FLUCTUATIONS OF SOLID SUBGRADE

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ABSTRACT

The results of measurements of the characteristics of vertical oscillations of the base of the main site of a stable embankment of subgrade of a railway track under the influence of an electric locomotive VL-80 with different speeds of movement are given. Experimental studies were carried out in Kazakhstan on the section of the enlarged Almaty maintenance section. The dependencies of the parameters of the oscillatory process on the speed of locomotive motion that can be used as evaluation criteria in the development of railway embankment monitoring systems are revealed. The expediency of further experimental studies in the zones of problem embankments with soils prone to thixotropy was noted.

<u>Keywords</u>: railway track, subgrade, main platform, vibration speed, vibration displacement, vibration acceleration, vibrogram, accelerogram, amplitude-frequency characteristics.

Background. In the world practice, it is customary to evaluate the vibration effects on the elements of the railway track construction on the basis of measuring the speed of the oscillatory process [1–12]. This is due to the fact that this parameter characterizes the energy of seismic waves affecting the structure. The tasks of studying the oscillations of track elements under vibrodynamic action of a mobile load can be successfully solved by methods and means used in seismic survey.

Objective. The objective of the authors is to consider fluctuations of solid subgrade.

Methods. The authors use general scientific and engineering methods, graph construction, evaluation approach, mathematical apparatus.

Results. It is known that when a vibrating effect of a higher frequency is imposed on the main background of a dynamic effect, the resistance of the medium is sharply reduced. This is due to a decrease in the effective coefficient of friction and adhesion between sleepers and particles of the ballast base, as well as manifestations of such phenomena as thixotropy of soil under certain conditions (vibrations and single impacts). The rigidity of reinforced concrete sleepers is much higher than that of wooden ones, and their ability to extinguish harmful vibrations is incomparably lower. Therefore, with the introduction of such sleepers, the residual sediments of the track increased by 2-2.5 times, although the force influence of the main background of sleepers on ballast differs insignificantly, and the thickness of the gravel bed is known to be greater with reinforced concrete sleepers.

The data of numerous studies shows that, other things being equal, on the track with reinforced concrete sleepers there is a more intensive deformation of the solid subgrade than on the track with wooden sleepers. Without taking certain measures, it is possible that ballast tanks will be formed over a large stretch of sections with reinforced concrete sleepers.

In order to assess the impact of the rolling stock on the dynamic (amplitude-frequency) characteristics of the subgrade of the railway track on the main section of the enlarged Almaty maintenance section UPCH-46 of JSC NC KTZ in-situ experimental studies of the vibrodynamic impact of the mobile load on the track were carried out.

To identify the patterns of oscillations of the main site under a mobile load, the study should be performed with known axial load and parameters of the source of vibration. Since the main means of traction is the VL-80 electric locomotive on the investigated section of the railway it was chosen as a source of excitation in analyzing the regularities of the oscillatory process. The static load from the wheel on the rail for the locomotive VL-80 is P_{cr} = 12 tons.

As a measurement tool, a mobile vibration measuring system with a package of data processing and visualization applications was used. Measuring devices that are part of the mobile vibration measuring system are certified and included in the State Register of Measuring Instruments of the Russian Federation and of the Republic of Kazakhstan.

Vibration sensors of the generator type MV-25D-V were used as primary converters, which convert the mechanical vibrations acting on them into an electric signal and serve for measuring the speed of the oscillatory process. The choice of vibration sensors MV-25D-V as primary converters was based on the following principles:

 induction primary converters operate without amplifiers, introducing significant errors in the measured quantities, and allow the production of precision (high-precision) measurements;

 the measured value is the speed of the oscillatory process, which is taken as a basis and is included in various national standards of developed countries and ISO international standards when assessing the level of vibration;

- the transition from speed to displacement and acceleration does not introduce significant errors in the process of integration and differentiation (in order to move from displacements to accelerations when using the displacement sensor, it is necessary to differentiate the received signal twice, and the transition from accelerations to displacements when using an accelerometer requires double integration);

– the vibration sensor MV-25D-V has dimensions and weight that do not affect the process of oscillating the railway track from the train load, and can be installed on almost all elements of its design – rails, sleepers, rail fasteners, ballast base, subgrade.

During the research, the following recording parameters of the signals were set: the sampling frequency per channel is 8000 Hz, the recording time is 65,536 s, the input signal range is ± 10 V, the signal level synchronization is 0,001 V. The entries of the cargo and passenger trains were made in summer for 15 days. The impact of all passing trains on the track during the daylight hours (from 7.00 to 20.00) was registered. Over the entire observation period, more than 200 entries were made (see Table 1). The speed of the passing trains was determined with the help of a radar speed meter of vehicles «lskra-1» and was specified by vibrograms.

