the fact that examining the factors that influence effectiveness of the repairing works at water utilities networks by the berstlining method and the identification of the most important of them will make it possible to improve the efficiency of conducting reconstruction works.

2. Literature review and problem statement

The questions of reliable functioning of water-supply system are paid much attention to in a significant number of papers both of theoretical and practical character. Scientists over a period of many years have improved effective methods, which, first of all, include such as Inliner, Berstlining, and Relining. Paper [3] pays special attention to managing a water-supply system as a uniform technological process. In its turn, insufficiently investigated is the question of improving the reliability of functioning of water-distribution networks. Study [4] considers the process of restoring the underground engineering communications as a comprehensive process. At the same time, the issue of technological constituent of conducting repair works at the objects remains unresolved as yet.

Contemporary materials with increased corrosion resistance, applied for the construction, repair and restoration of pipeline systems are explored in detail in paper [5]. Article [6] pays special attention to the combined laying of underground utilities in the communication tunnels; in this case, the trenchless methods of construction and restoration are highlighted. As is noted, a joint laying of underground utilities makes it possible to reduce expenditures for the construction and operation of municipal networks of different designation. In their turn, organizational-technological peculiarities of the restoration of underground utilities in the communication tunnels have been insufficiently examined.

It was established [7] that from ecological and economic point of view, the construction of communication tunnels with the water utilities networks and other utilities is the most expedient variant for a city life activity under modern conditions.

Paper [8] examined in detail the process of restoration of technically worn-out pipelines by the compressed polymeric sleeves, paying special attention to the benefits of such technology. But, at the same time, special features of conducting the works and the expediency of applying this technology under limited financial resources were not taken into account.

Studies [9, 10] pay considerable attention to the questions of providing reliable and failure-free operation of the sewerage and water supply networks, in particular, to the development of organizational-technological solutions, which improve the operational resource of tunnel collectors and main water lines.

Paper [11] explored a complex of supply and distribution of water in housing and communal services. The process of water supply and removal is examined as a complex system process. The question of improving the stability of water supply on the whole remains unresolved.

In the practice of restoration and repair of water utilities pipelines, more and more attention is paid to the questions of using promising trenchless technologies of the restoration (sanitation) of water utilities networks, which is an alternative to the traditional open method of restoration and construction by the excavation and trenching methods.

An analysis of the world practice of the repair work demonstrated that the basic one is the traditional trenching method of repair («steel to steel»), at the possibility of conducting the earthwork. Larger volumes of operations are increasingly fulfilled with the application of polyethylene pipes, including PE 100, PEX, and multilayer polyethylene pipes. When applying these methods, the pipes are used made of polyethylene, polyvinyl chloride, glass-plastic pipes, «sleeves», impregnated with polymeric formulations, etc.

In Ukraine, the «Relining» method of repairing the pipelines of water supply is widely applied, which is based on the technology of pulling into the internal cavity of the repaired section of pipes (after pre-cleaning) of a new (preliminarily welded) lash of polyethylene pipes with maximally close size in diameter [10]. And increasingly used is the «Berstlining» method (replacement method), which has a number of peculiarities in the application for particularly assigned conditions, the careful study of which is of scientific and practical interest.

3. The aim and tasks of the study

The aim of present work is a study of the factors, which affect the effectiveness of applying the «Berstlining» method in the restoration of water supply networks based on the example of conducting the work in the city of Kharkov (Ukraine).

To achieve the set aim, the following tasks were to be solved:

– to collect, analyze and generalize technical and organizational-technological characteristics of the sections under restoration of water utilities networks by the «Berstlining» method based on the example of carrying out repair operations in the city of Kharkov (Ukraine);

– to diagnose the factors, which influence the effectiveness of restoring water-distribution pipelines by the trenchless method «with destruction of the existing pipe»;

– to identify the factors, which exert the largest influence on the effectiveness of the «Berstlining» method when restoring the water utilities networks.

