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THE DYNAMIC RESPONSE ANALYSIS OF THE VIADUCT SUPPORTED ON ANTI SEISMIC SYSTEMS WITH SELECTIVE LINKS AS VISCOELASTIC AND DRY FRICTION TYPE

PhD. Eng. Adrian LEOPA
“Dunarea de Jos” University of Galati,
Research Center for Mechanics of Machines
and Technological Equipments

ABSTRACT

This paper analyzes, on the theoretical level, the dynamic response of a viaduct section, dynamically isolated by systems with a selective type of links with viscoelastic and with dry friction. Evaluation of kinematic parameters of the dynamic response was performed in theory, in hypothesis of loaded system by impulsive actions coming from a truck passing over an obstacle placed across the road surface. There have been emphasized quantitative differences which in the cinematic parameters of the deck vibration for two considered cases: the case of using only the viscoelastic insulation type systems and the case of using viscoelastic insulation type systems with dry friction.

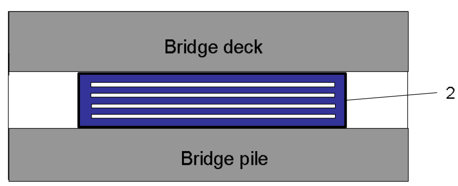
KEYWORDS: bridge, dynamic, dry friction

1. INTRODUCTION

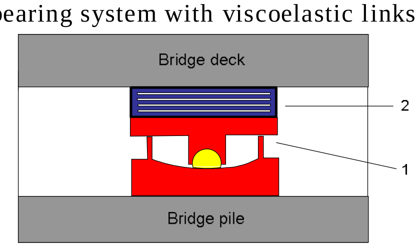
On the commissioning of a bridge or viaduct must be carried out a series of experimental measurements both statically and dynamically. These dynamic loads aimed at evaluating the dynamic response of the structure parameters viaduct (bridge) compared to normal values for such a construction.

This study has as starting point the real case of a road bridge whose superstructure is dynamic isolated through bearings made of neoprene composite. Starting from this objective was determined the theoretical dynamically response of a section bridge deck to dynamic loads from road traffic for two distinct situations:

- the deck leaned on the bearings with viscoelastic type links, fig. 1.a.
- the deck leaned on the bearings with viscoelastic type links and dry friction, fig. 1.b.



a. bearing system with viscoelastic links



b. bearing system with viscoelastic links and dry friction

Fig. 1 Bearing system used for dynamic insulations

2. THE OBJECTIVE CHARACTERIZATION

In order to avoid destructive effects on viaducts loaded by dynamic actions derived from road traffic or seismic actions, is used a series of passive systems for dynamic isolation. One such category is represented by viscoelastic type passive systems like the laminated rubber bearings. These dynamic isolation systems have been used as insulation elements between deck and piles bridge on highway in A3 Transylvania in Romania, the viaduct located at km 29 602.75 29 801.25 ↔ (at Săvădisla between Targu Mures and Cluj) [12]. Infrastructure viaduct consists of two abutments and four piers for each direction circulation.

Viaduct superstructure consists in transverse direction, of 4 U prefabricated beams, spaced 3.32 m between axles, over beams being molded a reinforced concrete topping plate with thickness of 25cm. The beams are made from reinforced concrete class C35/45 and plate Reinforced concrete topping, concrete class C25/30. Viaduct has five equal openings of 40m. The superstructure was supported on the infrastructure elements, abutment and piers, by neoprene bearings, Freyssinet type, with a height of 81mm.

The study developed in this paper has evaluated and quantified theoretically the dynamic response of the section located between P2 and P3 piles at the passage of a truck across an obstacle STAS 12504/86 – Testing of superstructure by standard loads fig. 2. It was considered that this section has an independent movement of the other section due to expansion joints.

