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# THE DEFORMATION MONITORING SYSTEM ON THE BRASA OVERPASS IN RIGA

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## Abstract

Engineering structures such as bridges, overpasses, and viaducts constitute a crucial component of the infrastructure of any industrial city. The wide-scale industrialisation of the twentieth century transformed the urban landscape. Many designs and solutions have become morally and physically outdated since those times, yet their usage continues, which is not always safe. With the aging of infrastructure, the issue of their further safe use inevitably arises. Geodetic monitoring of structural deformations can provide control and safety, as well as gather data for designers and engineers. The data collected by deformation monitoring systems should form the basis for the reconstruction and maintenance project of infrastructural facilities. Deformation monitoring systems are designed for each object based on the parameters of the structure, taking into account the constructive features, materials, and the importance of the infrastructural object to the city traffic. It is not always possible to completely close an overpass during reconstruction, as this would affect the transport flow in a specific district of the city. Monitoring of recently put into operation structures will ensure the collection of deformation data for the survival analysis. Once the structural health is defined, the period of service life until scheduled maintenance will be determined. As a result of our research on the Brasa overpass in Riga, we developed a scheme for swift response to signals from the monitoring system's sensors. Additionally, we ensured the safe operation of the old overpass during the construction of the new one by promptly utilising data obtained from the deformation monitoring system.

**Key words:** deformation monitoring, geodesy monitoring, accelerometers, inclinometers.

## Introduction

Deformation monitoring systems are becoming increasingly popular in Europe and globally (Zhang & Broere, 2023). During the design and construction phases, many structures are now integrated with safety systems based on deformation monitoring (Shardakov *et al.*, 2023). In such structures, such as the roofs of public buildings, safety systems are essential, due to not only the potential ageing of the structure but also additional loads caused by weather conditions, such as snow (Tsvetkov *et al.*, 2017). Deformation monitoring is also mandatory in structures with increased danger to the population, for example, reservoirs and dams of power stations. The collapse of such structures could lead to incredible destruction (Chrzanowski & Szostak-Chrzanowski, 2009). Currently, in Latvia, there is no widespread use of deformation monitoring systems, as it is not mandatory and not stipulated in legislation. Nevertheless, there are successful examples of such technology application in Latvia, indicating an interest in the use of such systems and suggesting that the demand for deformation monitoring will continue to grow and evolve over time (El-Din Fawzy, Kandeel, & Farhan, 2023).

One significant example of the application of deformation monitoring is the Brasa overpass. In 2023, the reconstruction of the Brasa overpass in Riga was completed. Initially, a reconstruction of the old overpass was planned, but a deeper structural surveying of overpass revealed that it did not meet safety requirements. The project client set specific objectives for the designers. Firstly, to develop a deformation monitoring system for the old overpass, and secondly, to design a system and protocol for responding to deformations that exceed acceptable limits. Engineers and builders were faced with the task of organising the safe operation of the old Brasa overpass during the construction of a new structure at the same location, as the overpass was a very important part of Riga's infrastructure. For this purpose, a deformation monitoring system was developed. The system included methods such as geodetic surveys at certain intervals, as well as continuous 24/7 monitoring with sensors attached to the structures of the old overpass. The monitoring system also included an alert system for responsible persons and a video monitoring system.

Figure 1. Half of old Brasa overpass, and pail drilling for new construction.

For the construction of a new overpass, there was no available space, necessitating the erection on the site of the old overpass 'Figure 1'. This entailed a singular approach: dismantling the old overpass in two phases. Following the removal of the first half, construction of the new overpass commenced, whilst tram movement was maintained on the remaining half. The Brasa deformation monitoring system installed on the overpass ensured the safe passage of public transport across the old structure, albeit in a reversible mode facilitated by traffic lights. The necessity for this system was twofold: not only was the old overpass in a state of disrepair, but the structural integrity was further compromised by the partial dismantlement of the bridge's construction along its axial line.

