
МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

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WORLD EXPERIENCE OF DESIGN OF BRIDGES AND THEIR OPERATING CONDITIONS ON RAILWAYS WITH A HIGH SPEED OF TRAINS

Purpose. Analysis of world experience of design bridge structures and their operation conditions for higher-speed railways. Browse questions of experimental and theoretical research of interaction of bridge structures and moving load. **Methodology.** To perform the analysis of published works that display world experience on design bridge structures and their operation conditions for higher-speed railways, university's library resource and possibility of unlimited Internet access were used. **Findings.** In this article the result of literature sources research, which displays world experience of design and computation of bridge structures on high-speed railways are presented. **Originality.** Results of this work show the present state of in research interaction of bridges and rolling stock on the high-speed railways of Ukraine and the world as well as of possibilities of using bridges, exploited for a long period of time, under loads which move on of high speed and what are features of work construction elements in this case must be considered. **Practical value.** A problem that regarded in the article will allow us to develop methodology of calculation for bridge structures that are in operation on the high-speed railways and apply results of the science work when developing of new projects span structures.

Keywords: stress-strain state; span; high-speed train; bridge-vehicle interaction; reliability; durability

Introduction

Until now, the consideration of dynamic influence of moving stock on bridges in regulatory documents is conducted based on generalization of experimental data. Such approach for solving the problem of dynamic effect of existing moving loading on bridge structures that are in operation becomes not sufficient. The urgent necessity of creating universal method of dynamic analysis for bridge constructions that would allow to correctly consider the most important features of interaction between existing and perspective moving loads and different types of bridge structures based on modern computer technologies is arising.

Purpose

The purpose of given article is to analyze world experience of bridge structures design and their operation conditions on high-speed and higher-

speed railways and the problem review for experimental and theoretical research of bridge structures and moving stock interaction.

Methodology

To perform the analysis of published works that display world experience on bridge structures design and their operation conditions for high-speed and higher-speed railways, university's library resource and possibility of unlimited World Wide Web access were used.

To develop the methodology of computation for stress-strain state of bridge structures with consideration of dynamic influence of high-speed trains the requirements and demands of Ukrainian regulatory documents for bridge design and requirements of European regulatory documents (Eurocodes) are reviewed. The comparative method for computation of dynamic factors with considering of Ukrainian and European normative documents re-

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quirements is used. Also methodology for modeling of bridge structures considering the loads and dynamic effect of moving stock that is train passing on the bridge with high speed was developed.

Findings

It may be advisable to review the literature that is linked to bridges operation on high-speed railways with dividing it into two groups. The first one, less numerable, is literature about problems of design, like the selection of bridge design, bridge scheme, cross-sections of spans and other elements, permanent way and others. In the second group there's literature that is devoted to interaction between bridge and moving stock in conditions of high-speed trains passage. This topic is being developed for some decades already and there are a lot of monographs and science works dedicated to it. Separated big group in these researches is works of Chinese, Korean and Japanese civil engineers.

Nowadays regulatory documents, methods, instructions and guidance's of local and foreign scientists that are put into operation are used for bridges design on high-speed railways. Such sources include classic bridge-design literature written by Hibshman M. E., Petropavlovsky A. A., Popov S. A., Bondar M. H. find others, also foreign experts Wai-Fah Chen [1], Benaim R., Iles D. C. and others. This can be explained by the fact that usually bridges for high-speed railroad are not considered to be separated group and are viewed along with all the other ones. It's notable that even the European regulatory documents (Eurocodes) don't consider bridges for high-speed railway to be a separated group, in return it's possible to find some works that include explanations of how to design such bridges [2-4]. Some data for the design is given in compiled articles [5, 6] that are fully dedicated to search for optimal parameters for bridge design. These publications clarify the process of selecting the optimal bridge scheme and cross-section design and also of performing of necessary computations of bridges under modern loads.

Since the bridges for high-speed railway abroad are built for rather long time already, it may be

advisable to use as an example or as a base of design the projects that had already been implemented or constructed, and data on which can be found on building companies web-cites or in articles of magazines, journals and science collections that are dedicated to building, engineering or transport. For example, some of the articles that are located on web-cite <http://www.bridgeweb.com/> of «Bridge. Design and engineering» journal are committed to bridge design for high-speed railways and contain descriptions of structure and construction details.

Also repository-cites of science articles contain ones, that in finer details describe one or another bridge, its scheme, structure, cross-sections, nominal and calculated loads and construction methods [7-12].

Reviewing the second group, printed works that are dedicated to bridge-vehicle interaction in conditions of high-speed trains passage, it should be noted that the dynamic equation for system «bridge – rolling stock» must be composed individually for every system depending on vast number of parameters that influence the system or describe it's work, so the derivation of universal equation system with consideration of every single parameter is very hard and labor-intensive. Nowadays to derive such equations it's almost obligatory to use modern software complexes and interaction process modeling.

