МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

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V. V. MAROCHKA[1], S. H. BOBOSHKO[2*]

[1] Department «Bridges and tunnels» of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan Str., 2, Dnepr, Ukraine, 49010, tel. +38 (056) 776 83 10, e-mail markay905@gmail.com, ORCID 0000-0001-8856-5708
[2*] Department «Bridges and tunnels» of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Lazaryan Str., 2, Dnepr, Ukraine, 49010, tel. +38 (056) 776 83 10, e-mail stepanboboshko@gmail.com, ORCID 0000-0002-7612-0696

DEVELOPMENT OF TECHNOLOGY OF ARRANGING AREAS WITH TRANSITIONAL STIFFNESS INDEX ON APPROACHES TO RAILWAY BRIDGES

Purpose. To investigate the issue of transitional rigidity on the railways of Ukraine, to form a complex of existing measures to strengthen the transitional sections, to develop and justify the solution to the problem of transitional stiffness on approaches to railway bridges. **Methodology.** Theoretical research methods analysis and synthesis has been used. For mathematical modeling of the structure, a finite element method has been used - a three-dimensional mathematical model was created with stiffnesses corresponding to real ones, and loaded by static load of the rolling stock. **Findings.** The analysis of the literature and the experience of developed countries on the issue of arranging areas with transitional stiffness index on approaches to railway bridges, proposed and developed a solution for amplifying sections with transitional stiffness, a theoretical calculation of the mathematical model of the corresponding areas was developed the working draft for arranging areas with transitional stiffness index on approaches to railway bridges has been designed. **Originality.** The technology of amplification of areas with transitional stiffness has been proposed, a model of a section with a transitional stiffness index has been developed and constructed in the first approximation. **Practical value.** Developed construction of soil-cement piles allows to enhance areas with transitional stiffness index on approaches to railway bridges. The obtained data open up new possibilities in the experimental study of areas with a transitional stiffness index.

Keywords: transitional stiffness; approaches; embankment, abutment, soil-cement; mathematical model

Introduction

There are more than 21 879 km of ground canvas in Ukraine, that includes about 19500 artificial structures with a total length of more than 625 km.

An analysis of the experience of railways operation in the US, Europe and Australia showed that as of 2006, about 50% of approaches to bridges have local under-depths from 60 to 102 mm in depth and from 1.2 to 15.2 m in length. On the territory of railways with a width of 1520 mm, the same data were not analyzed, but this problem is no less relevant.

The problem of transitional areas was so significant that many countries try to solve it in a variety of ways today. There are significant and sufficiently large studies of transitional areas are carried out in the US, China, Poland and other countries due to the abrupt increase of the velocity of motion.

Purpose

To develop a technology for strengthening the ground canvas on approaches to the bridge to prevent the emergence of bumps. To confirm the correctness of the developed technology through theoretical calculations.

Methodology

It is clear that the embankments and supports of the bridges differ fundamentally not only by the material they are composed of, but also by the way of their reliance on the foundation. At the same time, the temporary loads received by them are the same, which leads to a substantial difference in the character of the use of embankments and bridges.

In railway and highway bridges constructing, the bridge with the embankment is usually not arranged. Generally speaking, bridges subsidences are much smaller than the subsidences of the embankments that connect with it. As a result, in a place of connection of the embankment and bridge, there are forming subsidences that make the entrance to the bridge more complicated. These subsidences are usually called bumps.

The consequence of the appearance of bumps may be the appearance of so-called "hanging" sleepers under which the gaps are formed, which leads to a thrust at the passage of rolling stock. Phenomenas like this are unacceptable, especially in arranging of lines of high-speed traffic [11].

Transition areas can only be considered in conjunction with bridges and embankments, which create a whole range of impacts on these elements, as discussed in Fig. 1.

The abrupt change in the vertical stiffness of the track leads to an abrupt change in the movement of the wheel in the rolling stock, which causes uneven bending of the track [5]. This change in movement results in the vertical acceleration of the attached mass of the rolling stock, what leads to the application of additional vertical force. This mechanism is self-replicating as a dynamic load, which increases the amount of deflection each time and, consequently, the influence on the structure [13].

