

FEATURES OF THE THEORY OF A TWO-MASS SYSTEM WITH A RIGIDLY CONNECTED END OF THE BRIDGE, IN CONSIDERATION OF SEISMIC INFLUENCE ON HIGH-SPEED RAILWAYS

T.R. Rashidov,
*Doctor of Technical Sciences, Professor U.Z. Shermukhamedov,
Ph.D., associate professor*

Rashidov Tursunbay
Doctor of Technical Sciences, Professor, Academician of the Academy of Sciences of the Republic of Uzbekistan, Head of the Laboratory "Seismodynamics of Underground Structures, Grounds and Foundations" of the Institute of Mechanics and Earthquake Resistance named after M.T. Urazbaeva tur.rashidov@list.ru.

Shermuxamedov Ulugbek
Ph.D., associate Professor, head of the Department "Bridges and tunnels" of the Tashkent Institute of railway engineers, ulugbekjuve@mail.ru.

Annotation. *This article discusses a two-mass system with a rigid fixation of the end part (foundation) of the bridge on high-speed railways. The results of selecting the optimal parameters of dynamic vibration dampers (DVDs) for setting stiffness and damping in the case of a two-mass system with a rigidly fixed end part of the bridge are presented. It is shown that such a solution is recommended for the case when the bridge is located in a steep gorge, the intermediate supports are high and flexible, and the end supports are quite rigid, since they give the designer a wide opportunity to choose the dimensions and rigidity of the designed seismic protection elements.*

Keywords: *bridge, pier, dynamical vibration absorbers, optimization parameters, stiffness, damping, amplitude and frequency characteristics.*

Introduction. From the first days of independence in the Republic of Uzbekistan, special attention has been paid to the development of all types of transport, improving the quality and safety of freight and passenger transportation, in particular, by rail. One of the priority tasks is by definition of the head of state Sh.M. Mirziyayev design and construction of the most convenient and shortest high-capacity railways and bridges, which would ensure Uzbekistan's access to the world market [1, 12-15].

It is known that the state economy largely depends on the successful operation of transport, and especially the railway. In the Republic of Uzbekistan, rail transport accounts for more than 30% of the freight turnover carried out by all modes of transport [1, 16-19].

In countries where high-speed highways (HSRs) are being built – Japan, France, Germany, Italy, and others – intensive research work is underway to develop constructive and technological solutions for artificial structures on the HSR. Vibrodynamic loads are often a determining factor in the design of bridges on the high-speed rail. As a rule, for all railway bridges the induced train speeds of more than 200 km / h, dynamic analysis is required [10-11].

Various artificial structures (AC) are being erected on the highways, most of which are bridges. A number of such ACs have to be built in areas prone to seismic impacts. In addition, from the action of the rolling stock there are increased vibrodynamic loads on structural elements of bridges on high-speed lines.

Interest in the dynamic behavior of railway bridges has increased in recent years due to the introduction of high-speed trains. In accordance with high speed loads, bridges are subject to great dynamic impacts. It is known that Uzbekistan is located in a seismically active territory. Therefore, the issue of seismic protection is relevant [2].

With the commissioning of the new Tashkent-Samarkand-Karshi high-speed railway line, it became necessary to ensure the bearing capacity and seismic resistance of bridge structures.

The construction of high-speed railways must satisfy not only the general requirements for earthquake-resistant construction, but also the specific requirements associated with the features of the high-speed rail. General requirements are contained in the regulatory and technical documents of all countries subject to seismic impacts.

The structures under consideration, therefore, are classified as so-called barrier objects, and their anti-seismic reinforcement is given priority. The requirements for seismic resistance of bridge structures are set out in the current standards of all countries subject to seismic influences.

The main features of providing seismic resistance of high-speed lines include:

- a lot of damage during a train \Rightarrow it is necessary to quickly reduce the speed of a train when a dangerous situation is likely to occur; special events against the gathering;
- high damage when stopping traffic increased requirements for reliability;
- specific rolling stock \Rightarrow lightweight loads from rolling stock;
- increased requirements for PW (permanent way) \Rightarrow problematic installation of seismic isolating supports, the use of systems with disconnected communications.

Existing local AC (artificial construction) design regulations are not common for high-speed lines. An analysis of the design, construction and operation of high-speed highways in highly seismic areas has shown that the general principles of earthquake-resistant transport construction need some adjustment.

