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CASE STUDIES

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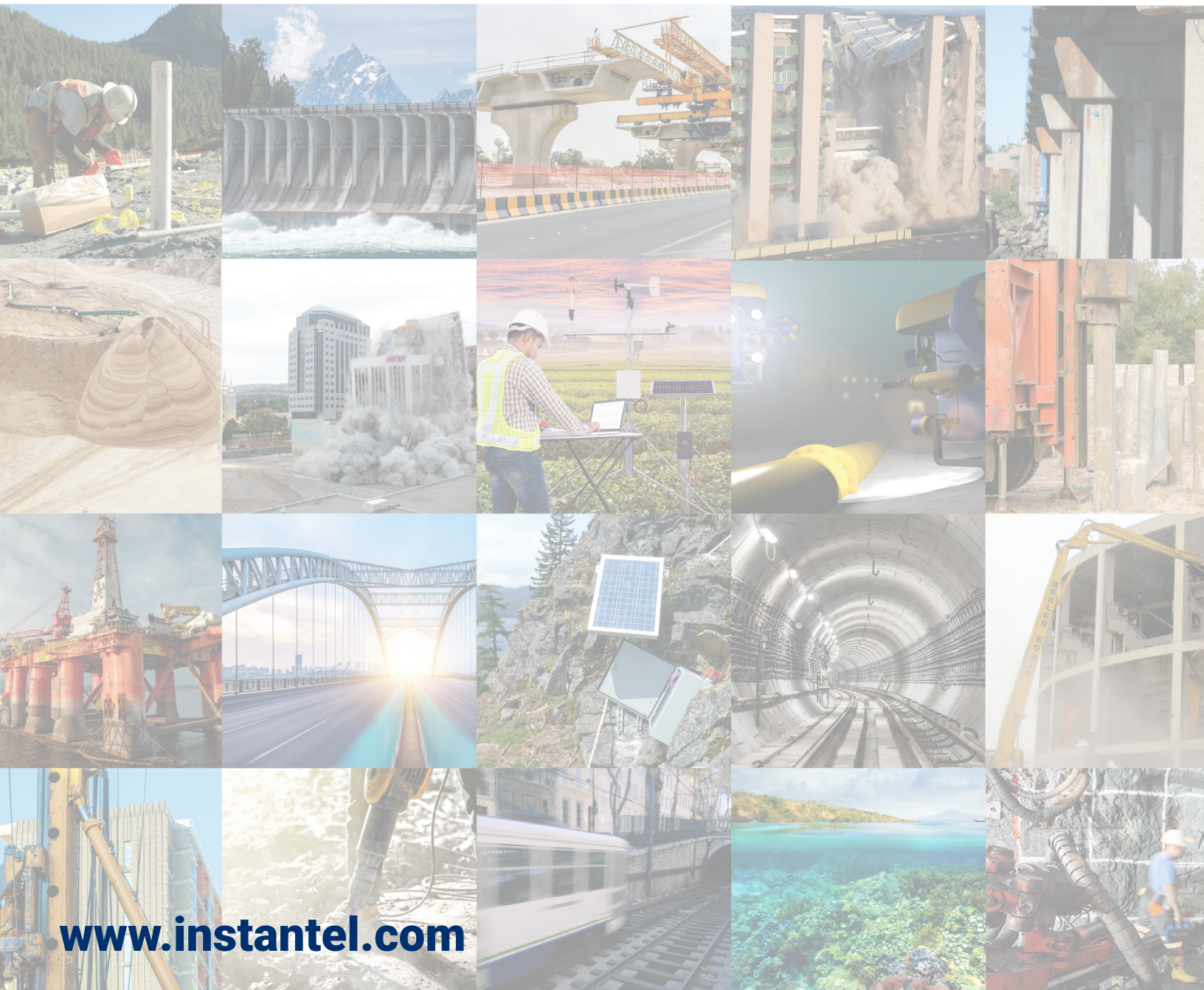

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Case Study:
Blast Design Optimization and Quantitative Evaluation of Blast-Induced Environmental Impacts

BACKGROUND

This case study examines the ongoing Of–Çaykara (DOKAP) Road project, which is designed to modernize the existing route, improve safety, and reduce travel times for both tourists and local residents, while ensuring reliable, year-round access to higher elevations. As a key transportation initiative in the Eastern Black Sea region, the project has involved extensive earthworks, the construction of major engineering structures such as bridges, and the excavation and lining of tunnels—providing an ideal setting for evaluating blast design optimization and assessing blast-induced impacts.