4. Materials and methods of examining the factors, which influence the effectiveness of restoring water utilities networks

4. 1. Basic examined materials and special features of the «Berstlining» technology for restoring water utilities networks

In the course of the study, we collected, analyzed, generalized and compared the data on the technological parameters of restoring worn water utilities networks by the trenchless method of repairing «Berstlining». The essence of the method is in the fact that an operating mechanism is introduced into the restorable pipeline; it displaces soil, tears apart the old pipe and simultaneously draws a new one in the formed cavity (Fig. 5). The remains of the ruined pipe are pressed into the surrounding soil [1].

In the course of conducting operations on the underground destruction and replacement of pipelines by the «Berstlining» method, specialized equipment is used:

1. Hydrostatic destroyer of pipes Hydrostatic Pipeburster.
2. Specialized pneumo-impact unit Hydrostatic Pipeburster [5].

The basic working unit (Hydrostatic Pipeburster) of the replacement method is placed in the prepared target trench. When put into operation, it pushes steel rods into the cavity of the old pipe. Traction rods are pulled throughout the entire extent of the restored section of the pipeline. Next, a knife-destroyer (knife's design includes dilator, cutting edge, a rafter tip that catches knife with the steel rod when pulled, chain coupling for the tow cap) and calibrator with the fixed polymeric pipe are immersed in the original trench, fastened to the traction rod.

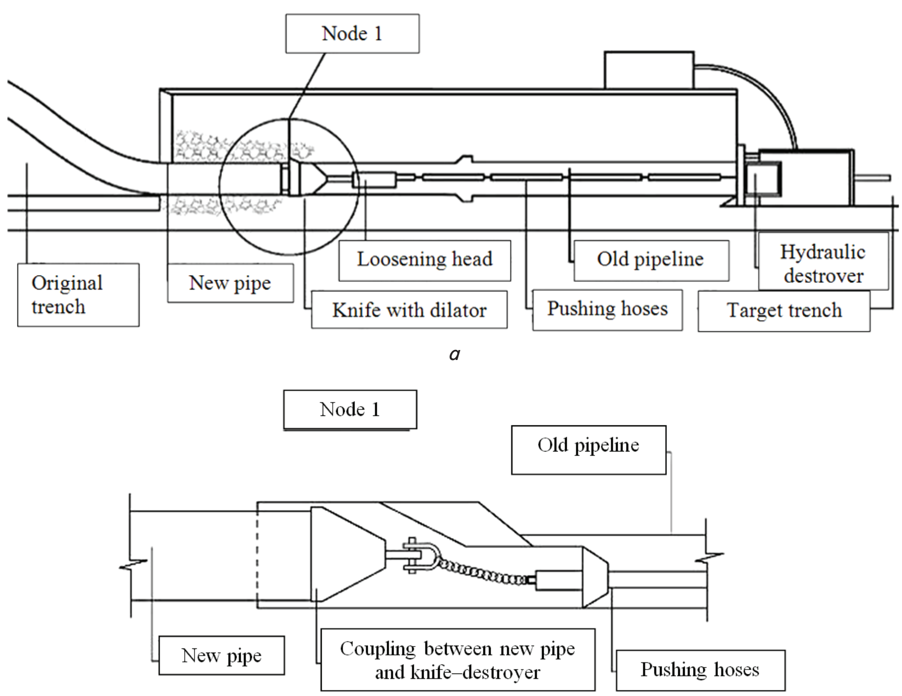

Fig. 5. Principle of conducting the operations by the «Berstlining» method: *a* — technology of the replacement method; *b* — design feature of the working body

Hydrostatic unit pushes the entire installed chain «rod – knife-destroyer – new pipe» inside the existing worn section of the pipe with its subsequent destruction. As a result of performed operations, pieces of the destroyed pipe are pressed into the soil, which allows its strengthening and compression, thus creating a tunnel, which contains the new pipeline [2]. This technology has a number of advantages compared with the traditional open method of restoring the water utilities networks, in particular, a significant decrease in the volumes of earthwork.