Main part. In bridge structures, under the influence of rolling stock, vibrations arise, characterized by amplitude, frequency, speed and other parameters. The nature of the oscillatory process depends on the type, condition and properties of the soil of the subgrade, the design of the upper track structure, speed, axial, linear loads and other factors [3, 9].

It should be noted that the more vulnerable part of the bridges is the supports. To do this, in order to maintain bridge supports from seismic loads, it is necessary to correctly select the parameters of the absorbers (seismic insulating support parts) settings.

Known solutions in which the span is used as a dynamic damper of support vibrations. They are proposed in various works by A.M. Uzdina, A.A. Nikitina, V.V. Sakharova [4-8].

This article discusses a two-mass system with rigidly fixed end part on the high-speed rail (Fig. 1).

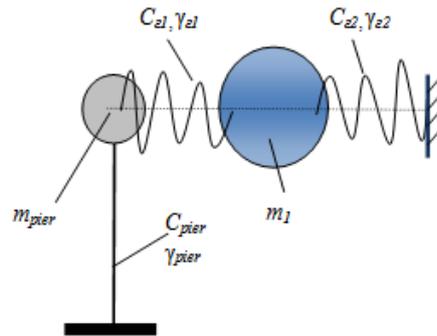


Figure 1. The design scheme of a two-mass system with a rigidly fixed end part

The proposed scheme shows the parameters:

- C_{21} – damper stiffness (intermediate part);
- C_{22} – rigidity of abutment (end part);
- C_{pier} – support stiffness;
- m_1 – damper mass (intermediate part);
- m_{pier} – mass of support;
- γ_{21} – attenuation coefficient of the absorber (intermediate part);
- γ_{22} – attenuation coefficient of abutment (end part);
- γ_{pier} – support attenuation coefficient.

In this scheme (Fig. 1), the elastic connection between the span and the support should be simultaneously ensured by the conditions of rigidity and strength, which is often not feasible. The span at one end rests on a rigid support, and the second end on a relatively high support, which must be protected from seismic load.

In this case, you can use the elastic connection of the span with the support and with the abutment and try to adjust the stiffness so that the span still remains a dynamic damper of the vibrations of the support. Consider this as an example of the presented two-mass system.

We get for it a diagonal mass matrix and a stiffness matrix

$$M = \begin{vmatrix} m_{pier} & 0 \\ 0 & m_1 \end{vmatrix}; \quad R = \begin{vmatrix} C_{pier} + C_{r1} & -C_{r1} \\ -C_{r1} & C_{r1} + C_{r2} \end{vmatrix} \quad (1)$$

Denote the partial frequency of the oscillations of the support (end part)

$$k_0 = \sqrt{\frac{C_{pier}}{m_{pier}}} \quad (2)$$

Then the partial oscillation frequency of the absorber of the intermediate part

$$k_e = \sqrt{\frac{C_{r1} + C_{r2}}{m_1}} \quad (3)$$

The ratio of the natural frequencies of the fundamental tone of the vibration damper and the natural frequencies of the fundamental tone of the vibration of the support will be denoted as

$$f = \left(\frac{k_z}{k_0} \right) \quad (4)$$

When constructing the equations of oscillations of multi-mass damped systems, we use the method of E.S. Sorokina:

$$\mathbf{B}_c = \gamma \mathbf{R}, \quad (5)$$

For a two-mass system with a rigidly attached end part, we write formula (5) as follows:

$$\mathbf{B}_c = \begin{pmatrix} C_{\text{pier}} \cdot \gamma_{\text{pier}} + C_{r1} \cdot \gamma_1 & -C_{r1} \cdot \gamma_1 \\ -C_{r1} \cdot \gamma_1 & C_{r1} \cdot \gamma_1 + C_{r2} \cdot \gamma_2 \end{pmatrix} \quad (6)$$

where γ_z and γ are the inelastic drag, absorber, and support coefficients, respectively.

The amplitude of the oscillations was calculated by the formula (7-9) and the optimal parameters of the DVD were selected [9].

$$U_s(\omega) = \sqrt{\mathbf{a}_s(\omega)^2 + \mathbf{a}_c(\omega)^2} \quad (7)$$

where \mathbf{a}_c and \mathbf{a}_s are the desired amplitude vectors, respectively, with cosine and sine,

$$\mathbf{a}_s = \left[(\mathbf{R} - \mathbf{M} \cdot \omega^2) \cdot \mathbf{B}_c^{-1} \cdot (\mathbf{R} - \mathbf{M} \cdot \omega^2) + \mathbf{B}_c \right]^{-1} \cdot \mathbf{M} \cdot V_p \cdot A \cdot g \quad (8)$$

$$\mathbf{a}_c = (\mathbf{R} - \mathbf{M} \cdot \omega^2)^{-1} \cdot \mathbf{B}_c \cdot \mathbf{a}_s \quad (9)$$

The results of selecting the optimal parameters of the DVD for tuning and damping in the case of a two-mass system with a rigidly fixed end part at $v=1$ are shown in Fig. 2.

