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RAYLEIGH WAVES AND HIGH-SPEED RAILWAYS

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Introduction

- Vibrations always occur at the wheel-rail contact during the running of a train.
- Most of them are radiated to the surroundings in the form of noise, while some of them spread further through the construction of the railway track and the subgrade into the surroundings of the railway line.
- Currently, in the Czech Republic, the spread of vibrations around the railway track is being addressed with regard to their negative effects on human health. To reduce the spread of vibrations, various elements are built into the construction of the railway track, e.g. USP and UBM.

Introduction

- **In connection with a large increase of train velocities, unknown problems began to appear, including the response of the soils forming the subgrade of the railway track to one of the components of vibrations generated by moving trainsets - Rayleigh waves.**
- **If the train velocity that generates the Rayleigh wave exceeds the so-called critical ground velocity, there is a resonance and a several-fold increase in the amplitude of the Rayleigh wave. The track response can only result in damage to the structures around the railway line or even train derailment.**

Introduction

- **The manifestations of Rayleigh waves from rail transport were first measured in 1997-1998 at the municipality of Ledsgard in Sweden. They occurred at a train speed of 200 km/h on a track whose subsoil was made of clay. The measured amplitudes of the vertical deviations reached 15–20 mm.**
- **This issue is becoming topical in the Czech Republic in connection with the preparation of the construction of high-speed railway lines with a considered maximum velocity for passenger trains of 320 km/h.**

Rayleigh waves

- On a free surface, Rayleigh waves are manifested by a specific motion of particles, which describe a retrograde elliptical motion (counterclockwise). The vertical deflection is about 1.5 times greater than the horizontal deflection.
- The propagation velocity of Rayleigh waves is less than the propagation velocity of transverse (shear) waves.
- In terms of the total energy transmitted by the waves, 67% by Rayleigh waves, 26% by S waves and 7% by P waves.
- Rayleigh waves propagate almost exclusively in a layer with a thickness of one wavelength, so this wave is significantly attenuated with increasing depths. The wavelength of Rayleigh waves ranges from 5 m to 50 m.

Soils and critical soil velocity

- **If the velocity of the movement of the wave source (train) approaches or equals the so-called critical velocity of the ground, interference will occur, which is referred to as a ground boom. This phenomenon is physically similar to the sonic boom when the velocity of sound is exceeded.**
- **It can have a negative effect on the stability of the geometric position of the track, the stability of the subsoil, the foundations of nearby buildings and structures.**
- **The critical velocity is the material constant of soils. Its size corresponds to the velocity of the propagation of Rayleigh waves through the soil.**

Soils and critical soil velocity

- **For soft clay soils, it is around 200-300 km/h, in very unfavorable conditions, it can be even lower.**
- **With the increasing stiffness of soils, their critical soil velocity also increases.**
- **Places with layers of <u>fine-grained soils with high plasticity</u>, ie layers formed by clays (MH, MV, ME) and clays (CH, CV and CE), appear <u>to be the most problematic</u>. They are especially risky if they are represented in strata of large thicknesses in the subsoil of railway tracks.**

Experimental work

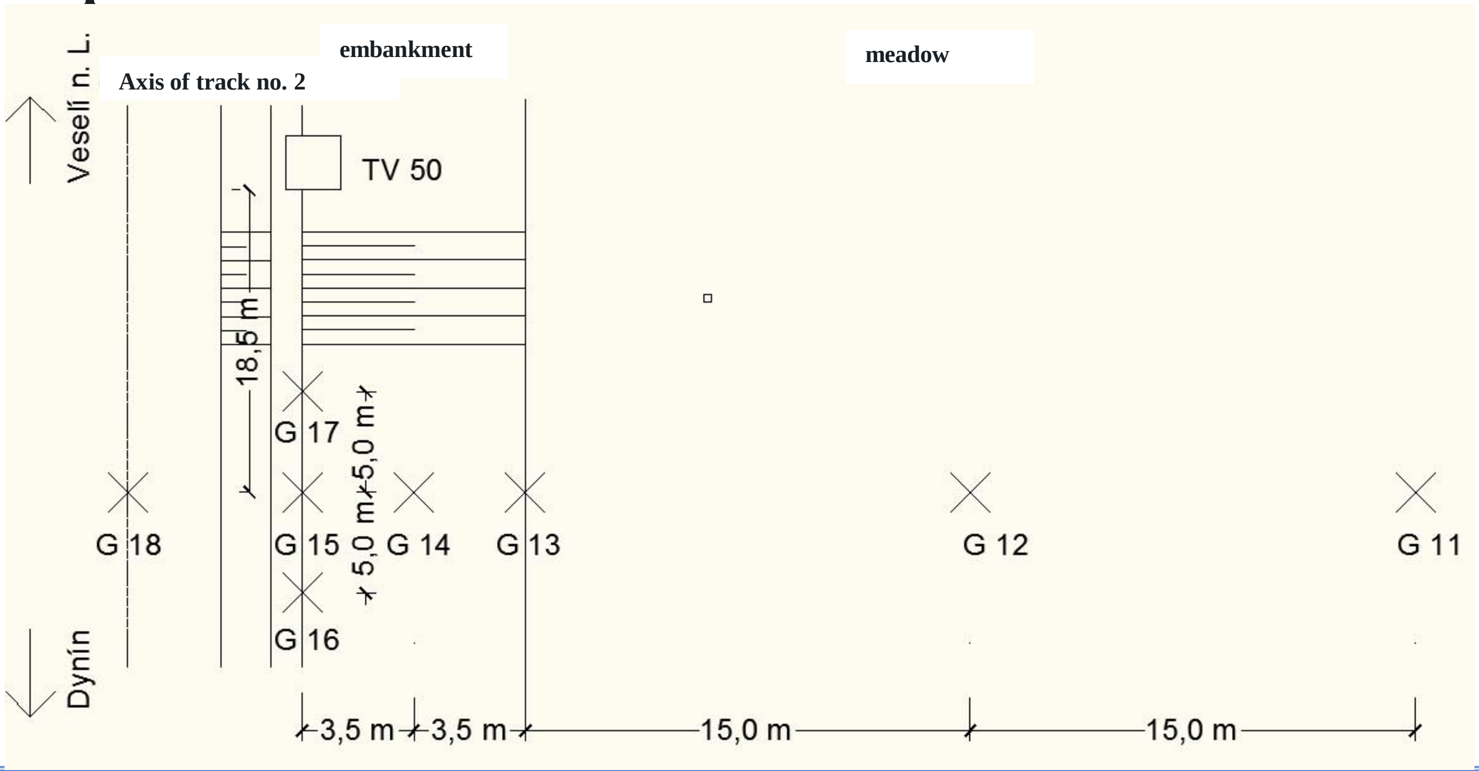
- **The experimental work focuses on research into the propagation of Rayleigh waves in the vicinity of railway lines in the Czech Republic.**
- **Locality is situated at the 4th transit corridor near the village of Horusice close to Horusice Pond. The maximum line speed in the monitored section is 160 km/h.**
- **The track crosses the shallow valley of the Bukovský Brook by a bridge, which is followed on both sides by an embankment approximately 5 m high, which gradually decreases with the distance from the object.**