4. 2. Technique for examining the factors, which influence effectiveness of applying the «Berstlining» technology

Underlying the study of factors, which influence effectiveness of applying the «Berstlining» technology are technical, organizational-technological data, obtained as a result of sanitation of sections of the water utilities networks with different diameters in the city of Kharkov. As the objects of study we selected five sections of water utilities networks in the city of Kharkov. In the course of the study, serial number was assigned to each object of restoration; we described its basic characteristics, as well as organizational-technological peculiarities of conducting repair works at them under existing conditions.

Based on the organizational-technological peculiarities of conducting repair work at each of the described-above objects of restoration, we defined the basic factors, which influence effectiveness of the «Berstlining» technology for the assigned conditions. Next, with the aid of the method expert evaluation of the technical, organizational and technical indices of the sections of water utilities networks, the most significant factors were identified, which exert the largest influence on the technical and economic indices and the effectiveness of applying the technology «with the destruction» of the existing pipe.

5. Results of the study

5. 1. Results of the studies of factors, which influence effectiveness of the «Berstlining» method in the course of restoration of water utilities networks

In order to conduct the study of factors that influence the effectiveness of applying the «Berstlining» technology, we selected five objects of restoration in the networks of water supply. Selected schemes of the examined sections of urban water pipelines at the objects of restoration 1 (OR1) in Prospekt Nauky Avenue are given in Fig. 6, at the object of restoration 2 (OR2) in Trinkler Street – are given in Fig. 7.

Repair work at the objects were carried out by the trenchless method with the destruction of the sanitized pipe using specialized unit Hydrostatic Pipeburster T125 and T40 (Denmark) that works with the force on destruction of 125 and 40 tons, respectively. The basic technological operations were preceded by the operations of preparatory period:

– setting up a temporary water pipe and reconnecting the multi-apartment houses for the provision of uninterrupted supply of drinking water to consumers;

– welding a lash from polyethylene pipes of the calculated diameter and length, necessary for the sanitation;

– arrangement of starting and target foundation pits at the objects.

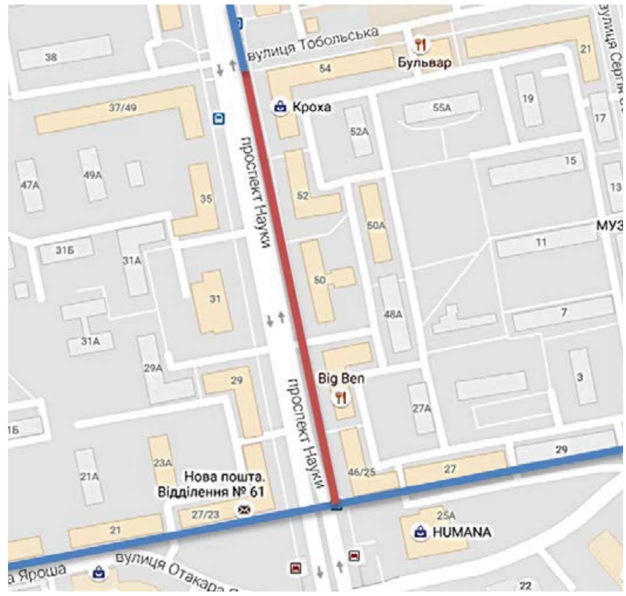

Fig. 6. Schematic of water utilities network at the object of restoration in Prospekt Nauky Avenue (OR1)