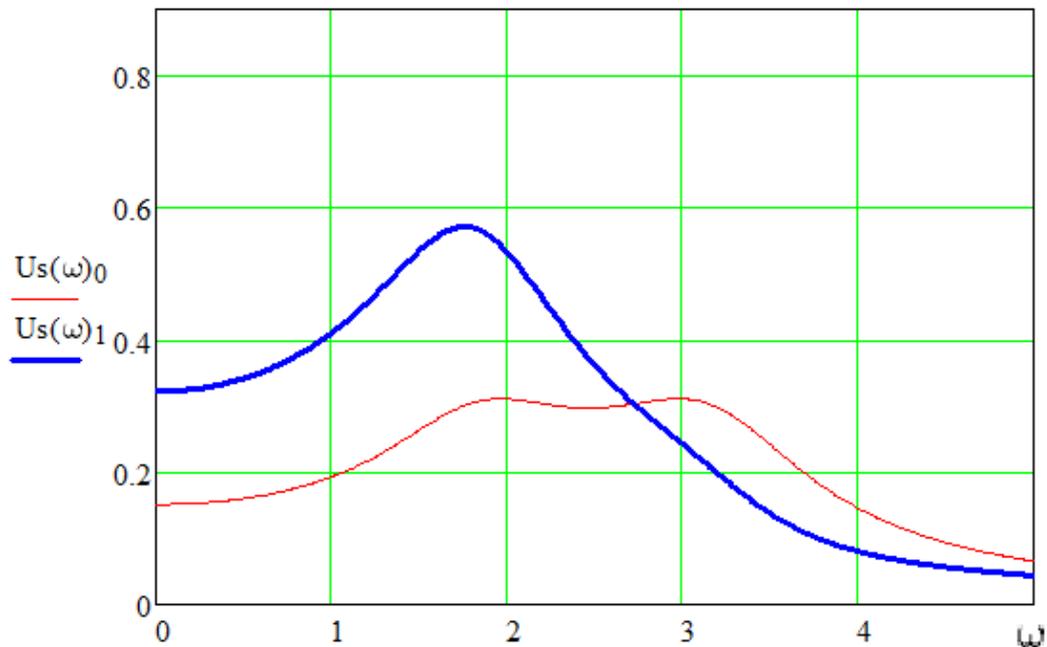


Figure 2. Frequency response versus perturbation frequency for given system parameters at $v=1$

$$(C_{21}=0.508, C_{22}=1.7, f_{opt}=0.47, \gamma_{21 opt}=5, \gamma_{22 opt}=0.1)$$

From the given fig. 2 shows that the vertical axis is $U_s(\omega)_0$ – the amplitude of the displacements of the support, $U_s(\omega)_1$ – the amplitude of the displacements of the span meters, and horizontal, ω – the frequency of the perturbation of the fundamental tone of the oscillations of the abutment.

If the stiffness of the span connection and abutment are equal ($C_{22}=0$), then the optimal stiffness of the connection between the span and the support C_{21} is realized, obtained in the works of A.M. Uzdina and A.A. Nikitina [5, 7].

With increasing rigidity of the span connection with the abutment ($C_{22}>0$), the optimal stiffness of the connection of the span of the support will vary, and you can observe the equality of the peaks (minimum displacement of the support and the absorber) on the frequency response, as did A.M. Uzdin and A.A. Nikitin [5, 7]. We determine the optimal settings.

In fig. 3 presents the option of selecting the optimal settings for various stiffnesses C_{22} . It can be seen that the actual sum of the stiffnesses C_{21} and C_{22} is not linearly dependent, i.e. when fixing the span, on the one hand, the optimal stiffnesses C_{21} and C_{22} in total are not equal to the optimal stiffness of the joint in a system with one damper, as one might assume.

