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CASE STUDIES

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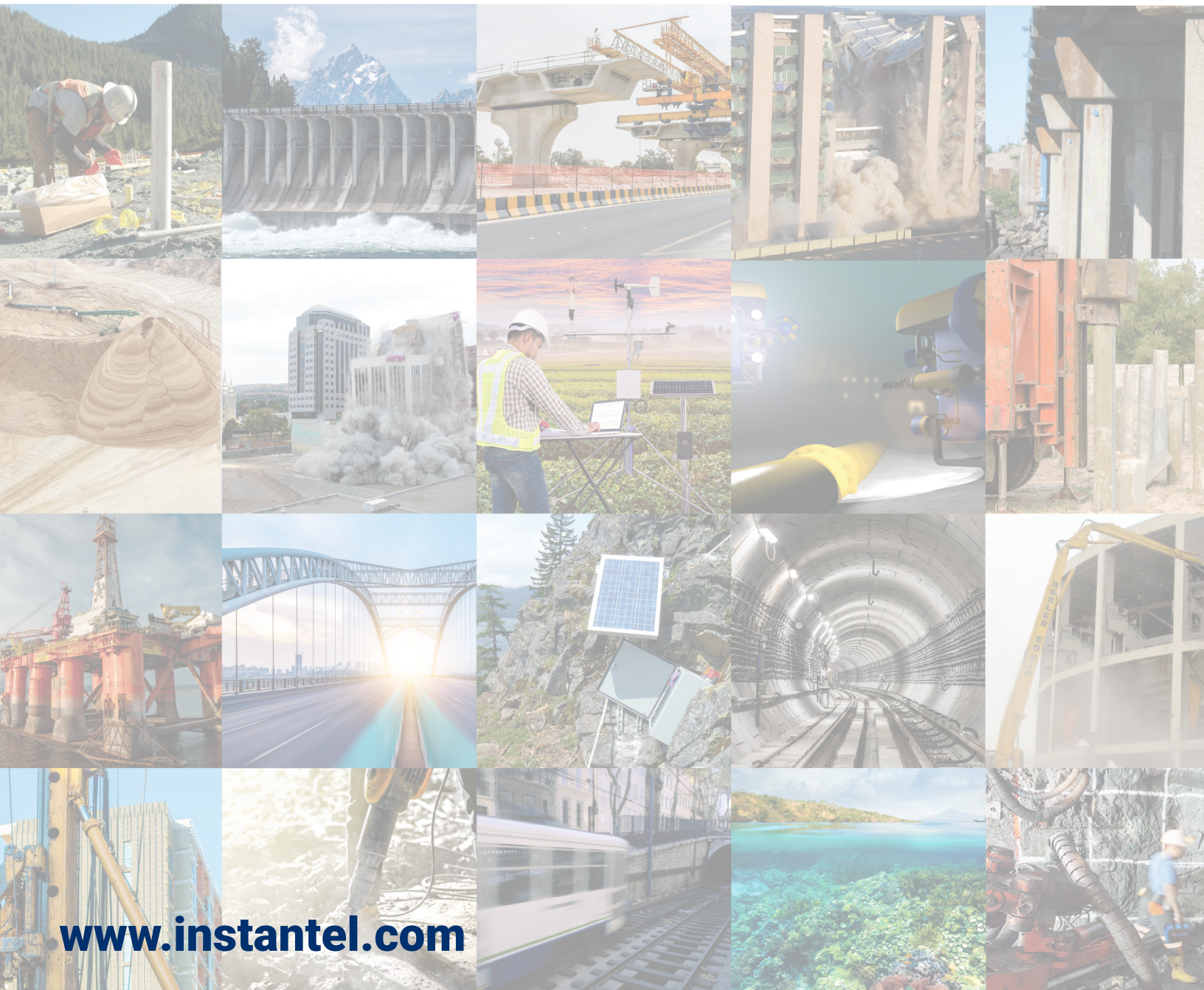

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Case Study:
Structural Vibration Monitoring for Slovenia's National Transport Infrastructure Project

INTRODUCTION

Professional vibration monitoring using Instantel equipment has delivered significant value to Slovenia's national highway infrastructure development, the Third Development Axis project. As part of the first phase of the northern section, Micromate units equipped with DIN-compliant geophones and linear microphones were deployed to monitor ground vibration and air overpressure. The primary objective was to ensure compliance with DIN standards, with a strong focus on protecting residential areas located along the highway corridor.