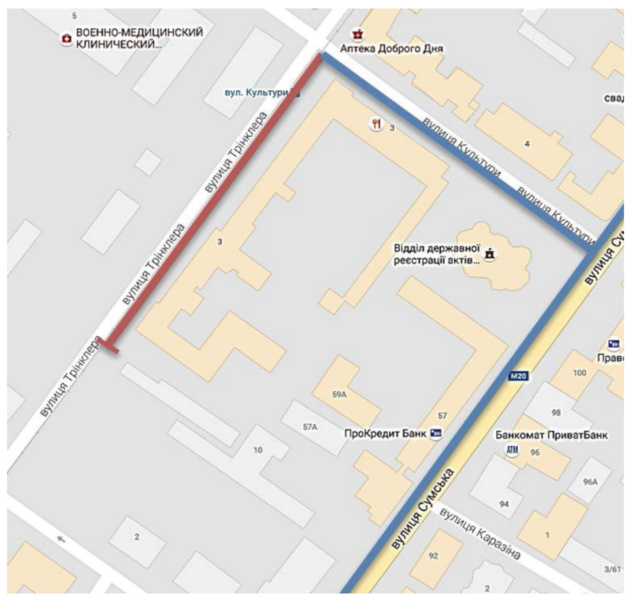

Fig. 7. Schematic of water utilities network at the object of restoration in Trinkler Street (OR2)

The basic technological operations for conducting the repair work are:

– disconnecting the restored pipeline from the feed system of the centralized water supply and discharge of water;

– arrangement of working unit Pipeburster with a specialized support into the target foundation pit;

– pushing steel rods inside the worn pipeline (Fig. 8, *a*);

– connection of the knife to the rods with the subsequent fastening of the lash of polyethylene pipes;

– hydrostatic pulling of chain «rod – knife – new pipe» with the strengthening for the destruction of old pipe to the route of the section (Fig. 8, *b*);

– setting up a coupling «polyethylene – steel»;

– installation of supports;

– reconnecting the water inputs of multi-apartment buildings to the sanitated pipe;

– hydraulic test with the subsequent washing and disinfection of the pipe;

– back filling of the starting and target foundation pits.

The arrangement of butt joint of pipes «polyethylene – steel» was carried out with the aid of the flange joint through a collar bushing. The basic characteristics of the objects of restoration (OR) of water utilities networks by the «Berstlining» method are given in Table 1.

a *b*

Fig. 8. Technological operations of the «Berstlining» method: *a* — installation of equipment into the target trench in Prospekt Nauky Avenue (September 2015), *b* — pushing the steel rods inside the worn pipeline in Trinkler Street (June 2016)

On the basis of generalized technical and organizational-technological characteristics of the objects of restoration, we determined the most significant, in the opinion of the Authors, factors, which influence effectiveness of conducting repair works by the «Berstlining» method, each of which is assigned with symbol F1...F12 (Table 2).

The ranking of factors in the ascending of descending order of any inherent property is performed with the aid of the method of expert estimations [12, 13]. When ranking, an expert in the subject area arranges the factors of influence on the efficiency of reconstruction works in the order, most rational to him, and assigns ranks to it. In this case, rank No. 1 obtains the highest degree of significance of the influence of factor on the effectiveness of performing reconstruction work, and rank No. N – the lowest. Therefore, the ordinal scale, obtained as a result of ranking, must satisfy the condition of equality of the number of ranks «12» to the number of ranked factors «n» [12]. Next we compiled the summary table of ranks for all experts of the group (Table 3).

Table 1

Basic characteristics of the objects of restoration of water utilities networks by the «Berstlining» method

No. of entry	Characteristic		Object, No. of entry				
			OR1	OR2	OR3	OR4	OR5
Technical indicators							
1	Diameter, mm	Sanitated pipe	300	100	250	400	200
2		New pipe	315	100	250	400	200
3	Pipe material	Sanitated pipe	steel	steel	steel	iron cast	steel
4		New pipe	PE	PE	PE	PE	PE
5	Technical condition	Degree of overgrowing of pipe's inner wall	considerable	considerable	considerable	insignificant	considerable
6		Number of damages over last 5 years, pcs.	13	9	14	19	18
7		Damage nature*	A, B, C	A, B	A, B, C	C, D, E	A, B
8		Method for repair of damage**	a, b, c, d, e				
9	Number of connections to the sanitated pipeline, pcs.		9	3	11	12	8
10	Existence of turns in the route of pipeline		yes	no	yes	yes	no
11	Slope of the route, height difference		considerable	insignificant	insignificant	insignificant	insignificant
Organization-technological indicators							
12	Restoration section length, m		250	150	400	450	285
13	Number of target foundation pits, pcs.		3	3	6	10	4
14	Approximate distance between target foundation pits, m		125	75	80	45	95
15	Technological equipment	Name	Hydrostatic Pipeburster				
16		Traction force	T125	T40	T125	T125	T40
17	Working body motion direction		combined				