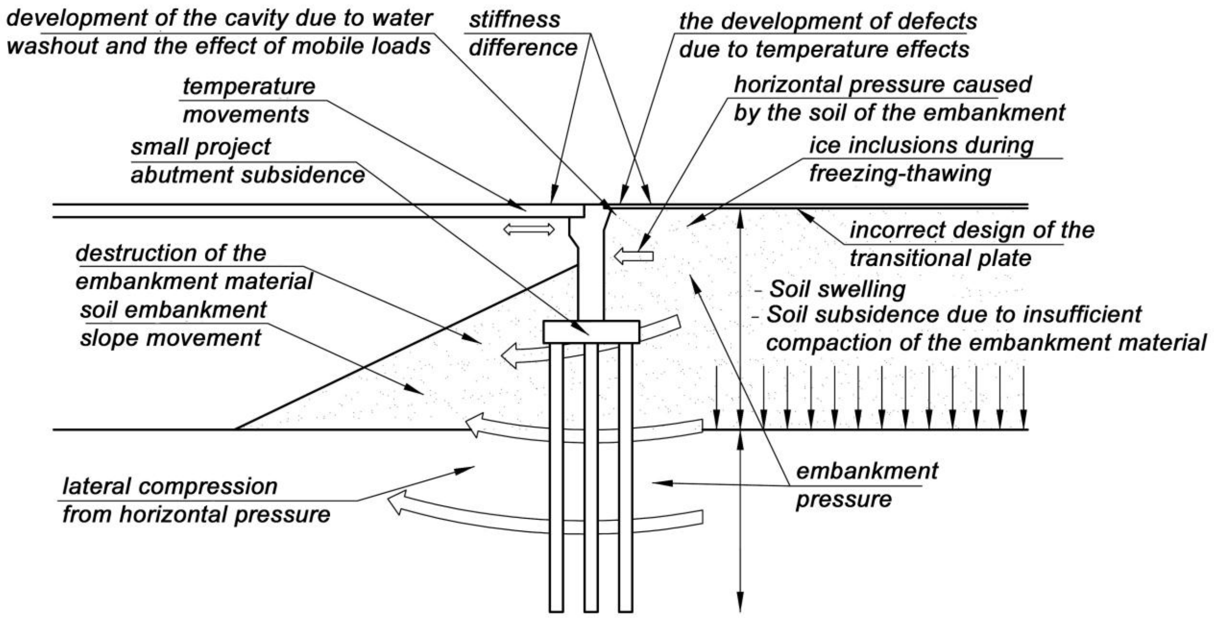

Fig. 1. Factors affecting areas with transient rigidity

This effect of increasing the load depends on the direction of movement of the train. When the train moves in the direction from the higher rigidity to the lower one, for example from the bridge to the embankment, the dynamic load is applied to the structure with less rigidity, resulting in a decrease in the velocity of subsidence. This phenomenon is characterized by the deterioration of the geometry of the track, the sprawl of the ballast prism, the general subsidence of the lower structure of the track.

In world studies of this issue there are a number of reasons that contribute to the emergence of this phenomenon, and various authors tend to different weight of various reasons. After analyzing and summarizing the world experience, the following classification of the causes of bumps was made:

- the difference of sinking of the embankment and abutment;
- difference of the modulus of elasticity of the track in adjacent areas;
- the quality of the transient construction;
- dynamic load;
- properties of ballast material;
- condition of drainage standing;
- damping properties of adjacent structures;
- type of abutment and its construction;
- structure of linking bridge and embankment;
- characteristics of temporary loads;
- overall quality of consolidated structures.

Summarizing these reasons, the researchers tend to think that in the design of structures of transitional rigidity, they must gradually change the three parameters of the base:

- sinking;
- stiffness;
- damping.

If not taking into account at least one of the above-mentioned factors, the design efficiency will be low. To solve the problem of bump, there is a significant number of solutions [1, 6, 9] that can be combined into several principal lines:

- floating plate arrangement.

The arrangement of the floating plate can be reduced or divided by a larger length of subsidence of the transition of the mantle (Fig. 2). The length of the floating plate is always determined depending on the height of the mound.