In our country fundamental researches of this branch are ones DEA Doctor of engineering, Professor Bondar Nicolay Herasimovich, honored worker of tech and science of Ukraine, academician of Ukraine National Academy of Sciences [13, 14]. His works are dedicated to problems of dynamic interaction of rolling stock and span. He developed the methodic of dynamic computation for bridges, interaction of «bridge – rolling stock» system with their mutual vibration in vertical and horizontal planes. Also he developed guidance's for rationing of dynamic factors, spans' stiffness, and horizontal forces from impact of rolling stock wheel in conditions of high-speed and higher-speed train passage.

Talking about other publications of local and foreign authors that are dedicated to interaction of

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moving stock and bridges, there are number of monographs on topic that may be viewed as fundamental, critical or useful for the science branch [15-20].

Reviewing the works about interaction of «bridge – rolling stock» system for the last decade, the most valuable of them is the work of National Taiwan University specialists [21] that is dedicated to the dynamic of «bridge – rolling stock» system interaction with application to high-speed railways. In the monograph analytical ways of solving the key problems, finite-element solving of some particular problems are reviewed and also results of some tests are given to confirm developed theories. Authors study problems of bridge reactions with elastic supports, dynamic reaction of beams caused by moving centrifugal force, reaction of two trains that are crossing the bridge and so on. This is one of the most cited modern books on given topic.

Famous scientific periodicals and science collections that are composed of materials of international scientific conferences [23-27] are dedicated to the topic of «bridge – rolling stock» system interaction and high-speed railways at all. They reflect last achievements in the branch including recent developed technic of dynamic analysis, problems of bridge design for high-speed railways, problem of viaducts' and long-span bridges fatigue, dynamic behavior of bridges and some examples are reviewed for specific bridges.

Concerning analytical method of dynamic equations solving, a large number of works published by local and foreign scientists is devoted to composing and solving of equations with lots of assumptions, simplifications and number of dimensions for system (two- or three-dimensional system). Methods and necessity of equations composing for «bridge – rolling stock» system are given in every of the following works of foreign scientists [28-30].

Big part of attention in the named periodicals is paid to the studying of bridge vibrations during rolling stock passage and the resonance check being conduct. Indeed, the study results show that the problem of bridge vibrations during high-speed trains' passage is one of the most important for correct modeling of beam behavior. In the article

[31] the problem of dynamic computation of bridges for lengthwise action of moving loads on the high-speed railroads of Russian federation is reviewed.

The majority of published works by local and foreign scientists describe dynamic computations and tests for the bridges that are already operational. Important part is that there already are some data that was previously obtained for these structures that can be compared to results obtained by computations. These comparisons show that actual parameters of the bridge (mostly, its vibration parameters) in the majority of articles match with the calculated ones and don't exceed permissible values.

This proves that regulatory documents that were used to design considered bridges, and these are European (Eurocodes) [32], American, documents of advanced Asian countries, that are also close to Eurocodes, give us methodology of design that results in accurate enough beam behavioral model for high-speed loads. The main difference between calculations by foreign documents and bridge structures' modeling by Ukrainian regulatory documents [33] consists not in the representation of structures by their physical properties (laws of mechanics don't differ, stresses are found by similar methods), but in the representation of moving loads. This is so due to empirical way of obtaining of the loading model. And more advanced states have conducted, and are conducting nowadays, larger number of tests that are needed to compose the regulatory documents.

Nowadays the countries that already have advanced high-speed railways either don't conduct, almost don't conduct or in Ukraine we don't have direct access to publish in science periodicals big fundamental studies of high-speed railways.

Today all the major methods of calculation for dynamic action on bridges and equations to solve are already derived. Usually all the work consists of conducting tests for some already operational bridge for new or existing loads, or testing some new computation methods by comparing modeling results and the results of experiment. Usually it's the test for some new finite-element models for bridge and moving stock.

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In addition to above-quoted works, that review the railroads of Europe and Asia, it's advisable to pay attention to article [34] and also to the whole named periodical.

These science works were created based on the results of resent researches that were conducted in Russian Federation and are dedicated to the study of high-speed trains' influence on the bridge spans. The necessity of these researches has arisen from the plans of high-speed railways development and construction of the high-speed track from Moscow to Yekaterinburg. At the same time in addition to information relevance the important role plays the similarity of artificial structures and moving stock of Ukraine and Russian Federation.

Originality and practical value

Results that were obtained in this work represent modern state of the problems of common work of bridges and moving stock study for railroads of Ukraine and world.

Nowadays there are no isolated railroad tracks for high-speed railways in Ukraine. The movement of high-speed train is being conducted on the already existing tracks. Artificial structures that are being operated on such railroads have wear and tear of main bearing elements that is connected to increased loadings that are being rotated on the bridge and the effect of anthropogenic and operational factors. Thus the problem arises if it's possible to use bridge structures that are being operational for some lasting period for moving stock that moves with high speed and what are the features of structures' elements' operation must be considered in this case. The experience of structures' operation on the high-speed railroads of the other countries and the research of this topic by local scientists and civil engineers of ex-USSR countries will allow us to develop the methodology of bridge structures computations for bridges that are located on high-speed railways and to use obtained results for the design of new span types.

