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Research of Operation of Mobile Overpass Constructions

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Abstract. *The issues of calculation and research of operation of mobile overpass constructions are described. The proposed design has no analogues in the world and represents a new type of transport equipment that is a mobile overpass. The overpass combines a bridge structure and its own undercarriage for its transportation. The overpass is designed for vehicle driving along it and used to eliminate traffic jams on city roads during the repair of underground utility networks, by installing it above the repair trench. The idea of using the overpass is to eliminate congestion on the roads, improve the ecological condition of cities and transport logistics.*

Keywords: *transport equipment, undercarriage, mobile bridge construction, congestion, mobile overpass, temporary overpass, repair of communal networks, mobile overpass, temporary bridge, traffic congestion, city logistics.*

Introduction

Every year in large cities and megacities the number of different vehicles is growing. Tight road traffic causes traffic congestions because of various reasons. One of these reasons is the repair of communal networks (heating, water, etc.) located under the roadways of urban roads. During the repair of communal networks, vehicles are forced to bypass repair trenches along other streets, which creates traffic jams and worsens the transport picture of the city. Especially severe traffic jams harm the ecology of cities due to the simultaneous constant release of pollutants into the atmosphere from the exhaust gases of cars. In addition, traffic jams cause social and economic damage to residents and enterprises of the city.

To solve these problems, during the repair of communal infrastructure, there is a need for direct crossing of repair trenches by traffic flows to eliminate traffic jams and continuous movement of vehicles. To implement this idea, a communal mobile overpass was developed for the direct intersection of repair sections of roads and continuous traffic (Figure 1).

The mobile overpass is a temporary mobile bridge structure equipped with its own wheeled chassis for transportation, as well as special movement control and assembly mechanisms before operation [1].

Before starting the repair of communal networks the overpass is transported to its place of operation, installed over the trench in the perpendicular direction, which allows transport to make a direct crossing of the trenches along the overpass. This eliminates the need to detour repair areas and create traffic jams and congestion. When the repair of communal networks is completed, the overpass is set on its wheels and taken to its storage area. The transportation can be carried out using conventional tractors.

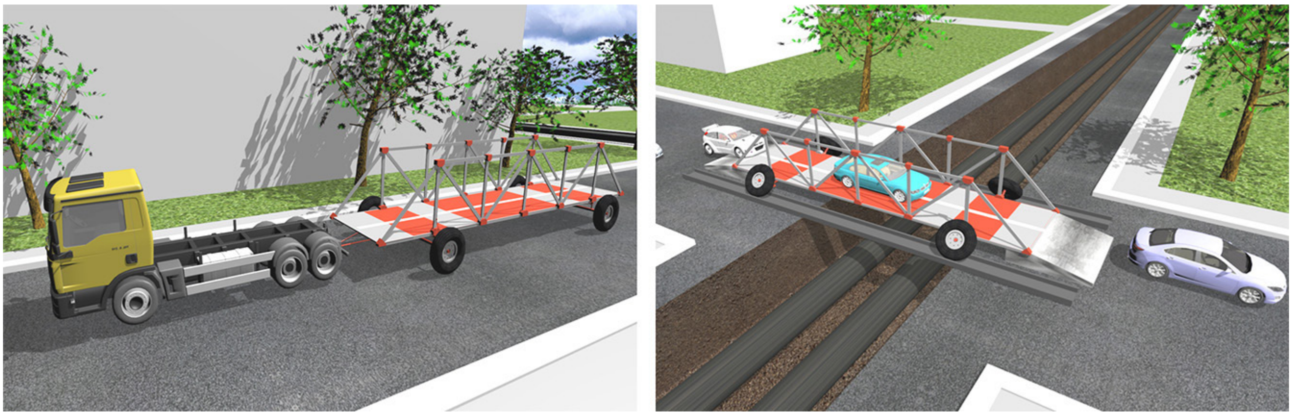
There are many ways to eliminate traffic jams and improve the ecology of the city. One of the possible was proposed by us that is the use of temporary mobile overpasses. As the review showed, such designs are practically absent. Similar constructions are found in engineering troops: tank bridge layers, tracked crossbars, etc. The high cost of tank bridge layers and other similar military equipment, as well as temporary stationary bridges, makes it impossible to use them in urban conditions. For these purposes, we proposed a communal mobile overpass, which lacks prototypes and analogues. The mobile overpass is a new development in the field of transport technology, which can be operated as a bridge and a vehicle simultaneously. This defines it as a new type of transport equipment [2].

During the movement of the overpass and its operation as a bridge, different loads occur that act on its constructions from both modes of operation. Therefore, the main task before creating an overpass is to determine all the design parameters of the overpass operating in different load ranges.