BACKGROUND

The Third Development Axis (Tretja razvojna os) is one of Slovenia's most important national transport infrastructure projects and considered a long-term, phased project, with planning and construction spanning many years (even decades). It is designed to create a new high-capacity road connection running from northern Slovenia (Austrian border) through the interior of the country down to southeastern Slovenia (Croatian border). The main goal of the project is to improve connectivity for regions that have historically been poorly served by motorways.

The first phase currently under construction focuses on the northern section, which runs from the Šentrupert motorway junction to Slovenj Gradec. This section is divided into two subsections:

- From the Šentrupert interchange on the A1 motorway (Šentilj–Koper) to the Velenje South interchange (approximately 14 km)
- From the Velenje South interchange to the Slovenj Gradec South interchange (approximately 17.5 km)

Development of these sections is governed by national spatial planning decrees covering both the Šentrupert–Velenje South and Velenje South–Slovenj Gradec South segments. This large-scale project traverses diverse geological conditions and passes near residential areas, requiring careful monitoring throughout construction.

The four-lane road begins at the existing G1-4 Dravograd–Arja Vas road near Trebuška vas at the Slovenj Gradec South interchange. From there, it runs south along Homec hill, cuts through the Dobrova ridge, and descends into the Suhodolnica valley, continuing along the eastern side of Podgorje to the Podgorje interchange. The route then crosses the Jenina valley and passes below the Visočnik farm, where it splits into two carriageways through the Vodriž and Pusta Gora tunnels. After the tunnels, it descends into the Velunja valley, crossing it twice, and continues along the eastern side of the Velunja River toward Potoški vrh. Turning east, the alignment heads toward the Gaberke interchange, crosses the Lepena valley, and passes through the Turnska gošča forest. It then descends toward Škale Lake, bypasses it on the eastern side, and connects to the N1 link road at the Škale interchange, providing access to northeastern Velenje. The section ends at the Velenje South interchange. Upon completion, the full route will include substantial infrastructure, including roadwork and tunnels.

As part of the project, construction activities—particularly blasting and heavy earthworks—generate ground vibrations and air overpressure that may impact nearby structures. Continuous monitoring and analysis of these parameters are therefore required to ensure compliance with regulatory limits and to protect surrounding buildings and communities.