*Notes: * – nature of damage: A – pitting corrosion; B – through corrosion; C –breakdown of joint connection; D – longitudinal cracks; E – transverse cracks (breaks). ** – method for repair: a – local repair; b – steel clutch; c – closing of butt joint; d – partial replacement of pipe; e – application of anticorrosive coating*

Table 2

Factors that influence the choice of method for repairing a water utility network

No. of entry	Factor
F1	Diameter of the existing pipe
F2	Material of the worn pipeline
F3	Degree of overgrowing of pipe's inner wall
F4	Technical condition (availability of damage statistics, methods for damage repair)
F5	Existence of turns in the route of pipeline (longitudinal profile of the repaired section)
F6	Slope of the route, height difference (longitudinal profile of the repaired section)
F7	Restoration section length
F8	Number of target foundation pits
F9	Distance between target foundation pits
F10	Physical-mechanical properties of soil
F11	Number of connections to the sanitated pipeline
F12	Repair site (constrained construction, central part of the city, etc.)

Table 3

Results of a survey of experts who are included in the group

Factor	Expert										Total
	1	2	3	4	5	6	7	8	9	10	
F1	8	8	11	10	12	7	10	10	11	9	96
F2	6	6	6	6	5	5	6	5	6	5	56
F3	7	7	6	5	5	5	6	6	5	6	58
F4	1	2	3	2	1	2	3	2	2	1	18
F5	1	1	2	2	1	3	3	2	3	1	19
F6	3	5	4	4	5	5	4	3	3	4	40
F7	5	5	4	5	6	6	5	6	5	6	53
F8	12	10	11	12	12	10	10	10	12	11	110
F9	9	9	8	7	8	8	7	7	7	8	78
F10	2	1	2	2	2	1	1	1	1	2	15
F11	7	7	9	9	10	8	7	8	8	9	82
F12	8	10	11	9	11	9	11	9	8	10	96
Total	69	71	77	73	78	69	72	69	71	72	–

Since, in certain cases, the ranks, appointed by experts to one or another evaluated factor, coincide, we performed scaling of the ranks [12]. Scaling is the standardization of its kind and its purpose is to ensure that the sum of the ranks, appointed by each expert, is equal to the sum of members of natural series from 1 to n (where n is the number of factors of influence), which is calculated by formula:

$$R_{ij}^{stand} = \frac{R_{ij} \cdot D_{total}}{D_i}, \qquad (1)$$

where R_{ij} is the value of the i-th rank, j-th phenomenon; D_{total} is the sum of members of the series of phenomena.

The value of the sum of the ranks, assigned by the i-th expert to all factors, is determined by formula:

$$D_i = \sum_{j=1}^{n} Rij. \qquad (2)$$

Value D_{total} is found with the aid of the following ratio

$$D_{total} = n \cdot (n+1)/2, \qquad (3)$$

where n is the total number of factors of influence.

After conducting the standardization and calculations of all standardized ranks, we formed a table (Table 4, Fig. 9). It is evident from Fig. 9 that F4, F5, F6, F 10 gained the lowest sum of ranks, which indicates their largest significance.