Thus, the key problem of the study is the study of the work of the overpass constructions, which works in joint modes of the bridge and transport equipment at the same time. Due to the fact that the mobile overpass lacks prototypes and world analogues as a new type of transport equipment, the study of the work of the mobile overpass is an urgent task.

Materials and Methods

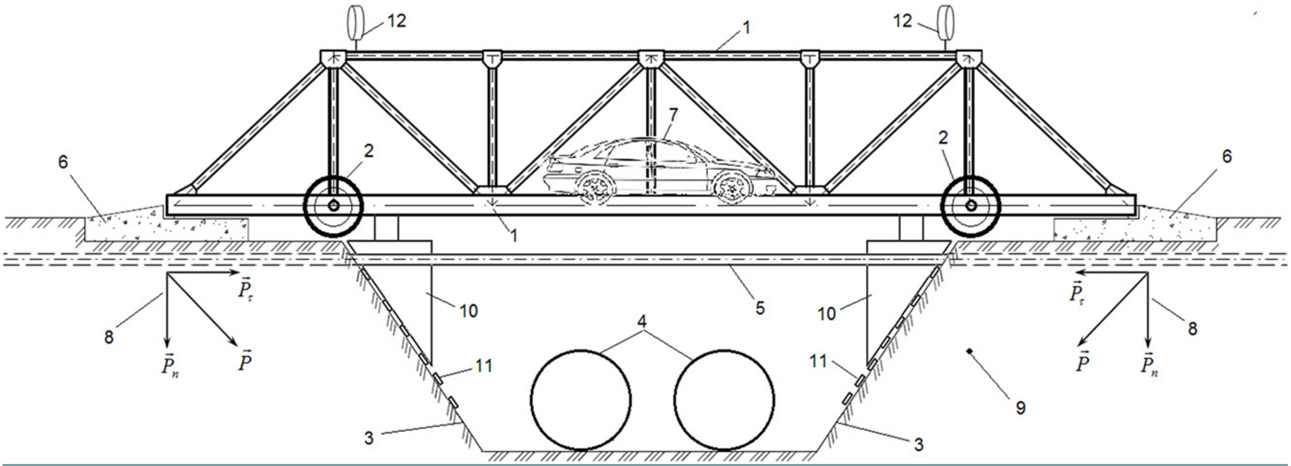
The communal mobile overpass is a single platform (Figure 2, item 1), is equipped with its own wheel chassis (Figure 2, item 2) and delivered to the installation site using a tractor on a trailer. After delivery, it is installed by means of lowering on trenches of communal networks (Figure 2, items 3, 4)



a) Overpass during transportation

b) Overpass during operation

Figure 1 – Communal mobile overpass



1 – bearing platform of overpass; 2 – wheel landing gear; 3 – trench boards; 4 – communal networks; 5 – guide skids; 6 – reinforced concrete supports; 7 – mobile transport; 8 – load on the ground; 9 – ground base. 10 – stop shields; 11 – ground deformation sensors; 12 – light signal

Figure 2 – Sketch scheme of an overpass with inventory equipment

using guide skids (Figure 2, item 5) thrown over the trench. After lowering on, the landing gear wheels are lifted and the overpass structure is lowered to reinforced concrete supports using jacks (Figure 2, item 6). An overpass with a length of 13.5m and a width of 3.1m can provide the driving of vehicles (Figure 2, item 7) weighing up to 3.5 tons over trenches up to 9m long and up to 2.5m deep. The overpass chassis consists of a frame structure of the front and rear axles carrying driving wheels, steering mechanisms of the front axle and mechanisms for lifting and lowering the wheels.

The overpass combines the bridge structure for driving vehicles and the structure of the wheel chassis. During the transport of the overpass (Figure 1, a), its construction, units and mechanisms experience variable loads and vibrations within a certain range. When the overpass works as a fixed bridge and transport moves along it (Figure 1 b, Figure 2, item 7), the operation of the overpass construction is already in another frequency range of loads and vibrations. In addition, during operation of the overpass as a bridge by means of its supports (Figure 2, item 6) loads are transmitted to the ground (Figure 2, items 8, 9), which may cause the destruction of the trenches boards during the operation of the overpass. This determines studies on the optimal location of overpass supports to prevent the destruction.

In addition to calculations on the optimal location of supports, in order to prevent the destruction of trench boards, mobile stop shields preventing the ground destruction have been developed (Figure 2, item 10), as well as special ground deformation sensors are used (Figure 2, item 11). As soon as the sensors detect the excess of permissible deformations of the trench board, the red light signal comes «ON» (Figure 2, item 12) prohibiting the entry of transport onto the overpass.