Fig. 2 Viaduct on the A3 Transylvania highway

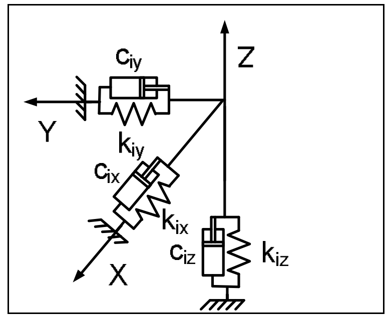


Fig. 3 Triortogonal viscoelastic bearing

The deck of this section is supported on 16 elements considered triortogonal viscoelastic supports, fig. 3.

3. DEVELOPMENT OF THE PHYSIC - MATHEMATICAL MODEL

To develop this study, we consider the real case of the viaduct located on Transylvania highway, except that its deck leaned on the bearings with viscoelastic type links and dry friction such as those shown in fig. 1. When the bridge is loaded with impulsive forces from seismic activity or heavy traffic, the hybrid systems (viscoelastic behavior and dry friction) have the following behavior: at small displacements is deformed the laminated rubber based system, but when the forces from system exceed the static frictional forces, from the pendulum systems with friction forces, these systems enter the oscillation motion. In this case, at displacements in the longitudinal and transverse sections of the bridge appear both the frictional forces and recovery forces.

In stage of physical and mathematical modeling of mechanical systems dynamically loaded, a particular importance is given to the more accurate definition of the excitation pulse functions, by setting their shape, amplitude and duration.

4. LOADING FORCE OF BRIDGE SECTION

In accordance with STAS 12504/86, the bridge's deck section was impulsively loaded by passing a truck (fig. 4) with four axles with the mass of 41 tons over an obstacle with a height of h = 40 mm, at a speed of 90 km/h.

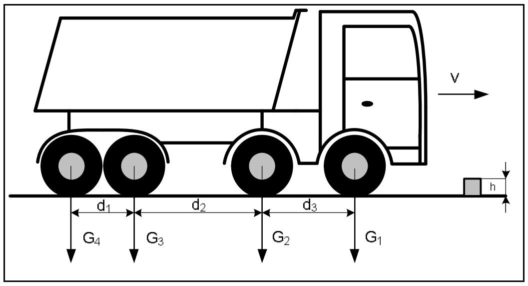


Fig. 4 The truck used for dynamic testing

m_1= 7440 kg, m_2= 7339 kg, m_3= 13149 kg, m_4= 13149 kg, d_1= 1,5 m, d_2= 2,5 m, d_3= 2,0 m, h= 40 mm

Impact forces are calculated using the following mathematical expression [14]:

$$F_y = \frac{mv_0}{3\Delta t}\frac{h}{R}\left(2\frac{h}{R}-5\right) \quad (1)$$

where h = 0.04 m, R = 1.2 m - wheel diameter, Δt = 0.03s - time required by the wheel to pass over the obstacle, m - mass distributed on the axle, v_0 = 20 km/h - the speed of the vehicle at crossing over the obstacle. Excitation forces corresponding axles passing over the obstacle were the following: $F_{y1}=1.4751\cdot10^5$ N; $F_{y2} = 1.4551\cdot10^5$ N; $F_{y3} = 2.6071\cdot10^5$ N; $F_{y4} = 2.6071\cdot10^5$ N.

Considering that the loading function is of a rectangular shape, the section excitation consists of a train of four rectangular pulses, fig. 5.

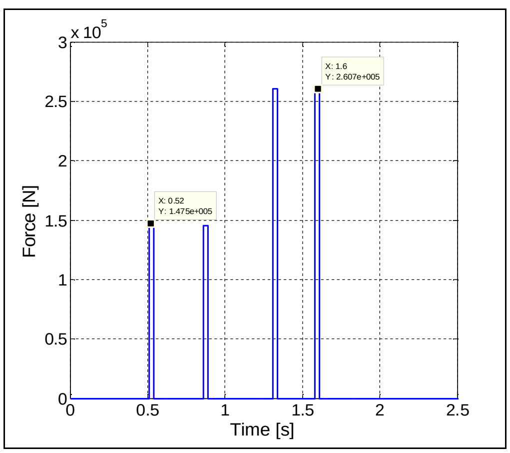


Fig. 5 Train of four rectangular pulses

5. CHARACTERIZATION OF MATHEMATICAL DYNAMICAL SYSTEM

We have studied the response of a section of the bridge deck, leaned on antiseismic systems of hybrid type, at the action of dynamic loads.