Homogenization of ballast by injection of synthetic astringent materials [1]:

- the method is based on gluing the crushed stone ballast on the transition region by injecting synthetic astringent materials in it (Fig. 3);
- reinforcing the embankment of transitional parts.

Using soils with higher requirements for sediment, which fall under the scheme shown in Fig. 4.

Geogrids are laid in a layer, through every 30...50 cm, in the places of docking with the bridge - are wrapped up.

Construction of transition areas from reinforced concrete boxes filled with crushed stone.

The design consists of reinforced concrete boxes, which are bottomless boxes, whose cavities are filled with a ballast, as shown in Fig. 5.

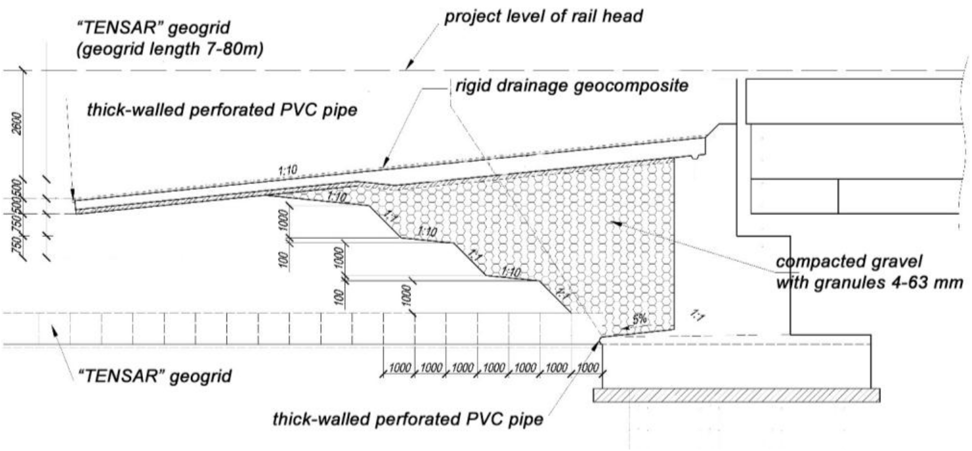

Fig. 2. Construction of a transitional area with a floating plate

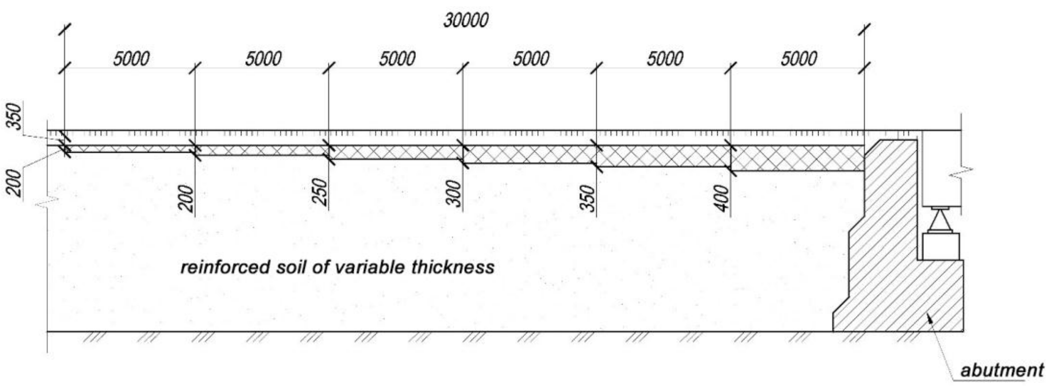

Fig. 3. Construction of the transitional area with the monolithic ballast

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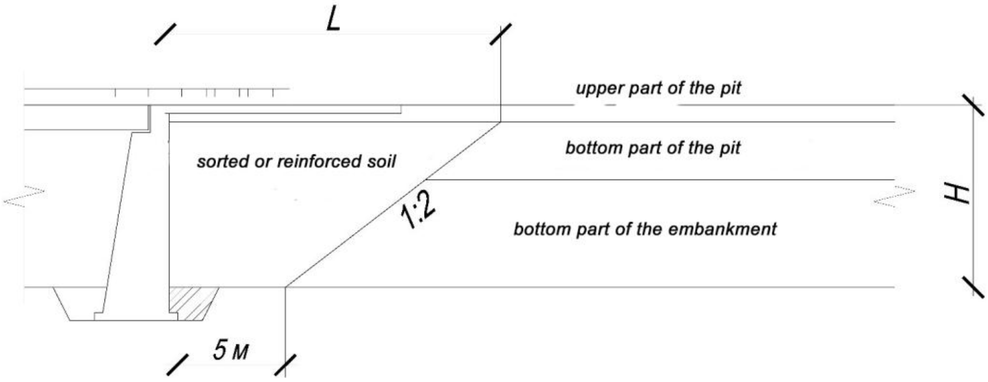