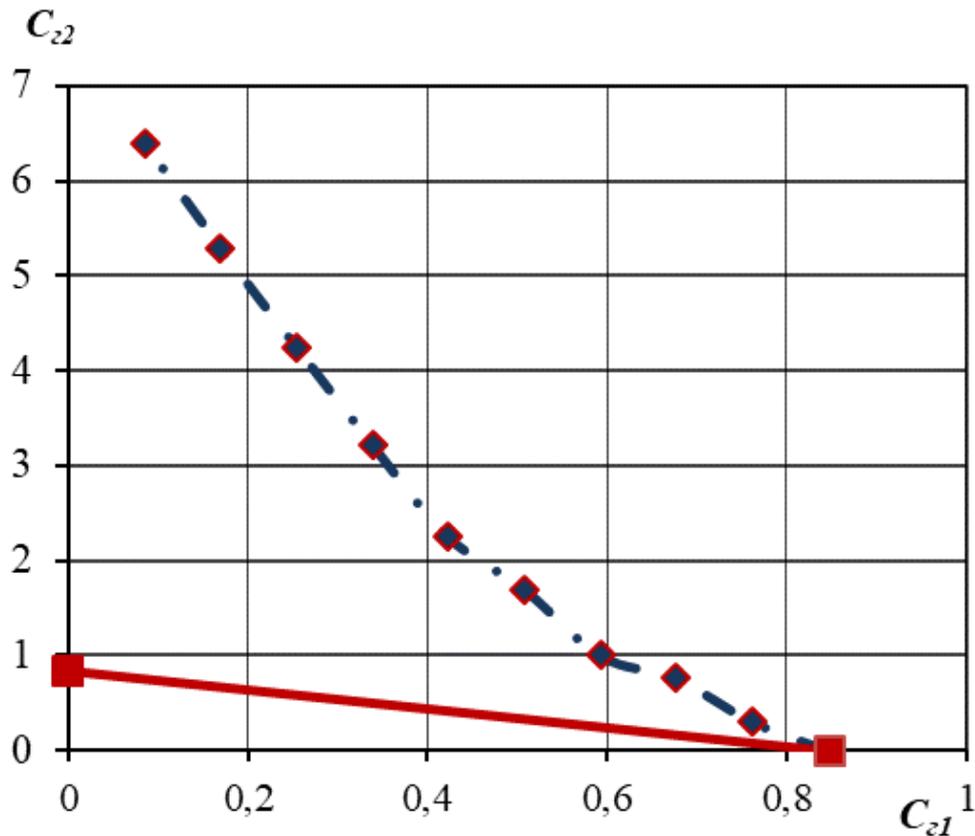


Figure 3. The graph of the dependence of the optimum stiffness C_{22} on the stiffness C_{21} at $v=1$, $C_{21} + C_{22} = C_{opt}^{(0)}$, $C_{22}^{opt}(C_{21})$

Conclusion. The analysis of research in the field of seismic isolation of bridges on high-speed lines allows us to conclude the following:

1. The bridges are significantly affected by seismic influences, which lead to interruption of traffic and great economic damage. In addition, this makes it difficult to provide assistance to the affected area.

2. As can be seen from the results obtained (Fig. 3), the total stiffness of the two absorber springs in this case is significantly higher than the optimal stiffness when using one elastic bond $C_{opt} < C_{21}^{(opt)} + C_{22}$. This solution can be quite effective for high-speed bridges, because strength increases with stiffness. Due to this increase in stiffness, it is easier to satisfy the conditions of strength, while when working with one elastic bond, this can be difficult.

3. It is shown that such a solution is recommended for the case when the bridge is located in a steep gorge, the intermediate supports are high and flexible, and the end supports are quite rigid and, of course, have a scientific novelty. The obtained estimates make it possible to significantly simplify the task of designing seismic protection devices for bridges on the high-speed line, since they give the designer a wide opportunity to choose the sizes and rigidity of the designed elements of seismic protection devices.