Table 4

Results of a survey of experts, who are included in the group, taking into account the scaling

Factor	Expert										Total
	1	2	3	4	5	6	7	8	9	10	
F1	13.1	9.8	9.0	10.7	7.9	8.8	10.8	11.3	11.1	12.0	104.5
F2	6.6	5.4	6.8	6.4	5.7	6.6	6.5	5.7	6.1	5.0	60.8
F3	5.5	6.5	7.9	5.3	5.7	7.7	6.5	6.8	6.1	5.0	63
F4	2.2	1.1	1.1	2.1	2.3	2.2	3.3	2.3	3.0	1.0	20.6
F5	3.3	1.2	1.1	2.1	3.4	1.1	3.3	2.3	2.0	1.0	20.8
F6	3.3	4.3	3.4	4.3	5.6	5.5	4.3	3.4	4.1	5.0	43.2
F7	5.5	6.5	5.6	5.3	6.8	5.5	5.4	6.8	4.1	6.0	57.5
F8	13.2	11.9	13.6	12.8	11.3	11.0	10.8	11.3	11.1	12.0	119.0
F9	7.7	8.7	10.2	7.5	9.0	9.9	7.6	7.9	8.1	8.0	84.6
F10	1.1	2.2	2.3	2.1	1.1	1.1	1.1	1.1	2.0	2.0	16.1
F11	8.8	9.8	7.9	9.6	9.0	7.7	7.6	9.0	9.1	10.0	88.5
F12	8.8	10.8	9.0	9.6	10.2	11.0	11.9	10.2	11.1	11.0	103.6
Total	78	78	78	78	78	78	78	78	78	78	

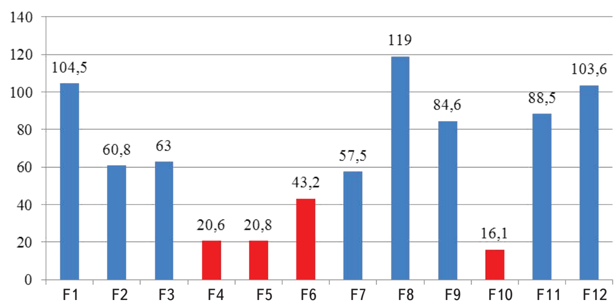

Fig. 9. Diagram of summary ranks of the examined factors according to the results of expert evaluation

In order to determine the coherence of experts, we used coefficient of concordance W [11], calculated by formula:

$$W = \frac{12S}{m^2 \cdot \left(n^3 - n\right)}, \qquad (4)$$

where m is the quantity of experts; n is the number of factors; S is the deviation of the sum of squares of significance from the mean squares of significance, which is determined by the following formula [11]:

$$S = \sum_{i=1}^{n}\left(\sum_{j=1}^{m} R_{ij}\right)^2 - \frac{\left(\sum_{j=1}^{n}\sum_{j=1}^{m} R_{ij}\right)^2}{n}. \qquad (5)$$

As a result of analysis of the standardized ranks and performed calculations, we obtained coefficient of concordance, equal to 0,828, which indicates a high degree of the coherence of opinions in the selected group of experts.

6. Discussion of results of examining the factors, which influence effectiveness of the «Berstlining» method when restoring water utilities networks

Out of the obtained data, it should be noted that from the above-described 12 factors, the highest degree of influence on the effectiveness of the «Berstlining» method when restoring water utilities networks is exerted by factors F4, F5, F6, F10 (summary rank of these phenomena – minimum), in particular: technical condition of pipeline (availability of damage statistics, methods for damage repair); physical-mechanical properties of soil; slope of the route; height difference (longitudinal profile of the repaired section); existence of turns in the route of pipeline (longitudinal profile of the repaired section).

At the object of restoration in Prospect Nauky Avenue, we observed partial «extrusion» of the existing pipeline from the ground massif into the target foundation pit. It testifies to the fact that they did not take into account the influence of such factors as physical-mechanical conditions of the soil, as well as technical condition of the pipeline. As a result of previous liquidations of emergencies, this section of water utilities network contained a considerable quantity of repair clutches. This resulted in heightened difficulty for the passage of working body of the traction installation (Fig. 10).