Fig. 4. Construction of the transitional area with the masonry reinforcement

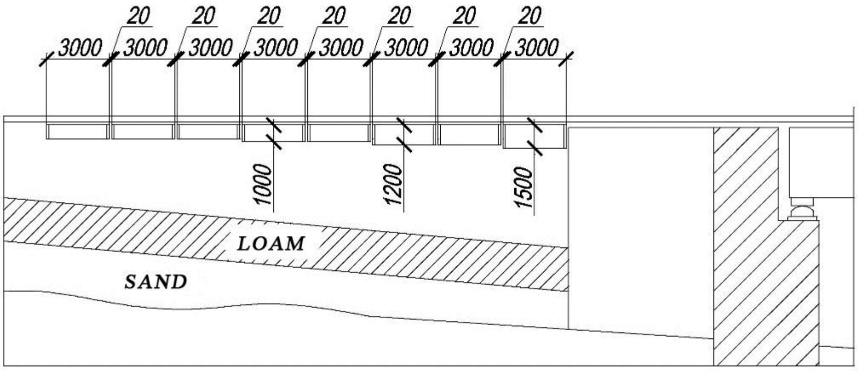

Fig. 5. Construction of the transitional area using reinforced concrete boxes

Such design significantly reduces the intensity of precipitation by prevention of ballast prism spraying due to the presence of lateral walls.

For the possibility of analyzing the data of field tests and conducting further theoretic researches on the regulation of the rigidity indexes on the approaches to the experimental bridge, which was provided by the regional branch "Pridneprovska zaliznitsa" of PJSC "Ukrzaliznytsya" for the research work, a mathematical model of the sections of the embankments on approaches to the bridge of the finite elements was calculated.

The model is based on a metal single-line railway bridge through the Bazavluk river, according to the scheme 2x55,00 m, the full length 126,60 m.

The model was built for a standing bridge and a 50-meter long bridge approach.

Findings

The construction of the model was carried out in the program complex "Lyra-CAD" taking into account the peculiarities of the construction of soil masses, given in [7].

To simplify the calculation, the model was constructed without taking into account slopes of the embankment, that is, almost in the form of a flat model.

The model includes: abutment on the ground-based foundation, embankment scarp in front of the abutment and the embankment behind abutment on which the load is applied [2].

The construction of the model was carried out according to the working drawings of the bridge by constructing the contour, its triangulation and protruding along the axis [8]. In this way, a mathematical model was obtained (Fig. 6).

Performing the calculation according to the norms [3,4], the deformation characteristic of the model has been obtained (Fig. 7).

To construct the model, taking into account the gain in the form of ground cement piles, we use the same initial data as for the previous one with the addition of ground cement piles in the form of rod finite elements.

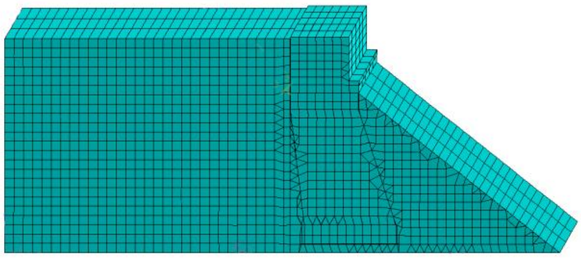

Fig. 6. Model of bulk finite elements

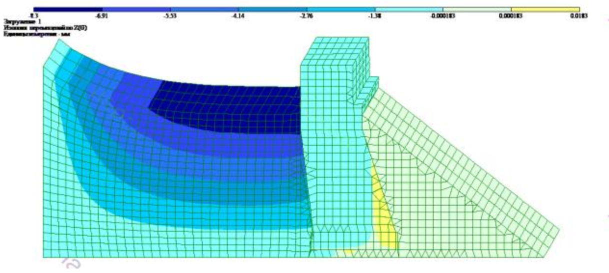

Fig. 7. Deformation of the model under load

Consequently, the model includes: abutment, surrounded by a soil array in accordance with the scheme of a bridge and piles of variable length (from 13 to 1 meter), located along the embankment behind abutment (Fig. 8).