Under the conditions of the bridge deck loaded by loads from heavy traffic, the movement is significant on the longitudinal direction of the bridge (direction OY). For this reason the development of the mathematical model for this movement is made under (2).

Coupled mode (Y, φ_x)

$$\begin{cases} m\ddot{Y} + \dot{Y}\sum_{1}^{16} c_{iy} - \dot{\phi}_x \sum_{1}^{16} c_{iy} z_i + Y\sum_{1}^{16} k_{iy} - \\ -\phi_x \sum_{1}^{16} k_{iy} z_i = F_y \\ J_x\ddot{\phi}_x - \dot{Y}\sum_{1}^{16} z_i c_{iy} + \dot{\phi}_x \sum_{1}^{16}\left(c_{iy} z_i^2 + c_{iz} y_i^2\right) - \\ -Y\sum_{1}^{16} z_i k_{iy} + \phi_x \sum_{1}^{16}\left(k_{iy} z_i^2 + k_{iz} y_i^2\right) = e_y F_y - e_z F_z \end{cases} \quad (2)$$

where:
m - mass of the bridge deck;
c_{iz} - damping coefficient of the bearing i on vertical direction;
k_{iz} - modulus of elasticity of the bearing i on vertical direction;
X, Y, Z - bridge deck movements on directions OX, OY and OZ;
ϕ_x, ϕ_y - mass m rotations around axes OY and OX;
x_i, y_i and z_i - coordinates of bearings;
J_x, J_y, J_z - principal moments of inertia;
e_x and e_y - coordinates of the point of application of forces to the center of mass excitation;
F_z, F_y - excitation forces.

The coefficient of friction between the two friction surfaces of the pendulum is of steel type - PTFE with the following values: static μ = 0.05 [19], dynamic μ = 0.04 [20].

For these hypotheses will be represented graphically and analyzed the following parameters of vibration:

- displacement, velocity and acceleration deck in time and in frequency domains;
- movement the phase plane;
- power spectral density;
- hysteresis loop;
- spectrogram acceleration.

The representation of these parameters, mentioned above, is made by comparison between two cases: with and without bearings friction, but under the same conditions of loading.

The movement of truck when passing over the obstacle was made to the speed of 90km / h.

5.1. THE DECK DISPLACEMENT ON OY DIRECTION

Excitation forces, from the crossing of the axles over the obstacle, have the following values: $F_{y1} = 7.8227 \cdot 10^5$ N, $F_{y2} = 7.7165 \cdot 10^5$ N, $Fy_3 = 1.3825 \cdot 10^6$ N; $F_{y4} = 1.3825 \cdot 10^6$ N.

From the analysis of representation of the deck movement in time on the OY direction fig. 6 can notice a decrease in amplitude of motion of 0.4 mm when using friction pendulum. The same downward trend is reflected also for spectral representation of the kinematic parameters of the bridge vibration, fig. 7.