In mining and civil engineering projects, drilling and blasting have been indispensable methods for rock fragmentation and excavation. Although advances in explosive technology and blast design optimization have significantly improved operational efficiency, blasting has inevitably generated dynamic energy that propagates beyond the intended excavation boundary. As a result, even well-designed blasts have produced adverse environmental effects such as structural damage to nearby buildings and environmental complaints due to air overpressure, flyrock, and blast-induced ground vibration. Therefore, each blast event has required systematic monitoring to assess and control these adverse impacts.

The Blasting Design & Vibration Monitoring Research Group (Patlatma Tasarımı & Titreşim Ölçümü Araştırma Grubu), based in Türkiye and led by researchers with more than 25 years of industrial and professional experience, has been actively engaged in blast design optimization, the preparation of explosive material requirement reports, and the quantitative evaluation of blast-induced environmental impacts. Monitoring programs have been conducted across a wide range of mining and civil engineering applications, including open pit and quarry operations, tunnel excavation, hydroelectric power plant tunnels, dam projects, underground mines, urban foundation excavations, natural gas pipeline excavation, and highway construction.

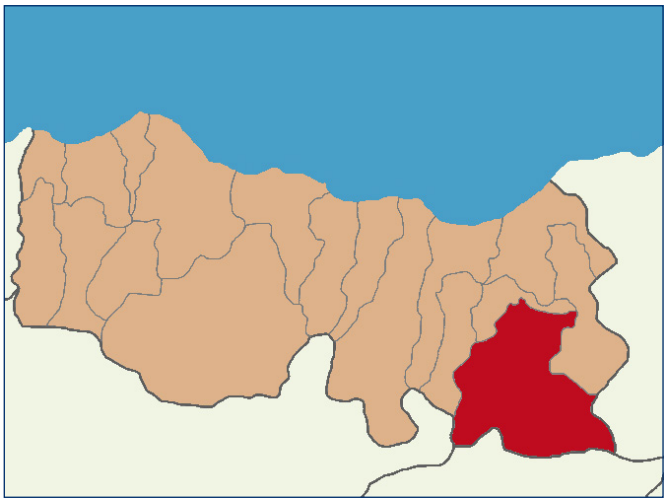

Figure 1 Turkey Map Çaykara District
Courtesy: Batuhan duz, CC BY-SA 4.0 - Wikimedia.org

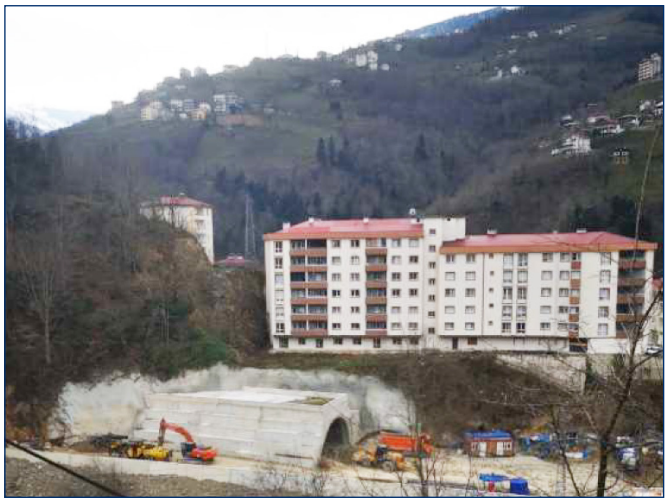

Figure 2 Çaykara Highway Tunnel

Within the scope of the study, the most appropriate blasting pattern has been determined through geological and geotechnical examinations conducted at the tunnel face prior to each blast, and blasting efficiency has been evaluated afterward. Most recently, Instantel monitoring devices and sensors were utilized for environmental monitoring during blasting operations in the Çaykara highway tunnel, located in the Çaykara district of Trabzon province in northern Turkey, to monitor vibration and air overpressure, with measurements carried out in accordance with regulations. This monitoring has helped ensure that blasting activities are performed safely while also contributing to the prevention or reduction of potential environmental complaints. The project is anticipated to be completed by the end of 2026, with continued activities currently in progress.