## Materials and Methods

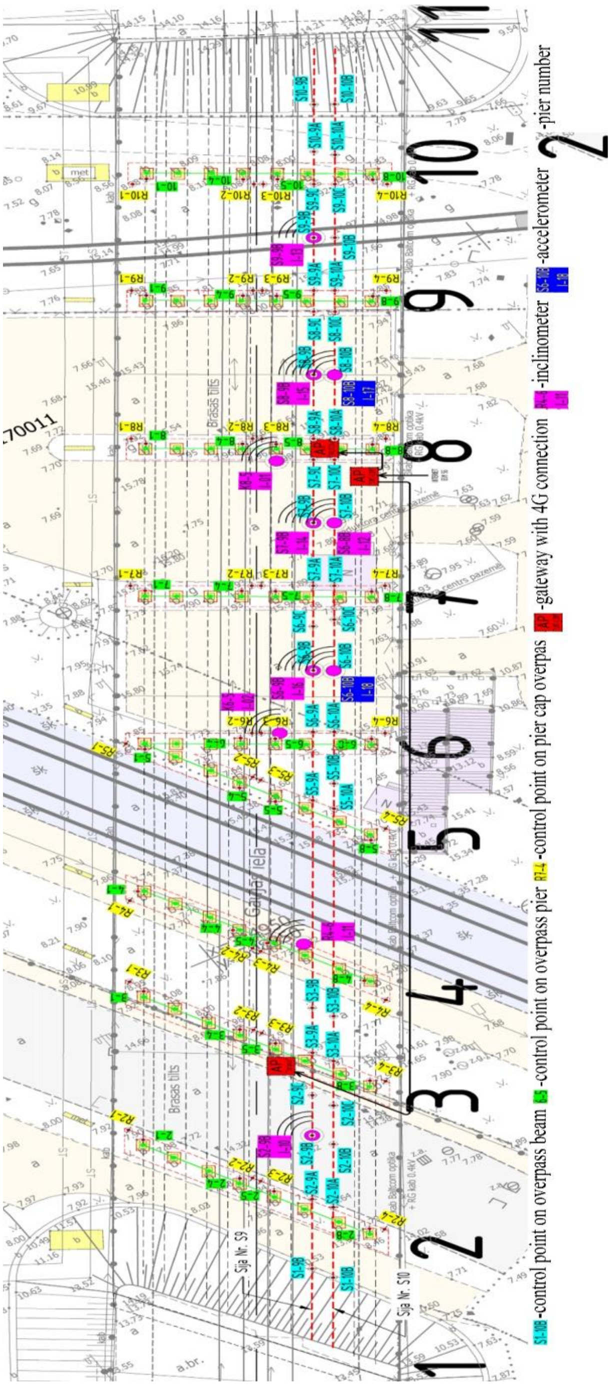

Figure 2. Overpass plan with monitoring points.

The company LLC (Limited Liability Company) 'Tiltprojekts' was tasked with monitoring deformations on the Brasa overpass. For the assessment of the bridge condition, methodologies such as geodetic monitoring were employed, encompassing monthly inspections by a surveyor of specific points using a total station, in addition to the implementation of continuous monitoring via sensors (accelerometers, inclinometers). For reporting purposes, photo fixation files were generated using a camera with a 360-degree capture angle to document changes in the structure (emergence of new cracks), while existing cracks were selectively filled with a gypsum solution to monitor the progression of their expansion. 'Figure 2' illustrates the overpass plan with monitoring points indicated, different types of sensors, geodetic marks, as well as the gateway internet connection site for data collection, processing, and transmission to responsible parties are distinguished by various colours.

Dimensional parameters, obtained by surveyors from the old overpass, along with the available original drawings of the overpass, formed the basis for the creation of a 3D model. The model incorporated the reinforcement parameters and materials from the original drawings. Utilising computer software and the model, the loads that the old, worn structure of the overpass could withstand were calculated, as well as what the safe limits of structural deformations would be. Utilising the data acquired during tram tests, permissible speed regimes for public transport movement, as well as standard deformation values for the bridge's span structures, were calculated.

Should these permissible values be exceeded, an alert system was activated. 'Figure 3' displays the block diagram of the emergency response system. An alarm signal was sent via SMS and duplicated to various engineers to mitigate the risk of unavailability or preoccupation of any specialist, thus eliminating the human factor. In the event of adverse circumstances, a stop signal from the traffic light was to be activated, halting movement across the old overpass. Additionally, notifications were dispatched to responsible services, including the railway. By closing tram traffic and removing the load on the spans, the safety of train movement beneath the overpass could be guaranteed.

Each month, the surveyor examined geodetic marks to analyse the subsidence of structures. A total of 112 reflectors were installed on the supporting structures of the overpass to monitor long-term subsidence and deformations. Through geodetic monitoring, weak points on the beams and supports were identified, where the subsidence was consistently increasing and exceeded the precision of the instrument. These areas received increased attention, and some precise sensors were relocated to these weak points for more detailed study and improved deformation control.