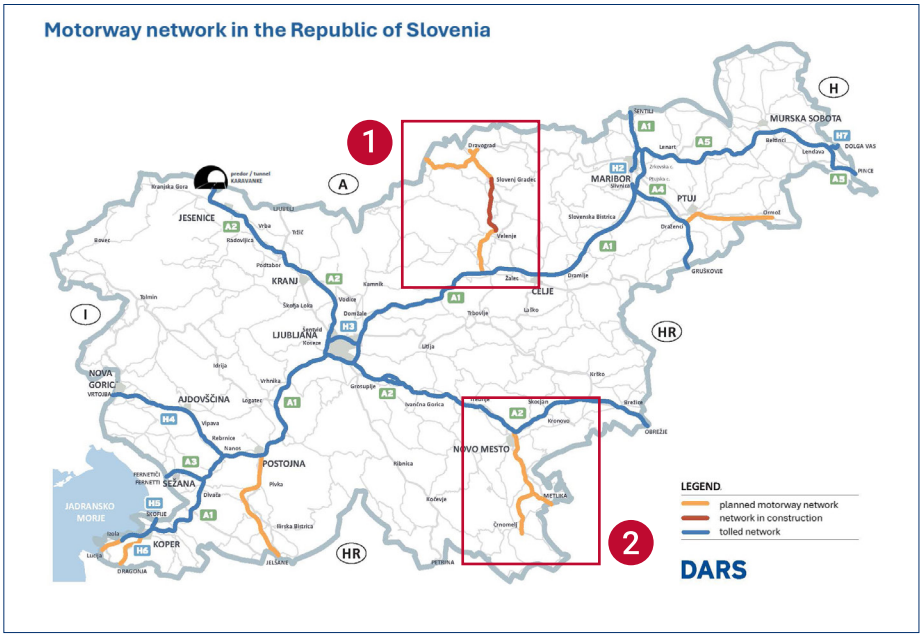


Figure 1 Courtesy: ASECAP/DARS (① North / ② South)

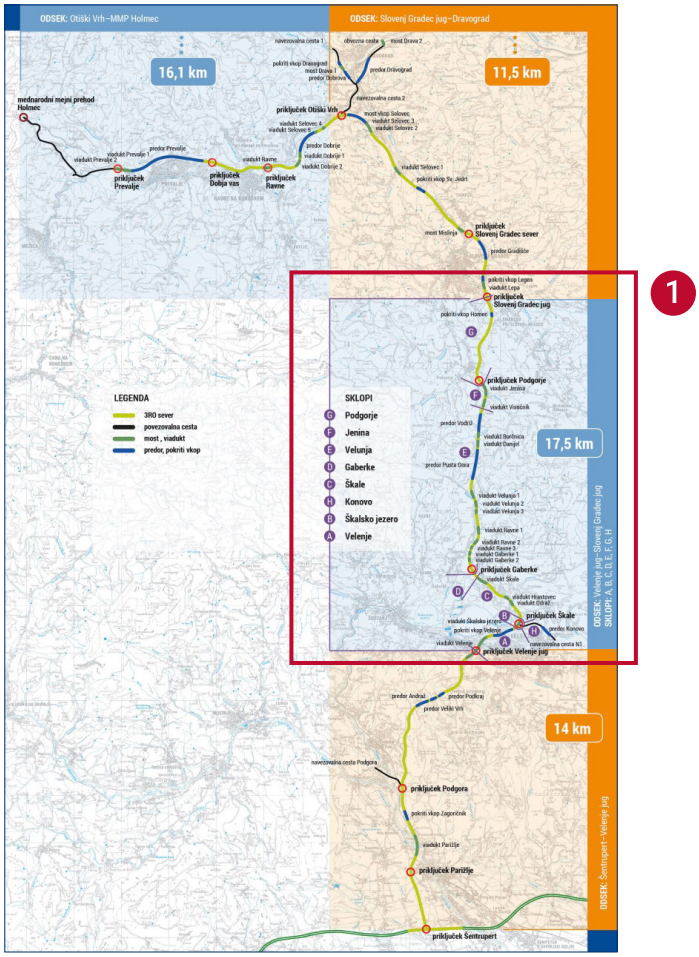


Figure 2 Courtesy: AATE
① North Section Under Construction

APPROACH

Utilizing the Micromate unit, DIN triaxial geophones, and linear microphones monitoring campaigns were carried out to measure vibration velocities during preparatory earthworks such as transport and compaction for the preparation of access roads, as well as during dynamic pile load tests for the foundations of the Škale viaduct.

Sectors were divided according to defined time schedules, following one another sequentially. Several included tunnels and viaducts with no residential and commercial buildings, or cultural heritage sites. In these areas, a single device was sufficient to carry out the required vibration monitoring.

In Section C (Figure 2 - Map) in Škale, monitoring was carried out during periods of intensive construction. During the drilling of piles for viaduct foundations and during dynamic load testing of piles, monitoring was carried out continuosly with an online connection (24 hours per day for two weeks).

Section D (Figure 2 - Map) involved the installation of noise-reducing material, including 810 m of noise barriers. This section was demanding primarily due to the immediate proximity of residential areas resulting in additional measures to ensure no impact on the residents' quality of life.