The purpose of the study is to substantiate, calculate and model the operation of the communal overpass construction. To achieve this goal, the research strategy was to solve the following problems: calculation and design of the load-bearing platform of the overpass from the action of the load of vehicles;

development and study of the wheel chassis operation taking into account interaction with the load-bearing platform; development of methods of optimal arrangement of overpass supports; development of methods of installation, transportation and additional equipment; development of a general calculation methodology. To solve these problems, the methods of mechanical and mathematical modeling were used; numerical modeling on LIRA and ANSYS software systems.

Results

Based on the results of calculations of the stress-strain state of the load-bearing platform, internal forces in its elements were obtained, the cross sections of all elements were selected, the percentage of use of load-bearing capacity by limit states was obtained, and structural stiffness was estimated. The results allow to design the construction of the bearing platform of the overpass. The calculation and design was performed by means of LIRA software complex [3, 4].

For the first time, the design of the overpass chassis for dynamic impacts was developed, justified and calculated, taking into account the joint work from the load-bearing platform and the loads from the overpass transportation. Internal forces and vibration fields of all chassis elements were obtained. The dependence of frequencies and internal forces on the terrain of the road during the transportation of the overpass was investigated. On the basis of these calculations, the cross sections of chassis elements were selected. Steering and landing gear and wheel lifting-lowering mechanisms have been developed.

The dependencies that determine the optimal positions of overpass supports from the edge of trench boards are obtained. They make it possible to arrange the supports in such a way that during the operation of the overpass, when transport is driving along it, there would be no critical destruction of the trench boards. These dependencies take into account the load of overpass supports on the ground base, all physical and mechanical properties and stress-strain state of the ground massif, geometry and boundary conditions of the calculated area. The dependencies are obtained on the basis of parametric optimization of ground calculation in the ANSYS software complex according to the Drucker-Prager non-linear model of ground deformation. In such problems, it was done for the first time, since the mechanics of grounds in most cases the Coulomb-More linear model, that provides insufficient accuracy is used [5, 6].

Two methods of mounting and dismantling the overpass have been developed: by means of the lowering on the trench and by means of crane installation. Installation cranes, tractors and trucks transporting the overpass were selected. The additional equipment required during the operation of the overpass has been developed: mounting crossarms, wheel braking system, lighting equipment, etc.

For the first time, based on the results obtained, a unified engineering methodology for calculating a mobile overpass was created. The terms of reference for production and design documentation have been developed.

In general, the scientific novelty is that the study of the construction that works as a transport vehicle when driving and as a bridge in a working position has been performed. This determines the new scientific result for each task in the form of the obtained dependencies.

Discussion

Similar studies on mobile overpasses have not been carried out before sufficiently. Most of them were performed for the first time. The high scientific and technical level of the research is determined in general by the novelty of the construction and the complexity of calculating a mobile overpass consisting of a different number of structures, supports, coupling devices, wheels, chassis and various mechanisms.

So in the problem of optimal placement of overpass supports, based on ANSYS, the Drucker-Prager non-linear ground deformation model was first used. According to this model, the calculation methods have been created that can be suitable for various grounds. To do this, we needed to confirm experimentally that this model works, so we conducted experimental studies. The aim of this study was to obtain deformation dependencies and characteristics of the ground sample experimentally and use them in a numerical experiment on ANSYS to test the Drucker-Prager non-linear model. At the first stage by means of special devices of compression and shear for ground sample deformation dependencies, modules of general deformation, angle of internal friction and specific adhesion are determined. At the second stage, the data obtained in the experimental tests for the ground sample were input in ANSYS and calculated. The results of the ANSYS ground sample compression calculations based on the Drucker-Prager model with experimental data are shown in Table.

It can be seen from Table 1 that at the first stage of loading the discrepancy between the experimental values and the calculated values reaches nearly 70%. As the load increases, the percentage of discrepancy decreases dramatically and at the final stages of loading it is slightly more than 4%. A large percentage of the discrepancy at the first stages of loading is due to the fact that under low initial loading, the elastoplastic model is ideally elastic and the initial values are obtained for the elastic body model. While, the ground itself is not an absolutely elastic body, which shows the nature of the distribution of deformations already at the initial stages of slight loading. As the load increases, in the elastoplastic model, plastic potentials associated with the nonlinearity of deformation are involved in the work and the calculated values reach the experimental ones. This behavior is characteristic of any nonlinear ground deformability model based on elastoplastic deformation [7].