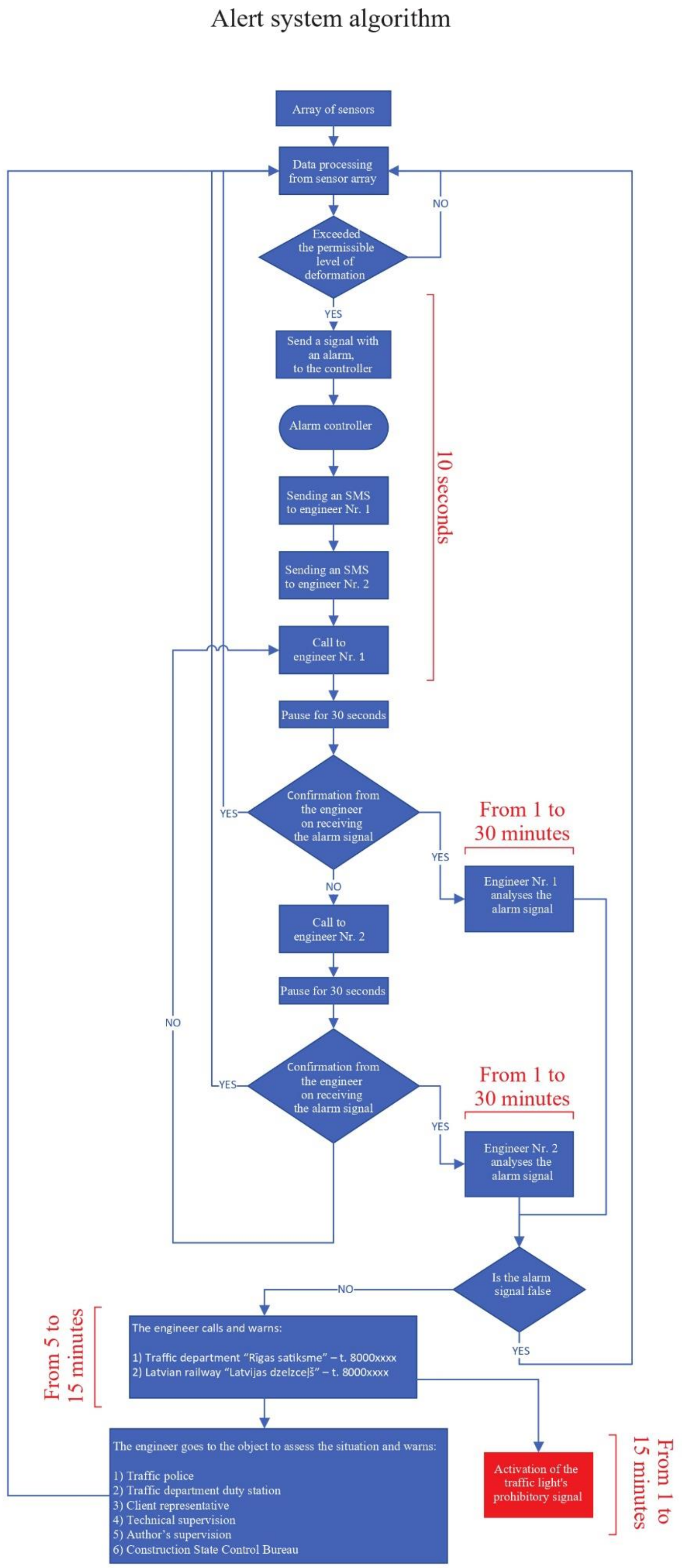

Figure 3. Alert system algorithm.

## Results and Discussion

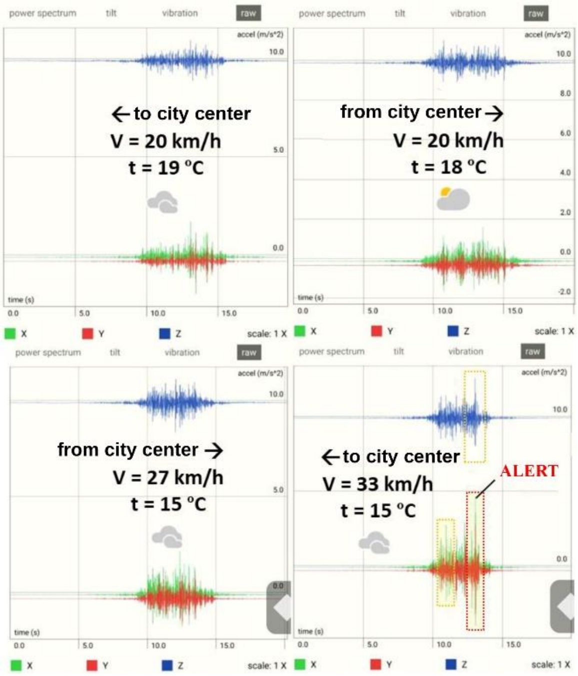

Figure 4. Diagrams from experiment with tram speed.