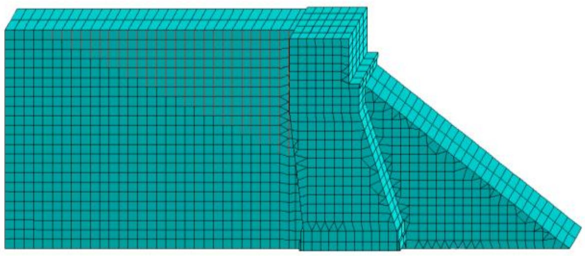

Fig. 8. The location of finite elements for modeling piles of fortifications

Performing the calculation according to the norms [3, 4], we obtain the following deformational characterization of the model (Fig. 9).

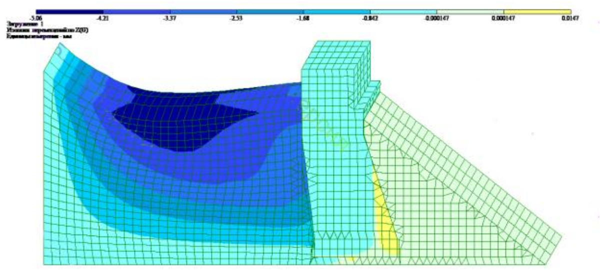

Fig. 9. Deformation of the model under load

Result of the calculation shows, that the use of ground cement piles significantly reduces soil draft loading in places of transitional rigidity from temporary load.

Experimental study of the mechanism of the work of the embankment in the road construction is possible using the method of centrifugal modeling, which allows to trace the qualitative picture of deformation, and knowledge of the general nature of deformation, which has led to the importance of correct statement of theoretical studies and to explain some phenomena occurring in nature.

The essence of the method of centrifugal modeling lies in the fact that as a field of force, such a gravitational field of centrifugal forces created when rotating a centrifugal machine is used. The model of a ground structure, made of natural material, is placed in a centrifuge, creating at its rotation a field of centrifugal forces similar to gravitational, but has a significantly higher intensity. Thus, the centrifugal modeling provides a complete preservation of the nature of the processes occurring in the design [9].

The results of practical research will be presented in the following scientific papers.

Originality and practical value

The proposed enhancement gives the possibility to amplify the embankment in areas with a transitional rigidity index without disassembling the upper structure of the track, which is a cost-effective solution in comparison with other similar types of reinforcements.

The reinforcement of areas with a transitional rigidity indicator is now a task that ensures the uninterrupted operation of the track in approaches to bridges. This problem is becoming even more relevant with the introduction of high-speed traffic on Ukrainian railways. The described decisions help to speed up integration of Ukrainian railways into the European space.

On the basis of theoretical research, a technology was developed for the construction of areas with transitional rigidity on approaches to bridges.

Conclusions

As a result of comparison of the data received by the theoretical and experimental model it is found out:

- when modeling the existing design of the approaches, maximum deformations of 8,3 mm are obtained for the theoretical model;
- in simulation of the construction with reinforcement in the form of ground cement piles, maximum strains were obtained which made 5.06 mm for the theoretical model.

The given results allow confirming the expediency and adequacy of the proposed type of reinforcement of sites with a transitional rigidity index.

The conducted research proves the relevance of this topic. The performed calculations open new possibilities for theoretical calculation of areas with transitional rigidity. The next step of the research will be to develop and calculate new types of enhancement of the embankments.