APPLICABLE STANDARDS

Table 3. Maximum Permissible Ground Vibration Values at the Nearest Structure Caused by Blasting in Mines, Quarries and Similar Areas

Building Type	Maximum Vibration Velocity at the Foundation of Buildings (mm/s) (Based on frequency, *f = Hz)*	Upper Floor Slab (Floor) for all frequencies [2]
	f = 1-10	*f* = 10-50
1. Industrial Buildings	20	40
2. Houses, durable structures such as brick and concrete	5	15
3. Structures sensitive to vibration excluding items 1 and 2; historical and natural structures [3]	2	8

Table-4: Maximum Permissible Ground Vibration Values Caused by Railway and Road Transport Vehicles, Workplaces, and Industrial Facilities at the Nearest Structure, and Ground Vibrations Caused by Machinery and Equipment Inside the Building

	Vibration Frequency (Hz)	Maximum Permissible Vibration Velocity (rms value (mm/s))
In Residences	1 (1)	1.5
	8 - 100	0.3
In Offices	1 (2)	3.5
	8 - 100	0.6
In Historical and Natural Structures (4)	1 (3)	0.8
	8 - 100	0.1

APPROACH

A comprehensive monitoring approach was implemented as part of this case study, utilizing four Instantel Micromate units equipped with DIN-standard triaxial geophones and linear microphones to capture both ground vibration (PPV and frequency) and air overpressure data during blasting operations. Monitoring campaigns were conducted in accordance with applicable local regulations, including the Turkish Regulation on the Assessment and Management of Environmental Noise, which defines compliance limits for vibration and air overpressure as outlined in Tables 3 and 4.

Data acquisition began earlier in the project lifecycle and is ongoing through to the anticipated project completion at the end of 2026. As excavation advanced through varying environments, including residential and industrial zones, site-specific trigger thresholds were dynamically adjusted to reflect the sensitivity of surrounding structures and receptors.

Blasting activities were scheduled within the permitted daytime window of 07:00 to 19:00 for non-residential areas, while in residential zones, operations were further constrained to mid-morning to mid-afternoon periods to minimize disturbance. Continuous monitoring during each blast event confirmed that measured peak particle velocity (PPV), dominant frequencies, and air overpressure levels consistently remained within the maximum permissible regulatory limits.

Micromate with DIN Triaxial Geophone and Linear Microphone

RESULTS

The results of the monitoring program demonstrated that blasting operations were effectively controlled throughout the duration of the study. Data collected from the four Micromate units consistently showed that peak particle velocity (PPV), vibration frequency, and air overpressure levels remained within the regulatory limits defined by the Turkish guidelines. Adjustments to trigger thresholds based on proximity to residential and industrial areas proved effective in maintaining compliance while optimizing blast performance. In residential zones, the restricted blasting windows further contributed to minimizing disturbance, with no exceedances recorded during the monitored events. Additionally, the correlation between blast design parameters and recorded vibration responses enabled continuous refinement of blasting practices, resulting in improved fragmentation efficiency without compromising environmental or structural safety. Overall, the integration of real-time monitoring and adaptive control measures ensured both regulatory compliance and a reduction in potential community impacts.

Sensitive historic structures requiring stricter limits for monitoring.

Monitoring conducted in nearby residential areas adjacent to the Çaykara Highway Tunnel construction zone.

CONCLUSION

- Blasting operations were maintained within controlled parameters throughout the monitoring period, demonstrating effective blast design and execution.
- Measured peak particle velocity (PPV), dominant frequency, and air overpressure levels consistently complied with the limits defined in the Turkish Regulation on the Assessment and Management of Environmental Noise (Tables 3 and 4).
- Recorded vibration levels remained below structure-dependent PPV thresholds (typically in the range of ~5–50 mm/s depending on building classification and frequency content).
- Air overpressure levels remained within acceptable limits (generally ≤120–140 dB(L) depending on receptor sensitivity and regulatory interpretation).
- Blasting within regulated time windows (07:00–19:00 for non-residential areas; mid-morning to mid-afternoon in residential zones) contributed to minimizing human exposure and complaint risk.

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