Fig. 10. «Extrusion» of the existing pipe from the ground massif at OR1 in Prospect Nauky Avenue (September 2015)

This fact led to an increase in the period of conducting reconstruction work.

Thus, results of the studies may find their application in the subsequent practice of performing repair and reconstruction work by the operating organizations in the networks of water supply. In future, it is of interest to quantitatively assess the factors, which influence effectiveness of the «Berstlining» method when restoring the water utilities networks.

7. Conclusions

1. On the basis of field research at the objects of restorations of water utilities networks, we generalized technical and organizational-technological peculiarities of conducting the work by the «Berstlining» method.

2. The factors are determined, which influence the effectiveness of conducting repair and recovery works by the «Berstlining» method: diameter of the existing pipe, material of the worn pipeline, degree of the overgrowing of the internal wall of a pipe, technical condition, the longitudinal profile of the section for restoration, length of the section for restoration, a quantity of target foundation pits and the distance between them, physical-mechanical conditions of the soil, a number of connections to the sanitized pipeline, the site of performed work.

3. It is established with the aid of the method of expert estimations that the highest degree of influence on effectiveness of the «Berstlining» method when restoring the water utilities networks is exerted by factors: technical condition of pipeline (availability of damage statistics, methods for damage repair), physical-mechanical conditions of the ground, slope of the route, height difference (longitudinal profile of the repaired section), presence of the turns in the route of pipeline (longitudinal profile of the section for restoration).

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STUDY OF THE PROCESS OF SOIL STRIP TILLAGE BY VERTICAL MILLING ADAPTER

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Об'єкт досліджень – процес смугового обробітку ґрунту вертикально-фрезерним адаптером розробленої конструкції. Предмет досліджень – визначення впливу кінематичних параметрів адаптера на показники якості обробітку. Виконані аналітичні дослідження дії адаптера на ґрунт та проведені експерименти за складеною методикою. Результати досліджень свідчать про можливість отримання заданих показників якості обробітку шляхом регулювання кінематичних параметрів

Ключові слова: смуговий обробіток ґрунту, вертикально-фрезерний адаптер, робоче середовище, кінематичні параметри

Объект исследований – процесс ленточной обработки почвы вертикально-фрезерным адаптером разработанной конструкции. Предмет исследований – определение влияния кинематических параметров адаптера на показатели качества обработки. Выполнены аналитические исследования действия адаптера на почву и проведены эксперименты по составленной методике. Результаты исследований свидетельствуют о возможности получения заданных показателей качества обработки путем регулирования кинематических параметров

Ключевые слова: ленточная обработка почвы, вертикально-фрезерный адаптер, рабочая среда, кинематические параметры

1. Introduction

Nowadays agricultural production is a major industry, which provides the internal consumer market and its saturation with foreign currency earnings through export. The agricultural sector is the most attractive for foreign and domestic investment. However, stable profitability in the sector is provided by extensive methods of management, and the introduction of new technologies is not becoming widely spread. This negative phenomenon is caused by a weak feedback between science and industry.

One of the new and promising technologies is the tripper strip soil tillage, which in the international practice became known as Strip-till. This method is the cultivation of the strip, into which crops will be sown, while the spaces between them will remain untilled, which combines the benefits of zero (No-till) and traditional technologies.

Therefore, a relevant problem of modern agricultural mechanics is the study of this technology, development of appropriate soil tillage tools, determining their effect on the environment and the substantiation of optimum parameters of cultivation process. This will make it possible to provide the agricultural sector with efficient equipment and to increase production intensity.

2. Literature review and problem statement

One of the main ways of influence on the natural environment in order to obtain products of plant growing is the change in volumetric mass (density) of soil by mechanical influence. To increase the volume of agricultural production in the middle of the last century, more than 50 % of Ukraine's territory was ploughed, which is one of the highest