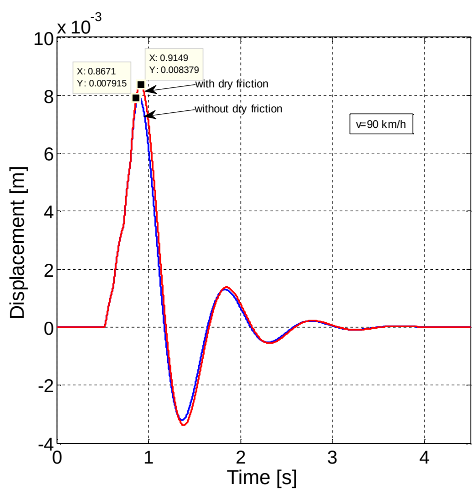


Fig. 6 The deck movement on OY direction

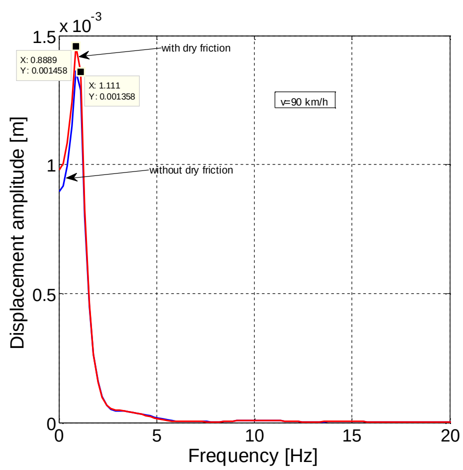


Fig. 7 The spectral representation of the deck movement on OY direction

5.2. THE SPEED DECK ON THE OY DIRECTION

The representation of the speed deck on OY direction, fig. 8, shows that in the presence of the dry friction, lower amplitude with 0.7 mm/s compared to the other case examined, which is not a relevant value for this parameter analyzed.

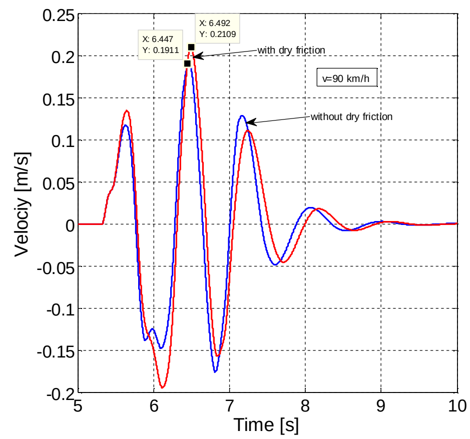


Fig. 8 The deck velocity on OY direction

5.3 REPRESENTATION IN THE PHASE PLANE

By eliminating the time from displacement and speed relations was obtained the phase plane representation in fig. 9, which is an indicator of the stability of motion. Both movements highlight the existence of the same attractor point, which demonstrates the stability of the movement.

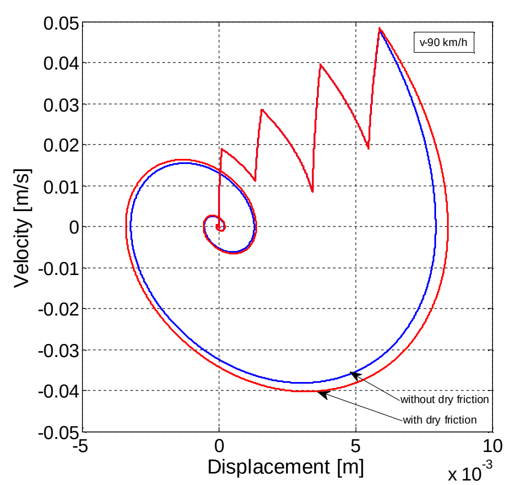


Fig. 9 The phase plane representation

5.4 THE ACCELERATION REPRESENTATION ON OY DIRECTION

The representation of acceleration in time domain shows an amplitude decrease by 20 mm/s^2, when using friction pendulum fig. 10. This trend is observed for the spectral representation of this parameter, being observed a decrease in the amplitude of the dominant frequency, fig. 11. At this level of excitation, it is not noticed any change of the period of oscillation deck.