REFERENCES

1. Вальцева, Т. Ю. Деформируемость железнодорожных насыпей на слабых основаниях, усиленных геосинтетическими материалами в условиях дальнего востока [Текст] : автореф. дис. канд. техн. наук : 20.05.2011 / Вальцева Татьяна Юрьевна, Дальневосточный государственный университет путей сообщения. – Хабаровск : 2011. – 24 с.
2. Городецкий, А. С. Компьютерные модели конструкций [Текст] / А. С. Городецкий, И. Д. Евзеров. – Киев : Факт, 2008. – 394 с.
3. ДБН В.1.2-15:2009. Споруди транспорту. Мости та труби. Навантаження і впливи [Текст]. – Надано чинності 2009-11-11. – Київ : Мінрегіонбуд України, 2009. – С. 14-16.
4. ДБН В.2.3-14:2006. Споруди транспорту. Мости та труби. Правила проектування [Текст]. – Надано чинності 2006-05-06. – Київ : Мінрегіонбуд України, 2006. – 233 с.
5. ДБН В.2.3-19-2008. Споруди транспорту. Залізниці колії 1520 мм. Норми проектування [Текст]. – Надано чинності 2008-01-26. – Київ : Мінрегіонбуд України, 2008. – С. 29-36.
6. Дыдышко, П. И. О комплексных подходах к обеспечению к обеспечению защиты земляного полотна и верхнего строения пути в прибрежных и горных районах [Текст] / И. Дыдышко // Вестник научно-исследовательского института железнодорожного транспорта – Москва : 2013. – Вып. 6. – С. 31-39.
7. Купрій, В. П., Моделювання сумісної роботи конструкції кріплення котловану та ґрунту з застосуванням методу скінчених елементів (МСЕ) [Текст] / В. П. Купрій, Є. Ю. Кулаженко, А. С. Гудкова // Мости та тунелі: теорія, дослідження, практика. – 2015. – Вип. 7. – С. 19-26.
8. Лира 9.4® Примеры расчёта и проектирования. Учебное пособие [Текст] / В. Е. Боговис, Ю. В. Гензерский, Ю. Д. Гераймович, А. Н. Куценко, Д. В. Марченко, Д. В. Медведко, Я. Е. Слободян, В. П. Титок. – Киев : Факт, 2008 – 280 с.
9. Пьянков, С. А. Механика грунтов : учебное пособие [Текст] / С. А. Пьянков, З. К. Азизов. – Ульяновск : УлГТУ, 2008. – 103 с.
10. Талавіра, Г. М., Відвід жорсткості підшпальної основи на ділянках перед штучними спорудами [Текст] / Г. М. Талавіра, А. В. Кудін // Мости та тунелі: теорія, дослідження, практика. – 2015. – Вип. 7. – С. 75-80.
11. Solomka, V. World experience of design of bridges and their operating conditions on railways with a high speed of trains [Text] / Valentina Solomka, Pavlo Ovchinnikov // Мости та тунелі: теорія, дослідження, практика. – 2014. – Вип. 6. – С. 147-153.
12. Weiher, H. «Verhalten von PE-HD Schutzhüllen bei der Umlenkung von verbundlosen Spanngliedern», Dissertation TU München, submitted in 2007.
13. Yau J-D, Yang Y-B, Kuo S-R. Impact response of high-speed rail bridges and riding comfort of rail cars. Eng Struct 1999; 836-44.

В. В. МАРОЧКА[1], С. Г. БОБОШКО[2*]

[1] Кафедра «Мосты и тоннели», Днепропетровский национальный университет железнодорожного транспорта имени академика В. Лазаряна, ул. Лазаряна, 2, Днепр, Украина, 49010, тел. +38 (056) 776 83 10, эл. почта markay905@gmail.com, ORCID 0000-0001-8856-5708
[2*] Кафедра «Мосты и тоннели», Днепропетровский национальный университет железнодорожного транспорта имени академика В. Лазаряна, ул. Лазаряна, 2, Днепр, Украина, 49010, тел. +38 (056) 776 83 10, эл. почта stepanboboshko@gmail.com, ORCID 0000-0002-7612-0696