Conclusions

1. Based on the analysis of literature sources it's possible to draw a conclusion that for today the

problems that are related to vehicle-bridge interaction draw a lot of attention of our foreign colleagues and are being studied by them and used for the bridges design on high-speed railways. But these problems remain not understood enough by Ukrainian scientists and their colleagues from ex-USSR countries.

2. The majority of science works, both fundamental and applied ones, is in one or another way dedicated to theoretical or practical studies in the area of interactions of bridges and moving stock. And if fundamental studies allow us to find analytical solution by using some large labor hours, applied ones describe every aspect of the problem separately, thank to what (or by orientation on such works) the possibility to get precise enough solution of the problem without the finding of needless details, that may be neglected.

3. Every theoretical research of interaction of bridge structures with moving loads is the attempt to solve analytically or to simplify dynamic equations for «bridge – rolling stock» system.

4. Methodology development for computations of bridge structures that are operated on high-speed railroad tracks will allow to reduce costs of operational maintenance of bridge structures. And the introduction of the new types of spans will allow to increase the durability of bridge structures and to reach high levels of comfort for passengers of the cars' salons while the rolling stock is passing the bridge.

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Цель. Анализ мирового опыта проектирования конструкций мостов и условий их работы на направлениях скоростного и высокоскоростного движения поездов. Обзор вопросов экспериментальных и теоретических исследований взаимодействия мостовых сооружений с подвижной нагрузкой. **Методология.** Для анализа публикаций, в которых отображается мировой опыт проектирования конструкций мостов и условий их работы на направлениях скоростного и высокоскоростного движения поездов, был использован библиотечный ресурс университета и возможности неограниченного доступа к мировой сети INTERNET. **Результат.** В статье представлен результат исследований литературных источников, отображающих мировой опыт исследований по расчету и проектированию мостовых сооружений на высокоскоростных железнодорожных магистралях. **Научная новизна.** Полученные в работе результаты отображают современное состояние вопроса по исследованиям совместной работы мостов и подвижного состава на высокоскоростных участках железных дорог Украины и мира. Рассматривается вопрос возможности использования мостовых сооружений, которые уже эксплуатируются длительный период времени, под подвижной состав, который движется с высокой скоростью и какие особенности работы элементов конструкций при этом необходимо учитывать. **Практическая значимость.** Вопросы, рассмотренные в статье, позволят разработать методологию расчета мостовых сооружений, которые находятся в эксплуатации на высокоскоростных железнодорожных магистралях и учесть результаты научной работы при разработке проектов новых пролетных строений.

Ключевые слова: напряженно-деформированное состояние; пролетное строение; скоростной поезд; взаимодействие моста и подвижного состава; надежность; долговечность

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СВІТОВИЙ ДОСВІД СТВОРЕННЯ КОНСТРУКЦІЙ МОСТІВ І УМОВ ЇХ РОБОТИ НА НАПРЯМКАХ ШВИДКІСНОГО Й ВИСОКОШВИДКІСНОГО РУХУ ПОЇЗДІВ

Мета. Аналіз світового досвіду проектування конструкцій мостів і умов їх роботи на напрямках швидкісного і високошвидкісного руху поїздів. Огляд питань експериментальних і теоретичних досліджень взаємодії мостових споруд з рухомим навантаженням. **Методологія.** Для аналізу публікацій, в яких відображається світовий досвід проектування конструкцій мостів і умов їх роботи на напрямках швидкісного і високошвидкісного руху поїздів, був використаний бібліотечний ресурс університету і можливості необмеженого доступу до світової мережі INTERNET. **Результат.** У статті представлений результат досліджень літературних джерел, що відображають світовий досвід з розрахунку і проектування мостових споруд на високошвидкісних залізничних магістралях. **Наукова новизна.** Отримані в роботі результати відображають сучасний стан питання з досліджень взаємодії мостів і рухомого складу на високошвидкісних ділянках залізниць України та світу. Розглядається питання можливості використання мостових споруд, які вже експлуатуються тривалий період часу, під рухомий склад, який рухається з високою швидкістю і які особливості роботи елементів конструкцій при цьому необхідно враховувати. **Практична значимість.** Питання, розглянуті в статті, дозволять розробити методологію розрахунку мостових споруд, що перебувають в експлуатації на високошвидкісних залізничних магістралях і врахувати результати наукової роботи при розробці проектів нових прогонових будов.

Ключові слова: напружено-деформований стан; прогонова будова; швидкісний потяг; взаємодія мосту і рухомого складу; надійність; довговічність

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