Experimental work

- **The subsoil around the railway line is formed by peat and clays to a depth of about 5 m. The locality also has a high groundwater level, which is located about 0.5-0.8 m below the surface.**
- **Seven measurement campaigns during the years of 2020–2022.**

Experimental work

- **8 geophones of the SM6 type with a natural frequency of 4.5 Hz were used to measure Rayleigh waves, arranged in a laid-out measured profile.**

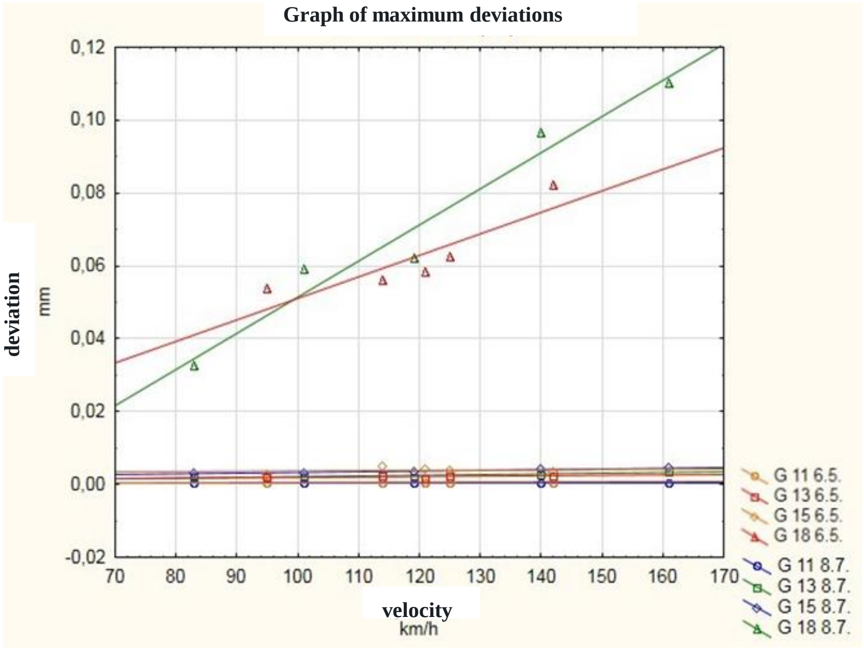


Experimental work

- During each measurement the passages of all trains on both tracks were recorded. With regard to the higher velocity achieved by passenger trains and the low frequency of freight trains, the emphasis in the subsequent evaluation was mainly on passenger trains.
- These trains consisted of sets of express cars of a classic construction pulled by locomotives.
- Due to the fact that the maximum deviations were recorded at the time of the locomotive's passage, the different numbers of cars in the sets were neglected in the detailed evaluation. The different weights of individual types of locomotives are also not considered, as the differences are minimal.

Experimental work

- As the <u>velocity of the trains</u> increases, the size of the vertical deviation increases as well.
- The magnitude of the deviations in the monitored geophones decreases with the <u>distance from the track axis</u>.



Conclusions

- **The issue of Rayleigh waves is being monitored abroad with regard to the potential risks of negative effects on high-speed railways. In terms of behavior, this is a different phenomenon than the propagation of vibrations, which we are still used to address in the conditions of the Czech Republic.**
- **In general, the risk that unwanted manifestations of Rayleigh waves cannot occur in some localities with problematic geology cannot be ruled out for the prepared sections of high-speed lines in the Czech Republic. Therefore, it is desirable to continue to pay close attention to this phenomenon due to its potentially significant harmfulness.**

Conclusions

Based on the experimental measurements performed in the Horusice locality so far, the following can be stated:

- **As the distance of the sensor from the track axis increases, the magnitude of vertical deflections decreases, while the <u>decrease</u> in the amount <u>of deflection is not linear</u> with respect to the distance from the track axis.**
- **As the train velocity increases, the magnitude of vertical deflections increases, with the increase in the magnitude of the <u>deflections being approximately linear</u>.**

Thank you for your attention