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ACTUAL PROBLEMS OF INTERACTION OF OBJECTS OF THE INFRASTRUCTURE AND ROLLING STOCK

There are a number of actual problems of modern bridge construction in a context of static-dynamic interaction of bridge designs and the railway rolling stock is considered. The integrated classification of settlement models for research of joint dynamics of system "bridge-train" is offered, the basic criteria and the factors influencing result of numerical modeling and dynamic calculation of bridges are allocated.

AKTUALNE PROBLEMY WZAJEMNEGO ODDZIAŁYWANIA INFRASTRUKTURY I TABORU

Dokument uwzględnia wiele aktualnych problemów współczesnej budowy mostów w kontekście statycznych i dynamicznych interakcji pomiędzy konstrukcji mostu i taboru kolejowego. Proponujemy klasyfikacji przybliżona modeli obliczeniowych do badania wspólne dynamiki «most-train», zwraca uwagę na podstawowe kryteria i czynniki wpływające na wynik symulacji i analizy dynamicznej mostów

1. INTRODUCTION

More than 100 years ago N. Garin-Mihajlovsky (the writer, the researcher, bridge constructor, graduated from the PGUPS) named the moving train «the nightmare for the engineer». Continuing this thought, it is possible to tell that for the scientist and the designer train movement on the way with artificial constructions (including the modern wide-span bridges) – «the double nightmare». And if movement occurs on an elevated overpass (fig. 1) scientific problems arises even more.

Obviously, after the sight in depths of bridge constructor history and the analysis of a modern situation, it is useful to try to glance in near and, whenever possible, objects of the

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infrastructure, including approaches to bridges, regulation constructions, the railway line, communications, etc.

Fig.1. Metro in Dubai [1]

2. THE BASIC PART

The richest historical review of the discussed problem as mechanics problems, it is given in work [2] as problems of bridge construction – in works [3–5]. The ordering executed by authors of given works, underlines necessity of the further testing and comparison of calculations of static-dynamic interaction of the bridge available today and train. Thus comparison should be spent not only at level of analytical expressions, but also numerically, taking into account results as almost 200-years prescription (Willis, Stocks), and later works. It is possible to carry works of great Ukrainian mechanic S. Timoshenko [6] to the last, works of the schools which have arisen in the XX-th century of the Kharkov Polytechnic Institute (A. Filippov [7], S. Kohmanjuk [8]), the Dnepropetrovsk construction institute (A. Morgaevsky [13], I. Kozhemjakina, V. Zaporozhets, I. Davidov, V. Kuljabko [14]), Institute of technical mechanics (V. Lazaryan [15], V. Ushkalov [16]), etc. Long-term researches of scientists of the Soviet school of bridge construction, in particular, chairs of bridges and branch research laboratory of dynamics of bridges DIIT, MIIT, PGUPS, VNIIZHT are reflected in works [3, 9–12, 17–19].

Last years the carload park of Ukraine (consisting, basically, from freight cars) began to be updated rather quickly, however intensity of inspection and repair of artificial constructions continues to remain low. Bridges are the deterrent both for the general improvement of the situation, and for development of the international goods turnover and the network of high-speed movement (to 350 km/h) in the CIS countries, Europe and Asia. Other problem having historical roots, consists in aspiration of engineers, who constructed the bridges, to eliminate the problem not at level of design decisions (using results of scientific researches, search of optimum variants), and cardinal methods – reconstruction,

replacement of flying structures the requirement in which arises no means always. In design decisions essential stocks of bearing ability that gives the grounds for the further specification of the corresponding factors raising firmness the characteristics of the design thus continue to remain.

The partial decision of the given problem sees in application in engineering activity of corresponding systems of the automated designing and calculation of designs (CAE). It is necessary to establish the fact that, despite wide circulation CAE abroad, in domestic engineering practice similar technologies are applied seldom enough, sometimes for the decision is trivial simple problems. Occurrence of new building materials, cars and mechanisms, methods of installation of designs opens prospects of erection of essentially new unique constructions which projects should be made with use of modern systems of the automated designing. Is not an exception and sphere of operation of building objects, many of which require carrying out of complex researches, for example:

- technical inspection with application of methods of dynamic diagnostics and certification (by results of natural dynamic tests);
- constructions of adequate static-dynamic models of interaction with general view loading;
- creations of essentially new software by calculations, tests and the automated processing of the information on the condition of designs;
- to working out of recommendations about application of rational ways of strengthening of designs, change of modes of movement of trains, etc.