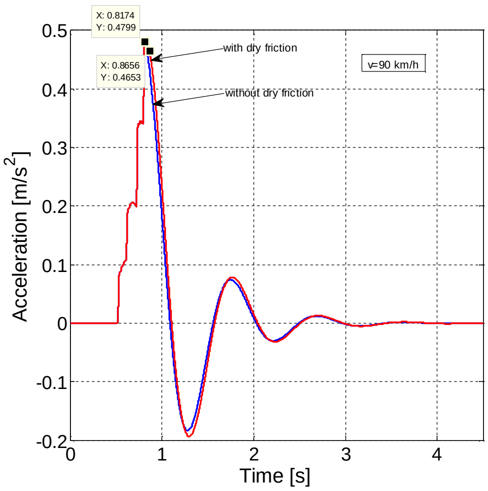


Fig. 10 The deck bridge acceleration on OY direction

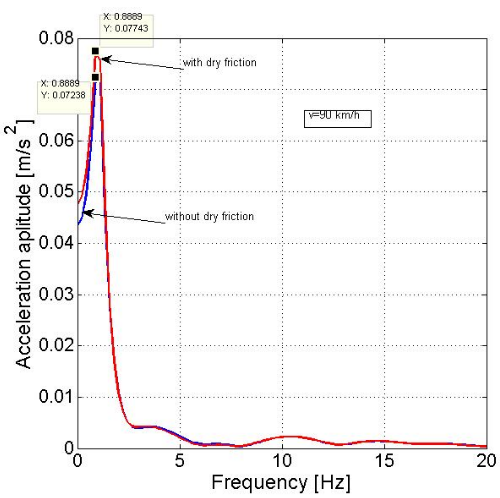


Fig. 11 The spectral representation of the deck bridge acceleration on OY direction

5.5 THE ACCELERATION SPECTROGRAM REPRESENTATION

The acceleration spectrograms are similar when the excitation system is activated, differences occur in the post-excitation system response. Thus, in the presence of dry friction due to the pendulum, the residual response of the system is characterized by significant spectral components with a frequency of 1800 Hz compared to the other analyzed case where the values are up to 750 Hz.

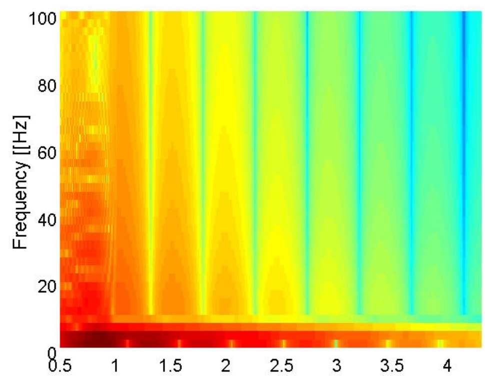


Fig. 12 Spectrogram: with dry friction

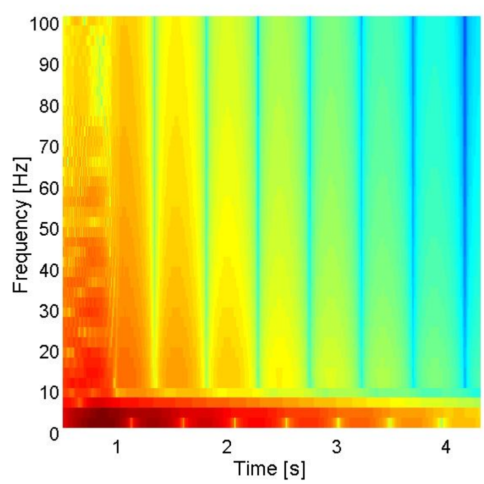


Fig. 13 Spectrogram: without dry friction

5.6 CONCLUSIONS

The presence of dry friction caused by the pendulum motion leads to a decrease of the amplitude for each of the three parameters examined: displacement, velocity and acceleration. Of the three kinematic parameters of vibration, acceleration was the parameter most sensitive to the presence of friction pendulum in this case were recorded the biggest differences.

It has been shown for both cases, by representing the motion in the phase plane, that the response system is stable over time, in other words chaotic motions have not been identified.

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