РАЗРАБОТКА ТЕХНОЛОГИИ УСТРОЙСТВА УЧАСТКОВ С ПЕРЕХОДНЫМ ПОКАЗАТЕЛЕМ ЖЕСТКОСТИ НА ПОДХОДАХ К ЖЕЛЕЗНОДОРОЖНЫМ МОСТАМ

МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ

Цель. Исследовать вопрос переходной жесткости на железных дорогах Украины, сформировать комплекс существующих мероприятий по усилению переходных участков, разработать и обосновать решение проблемы переходной жесткости на подходах к железнодорожным мостам путем комбинирования разных методик. **Методика.** Для решения поставленной задачи использованы теоретические методы исследования – анализ и синтез. Для математического моделирования конструкции использован метод конечных элементов – создана трехмерная математическая модель с жесткостями, соответствующими реальным, к которой приложена статическая расчётная нагрузка подвижного состава. **Результаты.** Выполнен анализ литературных источников и опыта развитых стран мира по проблеме устройства участков с переходным показателем жесткости на подходах к железнодорожным мостам, предложено и проработано решение по устройству усиления участков с переходной жесткостью, выполнен теоретический расчет математической модели соответствующего участка, разработан рабочий проект по устройству участков с переходной жесткостью на подходах к железнодорожным мостам. **Научная новизна.** Предложена технология усиления участков с переходной жесткостью, разработана и построена модель участка с переходным показателем жесткости в первом приближении. **Практическая значимость.** Разработанная конструкция из грунтоцементных свай позволяет усиливать участки с переходным показателем жесткости на подходах к мостам без разборки верхнего строения пути. Полученные данные открывают новые возможности в экспериментальном исследовании участков с переходным показателем жесткости.

Ключевые слова: переходная жесткость; подходы; насыпь; устой; грунтоцемент; математическая модель

В. В. МАРОЧКА[1], С. Г. БОБОШКО[2*]

[1] Кафедра «Мости і тунелі», Дніпропетровський національний університет залізничного транспорту імені академіка В. Лазаряна, вул. Лазаряна, 2, Дніпро, Україна, 49010, тел. +38 (056) 776 83 10, ел. пошта markay905@gmail.com, ORCID 0000-0001-8856-5708
[2*] Кафедра «Мости і тунелі», Дніпропетровський національний університет залізничного транспорту імені академіка В. Лазаряна, вул. Лазаряна, 2, Дніпро, Україна, 49010, тел. +38 (056) 776 83 10, ел. пошта stepanboboshko@gmail.com, ORCID 0000-0002-7612-0696

РОЗРОБКА ТЕХНОЛОГІЇ УЛАШТУВАННЯ ДІЛЯНОК З ПЕРЕХІДНИМ ПОКАЗНИКОМ ЖОРСТКОСТІ НА ПІДХОДАХ ДО ЗАЛІЗНИЧНИХ МОСТІВ

Мета. Дослідити питання перехідної жорсткості на залізницях України, сформувати комплекс існуючих заходів щодо підсилення перехідних ділянок, розробити і обґрунтувати рішення проблеми перехідної жорсткості на підходах до залізничних мостів шляхом комбінування різних методик. **Методика.** Для вирішення поставленого завдання використані теоретичні методи дослідження - аналіз та синтез. Для математичного моделювання конструкції використаний метод кінцевих елементів - створена тривимірна математична модель з жорсткостями, що відповідають реальним, до якої прикладене статичне розрахункове навантаження рухомого складу. **Результати.** Виконаний аналіз літературних джерел і досвіду розвинених країн світу щодо проблеми пристрою ділянок з перехідним показником жорсткості на підходах до залізничних мостів, запропоновано і опрацьовано рішення по влаштуванню підсилення ділянок з перехідною жорсткістю, виконано теоретичний розрахунок математичної моделі відповідної ділянки, розроблений робочий проект по влаштуванню ділянок з перехідною жорсткістю на підходах до залізничних мостів. **Наукова новизна.** Запропоновано технологію посилення ділянок з перехідною жорсткістю, розроблена і побудована модель ділянки з перехідним показником жорсткості в першому наближенні. **Практична значимість.** Розроблена конструкція з ґрунтоцементних паль дозволяє підсилювати ділянки з перехідним показником жорсткості на підходах до мостів без розбирання верхньої будови колії. Отримані дані відкривають нові можливості в експериментальному дослідженні ділянок з перехідним показником жорсткості.