The role of computer modeling in calculations of building designs is defined today not only difficult constructive forms of their elements, but also and quantity of considered loadings. Even for the simple settlement scheme (for example, single-span beam) with external forces in the quantity equal to number of cars in a real rolling stock, the manual account essentially is at a loss. Besides, recently in the field of computer technologies the tendency to use of the multinuclear processors was established, allowing spending separate blocks of calculations simultaneously, in the form of system of parallel calculations.

However, the comparative analysis of profile CAE-systems shows that the method of final elements realized in their overwhelming majority, as a matter of fact represents «decider» static problems, and its interpretation for the decision of problems of dynamics is the harmonious analysis of the design. This circumstance essentially narrows area of applicability CAE in dynamic calculations of constructions, in particular, to dynamics of bridges when «bridge-loading» is required to spend calculation of co-operating system in time area taking into account speed of movement of loading and various nonlinearities. With confidence it is possible to tell that profile systems of the automated designing of such class are inaccessible today, therefore their creation is an actual and demanded problem.

There are works in the direction of the account of static-dynamic interaction of trains with designs of bridges of various systems, including metal span structures in length to 110 m, in the conditions of accruing speeds of movement of trains today are conducted in Ukraine. In particular, similar researches are spent on Bridges Department of the Dnepropetrovsk National University of Railway Transport (DNUZT) which results are reflected in corresponding scientific reports, doctor's (2009) and candidate (2011) dissertations. Researches will be organized and spent in a complex, taking into account the given numerous natural experiments; a priority direction of activity of scientists of DNUZT

also is working out of the specialized software for modeling, static and dynamic calculation of bridge designs in the conditions of high-speed movement of trains [12].

Today there is very important and labor-consuming problem of mechanics before the modern researcher of dynamics of bridges: static-dynamic behavior of difficult system of designs from various building materials and the non-uniform subsystems of variable structure possessing various firmness, inertial and dissipative properties. We will notice that at computer facilities and the software of level of the XX-th century the decision of such problem was not represented possible!

Further it is possible to designate directions of the further researches of scientists in adjacent areas of a science and technics (builders, operative, designers of park cars and locomotives, railway engineers):

- joint static-dynamic problems of interaction of the bridge and train with the account of «a longitudinal statics» on different biases of a longitudinal profile of a way before a train input on the bridge;
- problems about loss of stability of all compressed and sharply braking train, about its derailment, various emergencies, including collision with other rolling stock or designs of bridge support, flying structures;
- problems about dynamic behavior of system «bridge-train» in the conditions of seismic activity of earth crust, various aerodynamic effects, influence of blast waves, etc.;
- account questions in traction calculations of the rolling stock of variable forces of resistance and energy swapping in system «the train with sprung in weights – the bridge»;
- calculations trailing and cable-stayed designs, bridges-tapes, pontoon crossings etc.

Besides listed, actual the problems which have already become for bridge designs «classical» – the harmonious analysis and rationing of size of dynamic factor also continue to remain. In the first case the major characteristic of the construction is frequency of its free fluctuations; in resonant conditions to this size there can correspond frequency of external indignation from some system of the concentrated cargoes which are located on periodically repeating intervals and move with constant speed. So, for cutting beamed flying structures of railway bridges in length from 23,0 to 110,0 m at speed of movement of loading 300 … 500 km/h we will have dangerous frequencies of indignation from 0,8 to 4,0 Hz. In case of not cutting systems the zone of a condensation of own frequencies will «cover» frequencies of indignation even more densely.

Let's notice that the one of the founders of domestic school of bridges constructors special attention gave to N. Bondar to calculations of bridges on action of single and periodically repeating pulse loadings, in linear and nonlinear statements.