An example of sensor reporting is depicted in ‘Figure 4’. These deformation graphs were obtained during the testing of the entire system by operating trams in various directions at different speeds. Through this experiment, a safe speed regime for trams was established, which did not induce critical deformations in the span beams. Trams were strictly prohibited from exceeding a speed of 30 km/h. Occasions occurred during operation where drivers exceeded this speed limit, imposing additional load on the structure, which was recorded by the system and, in conjunction with video surveillance, violators were identified and subjected to sanctions.

Figure 5. Deformation of the overpass span beam.

Geodetic measurements using a total station revealed deformations in the central beams following the dismantling of half of the overpass. It can be assumed with high probability that the cross ribs of the beam structure provided stiffness to the entire span. After the demolition of half of the structure, the central beam assumed the role of the outer beam, lacking the stiffness provided by the lost ribs, as illustrated in ‘Figure 5’. Consequently, surveyors were compelled to supplement their survey with monthly levelling of the tram rails to ensure that the span structure did not continue to deform.

During the summer period, amidst high solar activity, maximum deformations were reached at one instance, rendering the overpass operation hazardous. Following all stages from the block diagram, engineers decided to halt traffic across the old overpass. Immediate analysis of the data was undertaken. Recalculation of permissible deformations at high temperatures indicated that the threshold for critical deformations also shifts with temperature changes. Two days later, traffic was reopened on the overpass after adjusting the critical value levels according to the ambient environment. Other similar studies on deformations in comparable climatic conditions, characterised by sharp temperature fluctuations, encountered similarly rapid increases in the deformations of concrete structures.

As a result, the system was so well calibrated and configured that the operator monitoring the deformations noticed a minor surge in deformation. These surges coincided with the passage of the same tram over the overpass. Upon deeper inspection, it was calculated that the front axle on the right side of the tram had a defect, causing additional load on the spans. This tram was removed from service and sent for suspension repair.

## Conclusions

1. Contemporary structural health monitoring (SHM) methodologies for engineering edifices can render their utilisation safer for society, in addition to enhancing the predictability of structural wear for designers during restoration works. The successful implementation at the Brasa overpass serves as a paradigm that ought to be applied in other urban infrastructure repair and construction projects. The monitoring system can be scaled to accommodate any size of structure. Geodetic surveys conducted with traditional methods, such as total stations, fail to provide comprehensive data regarding the health of structures. Thus, the combination and integration of various deformation monitoring methods enable the provision of reliable control over aged structures. These methods complement and provide mutual support to one another. Monitoring systems, predicated on high-precision sensors, are capable of surveilling the condition of a structure 24/7, thereby implementing a significant advantage over alternative methodologies. The capability to connect sensors to the internet facilitates the prompt transmission of data to responsible services, allowing for informed decisions regarding the further exploitation of the structure under study.
2. Our research could serve as a foundation for the development of legislation in Latvia, mandating the monitoring of old structures that are in use during repair works. Such measures enhance public safety. In future research, we aim to reduce the response time to emergency situations by connecting the monitoring system to traffic lights. This integration would immediately close the overpass upon receiving a signal indicating that the permissible deformation limits have been exceeded.

## References

Chrzanowski A. & Szostak-Chrzanowski A. (2009). Deformation Monitoring Surveys – Old Problems and New Solutions. Reports on Geodesy, 2(87), 85-104. Retrieved February 20, 2024, from https://api.semanticscholar.org/CorpusID:59385518.

El-Din Fawzy, H., Kandeel, R., & Farhan, M. (2023). Detection of deformations in reinforced concrete structures using modern surveying techniques. *Alexandria Engineering Journal, 70*, 191–218. DOI: 10.1016/j.aej.2023.02.030.

Shardakov, I., Glot, I., Shestakov, A., Tsvetkov, R., Gusev, G., & Yepin, V. (2023). System for Monitoring Deformation Processes in High-Rise Metal Structure. *Procedia Structural Integrity, 48*, 127–134. DOI: 10.1016/j.prostr.2023.07.138.

Tsvetkov, R., Shardakov, I., Shestakov, A., Gusev, G., & Epin, V. (2017). Deformation monitoring of load-bearing reinforced concrete beams. *Procedia Structural Integrity*, *5*, 620–626. DOI: 10.1016/j.prostr.2017.07.028.

Zhang, X. & Broere, W. (2023). Monitoring seasonal deformation behavior of an immersed tunnel with distributed optical fiber sensors. *Measurement: Journal of the International Measurement Confederation*, *219*. DOI: 10.1016/j.measurement.2023.113268.