In Section E (Figure 2 - Map), the Vodriž tunnel was constructed using blasting techniques on rock. This portion involved daily measurements twice per day while blasting.

Section H (Konovo) required long-term continuous monitoring (24 hours per day) with online supervision during tunnel excavation works.

Micromate with DIN Triaxial Geophone and Linear Microphone

RESULTS

The vibration monitoring campaign was carried out in accordance with DIN 4150-3 to evaluate the effects of blasting, compaction, pile driving, and dynamic load testing associated with tunnel excavation, viaduct and road construction. Calibrated triaxial geophones were installed at representative locations, with secure coupling to ensure accurate ground-motion transmission. Measurements were recorded as peak particle velocity (PPV) in mm/s in three orthogonal directions (vertical, longitudinal, transverse), with vector sum values calculated and dominant frequencies analyzed to apply the appropriate frequency-dependent criteria.

For structural protection, the conservative DIN 4150-3 Category III limit of 3 mm/s was adopted for sensitive and critical infrastructure components. Throughout all monitoring periods, none of the recorded PPV values exceeded this threshold. Air overpressure was also monitored during blasting operations and remained within prescribed project limits. The results confirm that activities were executed within safe vibration levels, with no adverse impact on the integrity or serviceability of the tunnels and viaduct structures or impact on surrounding structures and residents.

Section C: Pile Testing Škale Viaduct

Section H: Konovo Tunnel

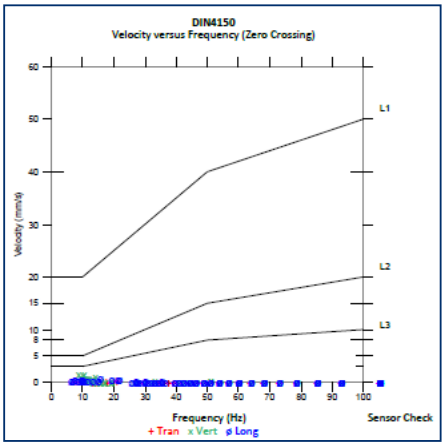
STANDARDS

Monitoring for structures followed Standard DIN 4150-3 and Line 3. Measured vibrations did not exceed the limit values.

Table 1 — Guideline values for vibration velocity, $v_{i,max}$, for evaluating the effects of short-term vibration on structures

-	Type of structure	Guideline values for $v_{i,max}$ in mm/s				
		Foundation, all directions, i = x, y, z, at a frequency of			Topmost floor, horizontal direction, i = x, y	Floor slabs, vertical direction, i = z
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz [a]	All frequencies	All frequencies
Column / Line	1	2	3	4	5	6
1	Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50	40	20
2	Residential buildings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15	20
3	Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings)	3	3 to 8	8 to 10	8	20 [b]
NOTE	Even if guideline values as in line 1, columns 2 to 5, are complied with, minor damage cannot be excluded.					

[a] At frequencies above 100 Hz, the guideline values for 100 Hz can be applied as minimum values.
[b] Paragraph 2 of 5.1.2 shall be observed.



Geophone	Tran	Vert	Long
Peak Particle Velocity	0.560 mm/s	1.553 mm/s	0.725 mm/s
Zero Crossing Frequency	12.3 Hz	10.6 Hz	15.8 Hz
Time (Relative to Trigger)	0.018 sec	0.243 sec	0.011 sec
Peak Acceleration	0.010 g	0.015 g	0.012 g
Peak Displacement	0.006 mm	0.022 mm	0.006 mm
Sensor Check	✓ Passed	✓ Passed	✓ Passed
Frequency	7.3 Hz	7.5 Hz	7.1 Hz
Overswing Ratio	3.1	3.4	3.9
Peak Vector Sum	1.556 mm/s at 0.243 sec		

CONCLUSION

- No recorded PPV values exceeded the 3 mm/s threshold during any monitoring period.
- Air overpressure measurements taken during blasting operations remained within prescribed project limits.
- The results confirm that all construction activities were executed within safe vibration parameters, with no adverse impact on the integrity of structures or residents.

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