Comparison of calculations in ANSYS with experiment

Loading q, N/m	Movements, mm			Relative deformations		
	Experiment	ANSYS, the Drucker-Prager model	Discrepancy, %	Experiment	ANSYS, the Drucker-Prager model	Discrepancy, %
4371,5	0,23	0,0677	70,6	0,009	0,002706	69,9
8743,0	0,40	0,135	66,2	0,016	0,005412	66,2
17486	0,50	0,271	45,8	0,020	0,010825	45,9
26229	0,57	0,406	28,8	0,023	0,016237	29,4
34972	0,60	0,541	9,8	0,024	0,021649	9,8
43715	0,65	0,677	4,2	0,026	0,027062	4,1

In the works of the authors the identification parameters of ground models on various stabilometers of Geotek (Russia) were determined, both for compression of the ground and for triaxial compression. Comparative analysis was performed with numerical calculations based on LS-DYNA and ANSYS programs. So for compression of the ground, the average percentage of discrepancy of experimental and calculated values based on the Craig, Schwei-Muray non-linear models of deformation, etc. reaches 42% [8, 9, 10].

In our case, the average percentage of discrepancy of experimental values and calculations in ANSYS is 37.55% (Table 1), which is much more accurate than in the classical methods of linear theory of ground mechanics and their modifications. In addition, this percentage is included in the zone of the stock factor according to construction codes and regulations. Thus, the Drucker-Prager non-linear elastoplastic ground model shows good convergence results with experimental results, which is also partially confirmed on other similar models by the work of researchers.

It should be noted that the comparison of experimental and calculated values according to the classical linear-elastic theory of ground can reach up to 100% or more. In this regard, various improved engineering calculation methods and correction coefficients are used that approximate the calculation to experimental values, which, in general, leads to sufficient accuracy for many engineering tasks to determine the deformability of ground bases. Thus, a difference of up to 50-70% in analytical engineering calculations with experimental results in ground mechanics is an acceptable result taking into account the additional coefficients of safety and strength.

Based on the above, the results of the experimental test of the Drucker-Prager nonlinear deformation model for the operation of the overpass support-ground base system give scientifically proved results for the engineering calculation of the optimization placement of overpass supports taking into account the main physical and mechanical properties of the ground base. The Drucker-Prager model was first applied to the calculation method of such structures and it is experimentally confirmed, which is a new scientific result.

Certainly, our approaches and research methodology are one of the possible and do not claim to be definitive originality. The results obtained require further improvement and development in order to improve the general engineering methodology for calculating, improve the efficiency of research and find new solutions.

Conclusion

The studies carried out contain new scientifically based results, the use of which provides the solution of an important practical task to create a new type of transport equipment that is a mobile overpass. The practical significance of the studies is determined by the development of a methodology for calculating the overpass construction, its installation, the creation of working drawings and design documentation for a prototype mobile overpass. The use of overpasses in large megacities is of great applied importance as the problem of traffic jams and environmental improvement is acute. This determines the further perspective development of the project, which consists in the creation of other constructions of mobile overpasses, consisting of many modules.

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Мобильді жол өтпесі конструкцияларының жұмысын зерттеу

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Аңдатпа. *Мобильді жол өтпесі конструкцияларының жұмысын есептеу және зерттеу мәселелері баяндалады. Ұсынылып отырған конструкцияның әлемде баламасы жоқ және көлік техникасының жаңа түрі – мобильді жол өткелі болып табылады. Жол өткелі тасымалдау үшін көпір конструкциясын және өзінің жүріс бөлігін біріктіреді. Жол өтпесі автокөліктердің жүруіне арналған және жер асты коммуналдық желілерін жөндеу кезінде қалалық жолдардағы кептелістерді жою үшін, оларды жөндеу траншеясының үстіне орнату жолымен қолданады. Жол өткелін қолдану идеясы жолдардағы кептелістерді жою, қалалардың, көлік логистикасының және т.б. экологиялық жағдайын жақсарту болып табылады.*

Кілт сөздер: *көлік техникасы, жүріс бөлігі, мобильді көпір конструкциясы, кептеліс, уақытша жол өтпесі, коммуналдық желілерді жөндеу, мобильді жол өтпесі, уақытша көпір, жол кептелісі, қала логистикасы.*

Исследование работы конструкций мобильного путепровода

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Аннотация. *Изложены вопросы расчета и исследования работы конструкций мобильного путепровода. Предлагаемая конструкция не имеет аналогов в мире и представляет собой новый вид транспортной техники – мобильный путепровод. Путепровод объединяет в себе мостовую конструкцию и собственную ходовую часть для ее транспортировки. Путепровод предназначен для проезда по нему автотранспорта и применяется для устранения пробок на городских дорогах во время ремонта подземных коммунальных сетей, путем установки его над ремонтной траншеей. Идеей применения путепровода является устранение заторов на дорогах, улучшение экологического состояния городов, транспортной логистики и т.п.*

Ключевые слова: *транспортная техника, ходовая часть, мобильная мостовая конструкция, затор, временный путепровод, ремонт коммунальных сетей, мобильный путепровод, временный мост, дорожная пробка, логистика города.*

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