References

- [1] Salikhanov S.S. To the issue of the development trend of the bridge-building industry in Uzbekistan. "Actual issues of high-speed train traffic" TashIRE. December 21, 2012.
- [2] Shermukhamedov U.Z., Sergeeva K.M. The influence of the accuracy of tuning dynamic vibration dampers on the earthquake resistance of building structures // Journal "Earthquake-resistant construction, safety of structures". – Moscow. – 2011, №2, p. 55-58.
- [3] Barr J.M. The seismic safety of bridges: a view from the design office. Proc. of 12-th European Conference on Earthquake Engineering. Oxford, UK, 2002. Paper Reference 840.
- [4] Nikitin A.A. Dynamic vibration damper for bridge supports // Earthquake-resistant construction. –1982. – №4. – p. 5-7.
- [5] Nikitin A.A., Uzdin A.M. The use of dynamic vibration dampers for seismic protection of bridges // Express information VNIIS. Ser.14. Earthquake-resistant construction. –1986. – Vol. 9. – p. 20-24.
- [6] Sakharova V.V., Simkin A.A., Nikitin A.A., Uzdin A.M. The use of span to absorb seismic vibrations of bridge supports // Express information VNIIS.Ser.14. Earthquake-resistant construction. –1982. – Issue 4. – p. 14-18.
- [7] Uzdin A.M., Dolgaya A.A. Calculation of elements and optimization of parameters of seismic insulating foundations. – M.: VNIINTPI, 1997. – 76 p.
- [8] Shermukhamedov U.Z., Sergeeva K.M. The influence of the accuracy of tuning dynamic vibration dampers on the earthquake resistance of building structures // Journal "Earthquake Engineering. safety of facilities" – Moscow. – 2011, №2, p. 55-58.
- [9] Shermuxamedov U.Z., Shaumarov S.S. Impact of configuration errors on the dynamic oscillation absorbers effectiveness of different masses on the seismic resistance of bridges // XXII International Scientific Conference on Advanced in Civil Engineering. Construction the formation of living environment 2019. April 18-21, Tashkent, Uzbekistan.
- [10] Shermukhamedov U.Z., Salikhanov S.S. The current state and prospects for the construction of flyover high-speed railways in the seismic conditions of the Republic of Uzbekistan // TIRE Bulletin, Issue. №3. – Tashkent. – 2019.
- [11] Mark Bresler, Shermukhamedov U.Z. Durability and performance of elements of the protection system of artificial structures. Expansion joints, support parts and seismic

- protection equipment of bridge structures // Scientific works of the Republican scientific and technical conference with the participation of foreign scientists “Resource-saving technologies in railway transport” December 18-19, 2018. Tashkent: TIRE, 2019.– p. 168-173.
- [12] Adilhodzhaev A.I., Shipacheva E.V., Shaumarov S.S., Shermuxamedov U.Z., Kandokhorov S.I. Some Aspects of the Photo-Optical Method of Estimation Composition of Light Concrete // International Journal of Engineering and Advanced Technology (IJEAT). ISSN: 2249-8958, Volume-8 Issue-5, June 2019. – pp.1924-1927.
- [13] Adilhodzhaev A.I., Makhamataliev I.M., Shaumarov S.S., Kadyrov I.A. To the Question of the Influence of the Intensity of Active Centers on the Surface of Mineral Fillers on the Properties of Fine-Grained Concrete. International Journal of Innovative Technology and Exploring Engineering (IJITEE). ISSN: 2278-3075, Vol. 8, Issue- 9S2, P.219-222 (2019)
- [14] Adilhodzhaev A., Shaumarov S., Shipacheva E., Shermuhamedov U. New method for diagnostic of heat engineering and mechanical properties of cellular concrete // International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-9 Issue-1, October 2019. – pp. 6885-6887.
- [15] Adilhodzhaev A. I., Shaumarov S.S., Umarov K.S. New Structure Assessment Method Cell Concrete // International Journal of Advanced Science and Technology Vol. 29, No. 5, (2020), pp. 1889-1893
- [16] Adilhodzhaev A.I., Shaumarov S.S., Makhamataliev I.M., Tsoy V.M., Ruzmetov F.Sh. Features Of Forming The Structure Of Cement Concrete On Second Crushed Stone From Concrete Scrap // International Journal of Advanced Science and Technology Vol. 29, No. 5, (2020), pp. 1901-1906
- [17] Adilhodzhaev A., Shaumarov S., Tsoy V., Khodzhaev S., Umarov K. Research of the influence of silicon-organic hydrophobizer on the basic properties of Cement stone and mortar // International Journal of Advanced Science and Technology Vol. 29, No. 5, (2020), pp. 1918-1921
- [18] Shaumarov S.S., Adilhodzhaev A.I., Kondrazhenko V.I. Experimental research of structural organization of heat-insulating structural building materials for energy efficient buildings. XXII International Scientific Conference on Advanced In Civil Engineering «Construction the formation of living environment» p. 1-7 (2019)
- [19] Shaumarov S.S., Adilhodzhaev A.I., Shipacheva E.V., Kandkhorov S.I. Development of New Constructive and Heat-Insulating Materials. International Journal of Recent Technology and Engineering (IJRTE). ISSN: 2277-3878. Vol.7. Issue-5S3. p. 577-580. (2019)