Abstract

The development of digitalization and structural monitoring systems is leading to the increasingly widespread use of digital twins in civil engineering. Their fundamental concept is to establish a connection between a real object and its virtual counterpart, enabling continuous analysis of structural response and the identification of phenomena occurring during operation. This approach is particularly important in the case of bridge structures, which are increasingly classified as strategic infrastructure.

Despite the dynamic development of digital twins, there is still no single universally accepted definition of this concept in the literature. Available studies focus on different aspects of the digital twin development process, while emphasizing the necessity of integrating measurement data, numerical models, and decision-support algorithms. One of the key challenges remains the identification of actual operational loads acting on the structure. This dissertation presents a methodology for addressing this problem, treating the load identification process as one of the fundamental elements of the information layer of a digital twin.

The research was conducted using the example of an arch bridge located in Wolin, on which a strain monitoring system was installed. For this purpose, fiber optic sensors based on Fiber Bragg Grating technology were used, with measurements performed in three sections located at $1/4$, $1/2$, and $3/4$ of the span length. Particular attention was devoted to the location of measurement points through a theoretical static analysis. The determined influence lines of the crossbeams demonstrated that it is possible to identify vehicles located in the immediate vicinity of the analyzed section without the results being disturbed by vehicles situated farther away. This characteristic of the structure enabled three independent weight measurements of the same vehicle during its passage across the bridge.

In the next stage, load testing was carried out, including both static and dynamic loading schemes. The acquired data were used for the identification of the numerical model, on the basis of which a training dataset was generated. This dataset was used to train neural network models applied in the process of weigh-in-motion. The developed solution was validated using data covering various traffic scenarios, achieving average MAPE values for random vehicle passages at the level of 7 – 8 %. The obtained results confirmed the possibility of integrating measurement data, numerical models, and machine learning algorithms within the information layer of a digital twin, thereby enabling the identification of actual operational loads.

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