Ключові слова: перехідна жорсткість; підходи; насип; стоян; ґрунтоцемент; математична модель

REFERENCES

1. Valtseva T. Yu. *Deformiruemost zheleznodorozhnyih nasyipey na slabyih osnovaniyah, usilennyih geosinteticheskimi materialami v usloviyah dalnego vostoka. Avtoreferat Diss* [The deformability of railway

embankments on weak foundations, reinforced geosynthetic materials in the conditions of the Far East]. Habarovsk, 2011, 24 p.
2. Gorodetskiy A. S., Evzerov I. D. *Kompyuternyie modeli konstruktsiy* [Computer models of constructions]. Kyjiv, Fact Publ., 2008, 394 p.
3. *DBN V.1.2-15:2009. Sporudy transportu. Mosty ta truby. Navantazhennya i vplyvy* [State Standard V.1.2-15: 2009. Transport facilities. Bridges and pipes. Loads and effects]. Kyjiv. Minrehionbud Ukrainy Publ., 2009, pp. 14-16.
4. *DBN V.2.3-14:2006. Sporudy transportu. Mosty ta truby. Pravyla proektuvannja* [State Standard V.2.3-14: 2006. Transport construcctions. Bridges and pipes. Design rules]. Kyjiv. Minrehionbud Ukrainy Publ., 2006, 233 p.
5. *DBN V.2.3-19-2008. Sporudy transportu. Zaliznyci koliji 1520 mm. Normy proektuvannja* [State Standard C.2.3-19-2008. Transport facilities. Railway track 1520 mm. Design standards]. Kyjiv. Minrehionbud Ukrainy Publ., 2008. pp. 29-36.
6. Dyidyishko P. I. O kompleksnyih podhodah k obespecheniyu k obespecheniyu zaschityi zemlyanogo polotna i verhnego stroeniya puti v pribrezhnyih i gornyih rayonah [An integrated approach to providing for the protection of the roadbed and track structure in the coastal and mountain areas]. Vestnik nauchno-issledovatelskogo instituta zheleznodorozhnogo transporta [Bulletin of the Research Institute of Railway Transport]. Moskow. 2013, issue 6, pp. 31-39.
7. Kuprii V. P., Kulazhenko Ye. Yu., Hudkova A. S. Modeliuvannia sumisnoi roboty konstruktsii kriplennia kotlovanu ta gruntu z zastosuvanniam metodu skinchenykh elementiv (MSE) [Modeling collaboration mount design, excavation and soil using finite element method (FEM)]. *Mosty ta tuneli: teorija, doslidzhennja, praktyka – Bridges and tunnels: theory, research, practice*, 2015, issue 6, pp. 132-137.
8. Bogovis V. E., Genzerskiy Yu. V., Geraymovich Yu. D., Kutsenko A. N., Marchenko D. V., Medvedko D. V., Slobodyan Ya. E., Titok V. P. Lira 9.4® Primeryi raschyota i proektirovaniya. Uchebnoe posobie [Lira 9.4® Examples of calculation and design. Tutorial]. Kyjiv, Fact Publ., 2008, 280 p.
9. Pyankov S. A., Azizov Z. K. Mehanika gruntov: uchebnoe posobie [Soil Mechanics: A Training Manual]. Ulyanovsk, UlGTU Publ., 2008, 103 p.
10. Talavira H. M., Kudin A. V. Vidvid zhorstkosti pidshpalnoi osnovy na diliankakh pered shtuchnymy sporudamy [Disqualification stiffness pidshpalnoyi bases in areas under artificial structures]. *Mosty ta tuneli: teorija, doslidzhennja, praktyka – Bridges and tunnels: theory, research, practice*, 2015, issue 7, pp. 75-80.
11. Solomka V., Ovchinnikov P. World experience of design of bridges and their operating conditions on railways with a high speed of trains. *Mosty ta tuneli: teorija, doslidzhennja, praktyka – Bridges and tunnels: theory, research, practice*, 2014, issue 6, pp. 147-153.
12. Weiher H., «Verhalten von PE-HD Schutzhüllen bei der Umlenkung von verbundlosen Spanngliedern», Dissertation TU München, submitted in 2007.
13. Yau J-D, Yang Y-B, Kuo S-R. Impact response of high-speed rail bridges and riding comfort of rail cars. Eng Struct 1999; 836-44.

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