In connection with wide application of the method of final elements for the harmonious analysis of bridges, obviously, it is necessary to execute the number of test calculations on quasistatic mobile loading in «building» program complexes Lira, Scad, Robot, etc., and to compare results with offered in domestic and foreign standard documents, including Eurocodes. For more universal program complexes which allow to carry out calculations in time area taking into account moving on an elastic design sprung weights, comparison of tests should extend not only on fields of moving and pressure in design elements, but also on fields of speeds and accelerations of solid-state objects (sprung weights). For the analysis it is necessary to consider as the important parameters also smoothness of course of the rolling stock, stability and safety of system «bridge-train» as the whole.

In practical problems, certainly, the estimation of errors from not taking into consideration the loadings, sluggishness the bridge, groups of nonlinearity is interested: geometrical, physical, constructional, genetic. Unresolved there are also such questions:

- the simultaneous account in one modeled object of the internal friction of elements from various materials - concrete, the steel, rubbers, etc.;
- the account of the external friction of designs of the rolling stock with the bridge cloth, the ballast, plates;
- the account of revolting influences of type of power and geometrical single roughness's («Timoshenko's roughness»), wavy deterioration of rails; type of influences slide on locomotive or car wheels;
- the account of casual indignations on the bridge from the train driving on it with the established initial fluctuations of difficult character.

Certainly, separately it is necessary to mention stability. Having specified, about what stability there is the speech: stability the general and local the compressed elements or all design in space? It is necessary to pay attention to influence of steady and unstable movement of crews also.

In a kind of that about 20 % of territory of Ukraine is in seismically active zone, one of perspective scientific directions is modeling of dynamic work of bridge designs in the conditions of seismic activity. Adjacent aerodynamic calculations, on separate and joint influence of wind loading on the bridge and the rolling stock here too are.

As the result we will notice that now there are more many white stains and «ambiguities» at creation of correct settlement models of interaction of the bridge and a train. It concerns, for example, modeling of movement difficult подрессоренной systems of inertial cargoes on elastic rod, slab, the volume design as in linear, and nonlinear statements; the same problems taking into account geometrical, physical, constructional and genetic (connected with history of loading designs) not linearity; calculations of dynamic stability of spatial system, etc. However, in all cases the cycle of researches should be accompanied by «transparent» numerical testing.

It would be interesting to study and compare not only direct influence of the train on the bridge with its own fluctuations and many inertial weights is elastic-dissipative subsystems, but also return influence of fluctuations of the bridge on train: on designs and their durability, endurance, on passengers and transported cargoes – whether final rigidity of span structures influences rational bases of cars and parameters of carts.

It is required to establish also frameworks of applicability of a traditional technique of the account of dynamic influence of the train on the bridge simple multiplication of static loading from a train on dynamic factor. The account of a site of lines of influence for one-flying bridges here turns to size of flight and the dynamic additive for flights, for example, 10 … 100 meters in ferro-concrete designs is equal 33 … 8 %, in steel 45 … 14 %. Certainly, these figures cannot approach designs of all perspective bridges and crews!

Let's notice that many scientists gave offers under the account of speed of movement of loading. In V. Lazaryan's school of thought in 1972, 1973 on the special high-speed car with jet draught speed of 250 km/h has already been reached and investigated (one of authors of the given work could take direct part in these tests; V. Lazaryan's school in territory of the CIS holds this record already almost 40 years!). Of «rather white» stains in bridge construction last year has reminded the Volgograd road bridge through the river

Volga named in a press «dancing» because of unusual behavior in an air stream (the problem of aerodynamics of elastic bodies in a stream here is obvious!).

As the whole, horizons of scientific problems of dynamics of bridges and interaction of bridge designs with rolling stock are represented to the Ukrainian scientists quite achievable. The major factors defining an urgency of given subjects in Ukraine, working out of modern specialized systems of the automated designing and dynamic calculation of bridge designs that will allow to project and erect essentially new objects of a railway infrastructure of III millennium are planned realization of government programs on creation of the network of high-speed railways, integration of domestic norms of designing with the European standards (Eurocodes), and also.

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