From the analysis of the results of measurements of the parameters of mechanical oscillations of the



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Number of entries at different speeds of the electric locomotive VL-80

Speed, km/h	Number of entries	Speed, km/h	Number of entries	Speed, km/h	Number of entries
45	8	69	8	79	8
50	8	70	8	81	8
53	8	71	8	82	8
59	8	73	8	86	8
61	8	74	8	91	8
63	16	75	8	95	8
66	8	76	8	100	16
67	8	78	8	103	8



Pic. 1: a) oscillogram of vibration speed of the soil at the base of the solid subgrade; b) vibration speed spectrum when the locomotive VL80 is passing at a speed of 71 km / h (maximum spectral emission at frequency of 35,8 Hz).



Pic. 2: a) oscillogram of vibration displacement of the soil on the edge of the solid subgrade, b) the spectrum of vibration displacement during the passage of the locomotive VL80 at a speed of 71 km / h (maximum spectral emission at a frequency of 35,8 Hz).



Pic. 3: a) accelerogram of soil vibrations at the base of the solid subgrade, b) the spectrum of accelerations during the passage of the locomotive VL80 at a speed of 71 km / h (maximum spectral emission at a frequency of 35,8 Hz).



Pic. 4. Dependence of the peak value of vibratation displacement on the edge of the solid subgrade on the speed of the electric locomotive VL-80.



Pic. 5. Graph of the dependence of the prevailing frequency of oscillations on the speed of movement of the locomotive.





base of the solid subgrade, arising from the movement of the locomotive VL-80, the following is revealed.

The prevailing frequencies within the spectra of vibration displacement $f_{p,s}$, vibration speeds $f_{p,u}$ and vibration acceleration $f_{p,s}$ in the entire investigated range of speeds of the locomotive from 45 to 103 km / h coincide and vary in the range from 29 to 56 Hz.

As an example, Pic. 1-3 show the amplitude-time characteristics (see Pic. 1a-3a) and the amplitudefrequency characteristics (see Pic. 1b-3b) of the vibration speed, vibration displacement and vibration acceleration recorded at the base of the solid subgrade during the passage of the locomotive VL-80 at a speed of 71 km / h.

Dependences of peak and rms values of vibration speeds and vibration acceleration on the speed of rolling stock on the solid subrade have a low

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coefficient of reliability of approximation (the coefficient of determination) and are not acceptable as generalized evaluation criteria.

On the edge of the solid subgrade, the dependence of the peak value of vibration displacement on the speed of the electric locomotive VL-80 is described by a parabola, and the rms value of the vibration displacement is described by a linear function.

The minimum measured peak displacement value 19 μ m was obtained at an electric locomotive speed of 45 km / h, maximum value of 40 μ m was measured at a speed of 103 km / h. Pic. 4 shows the dependence of the peak value of the vibration displacement on the solid subgrade on the speed of the electric locomotive VL-80. The obtained dependence is described by a polynomial of the second degree s_p = 0,0025V²-0,1066V+20.759 with a determination coefficient of 0,8428. The value of the ordinate s_p at the zero point corresponds to the elastic static displacement (deflection) of the base of the solid subgrade for the case of locomotive stopping in the area of the investigated section with the classical pressure distribution from the wheel pairs (s_{st} = 20,759 μ m). Pic. 5 is a graph of the dependence of the

Pic.⁵ 5 is a graph of the dependence of the prevailing frequencies of oscillations (maxima on spectra) on the speed of the locomotive.

The graph in Pic. 5 shows that at a speed of rolling stock from 66 to 86 km / h there are oscillations with prevailing frequencies from 43 to 56 Hz. Such frequencies can cause thixotropic phenomena in wetland soils.

Pic. 6 shows the dependence of the root-meansquare value of the vibration displacement on the solid subgrade on the speed of the electric locomotive VL-80. The dependence has the form of a linear function $s_e = 0, 1255V$ with a determination coefficient of 0,875.

Conclusions. The dependencies of the parameters of the oscillatory process on the speed of the locomotive can be used as evaluation criteria in the development of systems for diagnosis and monitoring of railway embankments.

The effect of mechanical oscillations arising on the edge of the solid subgrade during the movement of the electric locomotive VL-80, characterized by the rms value of vibration displacement, is approximated by a linear function of the form $s_{e} = 0, 1255V$ with a coefficient of determination of 0,875.

The maximum force influence on the edge of the solid subgrade during the movement of the electric locomotive VL-80, characterized by the peak value of vibration displacement, is approximated by the parabola $s_p = 0,0025V^2-0,1066V+20,759$ with a determination coefficient of 0,8428.

Techniques for monitoring railway embankments must be based on a set of indicators, including the determination of the physical and mechanical properties of soils and the measurement of the dynamic impact of rolling stock.

For railway embankments erected from local soils with manifested thixotropic properties, monitoring algorithms should provide for the possibility of developing a decision to reduce or increase the speed of trains in the event that the prevailing frequencies fall into the «dangerous» range.

In conclusion, we should note the expediency of further experimental studies of the influence of the vibrational dynamic effect of the rolling stock on problem embankments consisting of cohesive soils prone to thixotropy, especially during periods of thawing and maximum water saturation.

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