Evaluation of the impact of selected dynamic effects on key mechanical characteristics of flexible and semi-rigid road pavement

Abstract

The subject of the work was to investigate the influence of considering inertial forces in mechanical models on the results of deformation and deflection state of road pavement. The cases of loading were considered, which are essential for designing flexible and semi-rigid road pavement, as well as for non-destructive testing involving measuring deflections under known time-varying loads.

In the first chapter, the aim of the work was presented, its scope was described in detail, and the motivation for dealing with the discussed topic was justified. Then, within the second chapter, the literature on the subject was discussed, divided into individual issues addressed in the work. In the third chapter, the models used for road pavement in the work were discussed, and the tools used in the work, such as finite element models made in the ABAQUS program (including the use of special elements with infinite dimensions), the VEROAD program, Burmister's solution, and independently implemented solutions of known tasks that take into account inertial forces using integral transformations, were also presented. Special attention was paid to modelling the viscoelastic properties of asphalt layers and verifying the correctness of the created numerical models.

The next three chapters considered identified issues where dynamic effects have been taken into account due to the fundamental importance of the considered computational case or due to the significant influence of inertial forces on obtaining results. In each of the chapters, calculations were made for the case of considering inertial forces and when inertial forces were neglected in the equilibrium equations. Additionally, in both cases, calculations were made using a viscoelastic model for asphalt layers or an elastic model by assuming the dynamic modulus of elasticity for a given frequency of load. Five different frequencies of loading were considered. The calculations were made for one example pavement structure.

In the fourth chapter, a load from a 100 kN vehicle wheel of a heavy vehicle moving at one of five speeds of 5 km/h, 30 km/h, 60 km/h, 90 km/h, and 120 km/h was considered. The discrepancies in the obtained extreme deflection and strain results between the viscoelastic and linearly elastic models were commented on. Inertial forces were negligible in the considered case, whereas the variability of critical deflection and strain results and the durability of pavement calculations were caused by viscoelastic properties of asphalt layers. In the work, the mentioned dependence of the deflection and strain on speed for the considered pavement

structure was determined. Based on the relationship between results and velocity for the considered pavement structure, the fatigue life was calculated using the distribution of heavy vehicle traffic velocities. A method for calculating the effective speed was proposed, and results were considered for realistically occurring distributions of heavy vehicle speeds.

In the fifth chapter, the method of load modelling was supplemented by considering the influence of road surface unevenness on the magnitude of interaction. In the standard case, a constant load is assumed, but the vehicle moves along an uneven road, causing vibrations and therefore a variable force over time. Calculations were performed for an example unevenness, and it was found that at higher vehicle speeds, the force of interaction with the surface is greater. In this case, the viscoelastic properties of the asphalt layers were decisive, and the largest deflections and deformations were obtained for a speed of 5 km/h. However, they differed significantly from solutions assuming a constant force value. In the next step, a larger range of unevenness, derived from real measurements on the road network, was considered. The available data were divided into 20-meter road sections, for which International Roughness Index (IRI) and the standard deviation of the force from the vehicle wheel were calculated. In this way, using regression, a relationship between the standard deviation and IRI for different speeds was found. Based on the standard deviation, a confidence interval for the force loading the pavement was built, and the 95th percentile of the force was used as the load for the selected speed and IRI value to calculate critical deflections and deformations, and then durability. For large unevenness, the critical case was the loading of the surface with high speeds. In summary, the influence of inertial forces in the vehicle was significant in the analysed case, while the influence of inertial forces in the surface was negligible.

In the sixth chapter, the case of load in the Falling Weight Deflectometer (FWD) study, where the load value varies rapidly over time, was considered. Taking into account the inertia forces was important in this case, as the results of static and dynamic analysis differ significantly. The influence of these differences on backcalculations was examined, and dynamic effects should not be ignored. Additionally, attention was also paid to the issue of result sensitivity in inverse FWD calculations.

The final chapter was a summary of the calculations carried out in the previous chapters, determining the influence of considering inertial forces in individual calculation cases.

Keywords: road pavement mechanics, pavement dynamics, numerical modelling, mechanistic-empirical design, diagnostic testing