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# **ADVANCES IN SURFACE MINING FOR ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT-2025 (ASMES - 2025)**



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## Controlling Harmful Impacts of Rock Blasting for Construction Site Preparation in Ha Giang Province, Vietnam

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### **ABSTRACT:**

*The use of blasting methods for rock excavation to prepare construction sites in areas with complex terrain and close proximity to structures requiring protection necessitates strict control of harmful effects such as ground vibration, air overpressure, and flyrock. This paper presents the research results on the application of non-electric delay blasting techniques at the construction site of the Ha Giang Provincial Sports and Cultural Complex project, where no prior blast monitoring data were available. Through theoretical calculations and the implementation of five trial blasts, the research team determined the optimal blast scale, maximum instantaneous charge (MIC), reasonable drilling and blasting parameters, and an effective delay blasting pattern to ensure the safety of nearby structures. The monitoring results for ground vibration and air overpressure were all within the permissible limits specified in QCVN 01:2019/BCT. In addition, supporting measures such as steel mesh and sandbag coverings proved highly effective in mitigating flyrock hazards. The study provides both practical and scientific foundations for the safe and efficient application of blasting techniques in similar construction conditions.*

**Key words:** Air overpressure, Blast-induced ground vibration, Blast monitoring, Ha Giang Provincial Sports and Cultural Complex Project, Rock blasting

### **1. Introduction**

In civil and industrial construction activities, especially in mountainous areas with complex terrain, blasting remains a key method for breaking rock to prepare construction platforms. However, alongside its technical and economic efficiency, blasting operations can generate various adverse impacts on the environment and nearby structures if not properly controlled. Common issues include ground vibrations propagating through rock and soil, air overpressure, and flyrock - all of which pose risks of material damage, structural degradation, and threats to human safety (Nhu Van Bach, 2008; Kutuzov B.N., 1992). Therefore, strict control of these factors is essential, particularly when the distance between the blast site and structures to be protected is very short, as in the case study in Ha Giang Province.

This presents a major challenge for many new infrastructure projects across the country, where construction is often carried out on complex geological formations and in close proximity to existing structures. The lack of prior blast monitoring data significantly increases uncertainty and risk. Consequently, developing a systematic approach, encompassing theoretical calculations, trial blast design, experimental monitoring, and iterative adjustments, is not only essential for the Ha Giang project but also provides a referential methodology applicable to similar future projects.

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In practice, only a small portion of the energy from explosives is utilized for rock fragmentation; the majority is transformed into secondary energy forms such as ground vibrations, airwaves, noise, and dust, all of which adversely affect the natural environment, residential life, and occupational safety. The extent of these impacts depends on both technical factors (e.g., maximum instantaneous charge, blasting sequence, borehole spacing) and site-specific conditions such as geology, topography, existing structures, and weather. In this context, selecting an appropriate blasting method, accurately determining design parameters, and especially conducting thorough monitoring of vibration and air overpressure parameters are critical steps to ensure the safety and effectiveness of the project.

For projects without prior blast monitoring data, such as the ground leveling for the stadium within the Ha Giang Provincial Sports and Cultural Complex, the challenge of design and safety control is particularly significant. To minimize risks, detailed research steps are required from estimating the blast scale, determining the maximum allowable instantaneous charge, selecting suitable drilling and blasting parameters and initiation sequence, to monitoring field tests and making adjustments after each blast.

Based on these needs, this study aims to:

- Determine the appropriate blast scale and maximum instantaneous charge in accordance with technical and safety constraints;
- Establish optimal drilling and blasting parameters tailored to the local geological conditions;
- Select reasonable blast sequences and initiation points to minimize ground vibration and associated impacts;
- Propose additional mitigation measures such as flyrock shielding and structural reinforcement to enhance safety levels;
- Conduct monitored trial blasts and analyze field data to refine the blasting procedures for subsequent operations.

The findings of this research not only hold practical relevance for the Ha Giang project but also contribute to the development of reference data and methodologies for similar blasting operations in areas near sensitive structures lacking baseline monitoring data.

## 2. Environmental Impacts of Blasting

### 2.1. Impacts of Ground Vibrations

Blast-induced ground vibrations propagate through rock and soil media, typically in the form of sinusoidal waves. The amplitude and intensity of these vibrations are influenced by a combination of controllable and uncontrollable factors. Controllable factors include parameters such as stemming length, burden and spacing, explosive charge weight, borehole depth, and delay timing between charges. Uncontrollable factors involve the geomechanical properties of the rock mass, such as homogeneity, degree of fracturing, continuity, as well as the structural characteristics of the protected objects and the distance between the blast site and the structures to be protected. Table 1 presents the primary factors affecting ground vibrations during blasting operations.

Table 1. Classification of Factors Influencing Blast-Induced Ground Vibrations (Rosenthal & Morlock, 1987)

| Factors                                     | Level of Influence |        |     |
|---------------------------------------------|--------------------|--------|-----|
|                                             | High               | Medium | Low |
| <i>Controllable Factors:</i>                |                    |        |     |
| Maximum instantaneous charge (MIC)          | X                  |        |     |
| Delay timing                                | X                  |        |     |
| Burden and spacing between boreholes        |                    | X      |     |
| Stemming (material and height)              |                    |        | X   |
| Diameter and height of the explosive column |                    |        | X   |

| Factors                           | Level of Influence |        |     |
|-----------------------------------|--------------------|--------|-----|
|                                   | High               | Medium | Low |
| Borehole inclination angle        |                    |        | X   |
| Direction of borehole inclination |                    | X      |     |
| Total explosive charge weight     |                    |        | X   |
| Charging depth                    |                    |        | X   |
| Charging method                   | X                  |        |     |
| <i>Uncontrollable Factors:</i>    |                    |        |     |
| Type and depth of surface soil    | X                  |        |     |
| Surface topographic conditions    |                    |        | X   |
| Weather conditions                |                    |        | X   |

## 2.2. Impacts of Air Overpressure

In blasting operations, the generation of air overpressure waves is influenced by a variety of factors. Controllable factors include stemming length, height of the stemming column, explosive charge weight, stemming material, and delay timing between charges. On the other hand, uncontrollable factors involve the geomechanical properties of the rock mass, such as homogeneity, degree of fracturing, and continuity, as well as the structural characteristics of protected buildings, the distance from the blast site to these structures, weather conditions, and local topography.

Tables 2 and 3 summarize the controllable and uncontrollable factors that affect air overpressure during blasting operations at open-pit mines.

Table 2. Controllable Parameters in Blasting Operations (Rosenthal & Morlock, 1987)

| Parameter                          | Significant | Moderate | Negligible |
|------------------------------------|-------------|----------|------------|
| Explosive charge per delay         | X           |          |            |
| Total charge weight per blast site |             | X        |            |
| Delay timing                       | X           |          |            |
| Burden and spacing between holes   | X           |          |            |
| Stemming length                    | X           |          |            |
| Stemming material                  |             | X        |            |
| Charge column length and diameter  |             | X        |            |
| Borehole inclination angle         |             | X        |            |
| Blast face orientation             |             | X        |            |
| Initiation direction               | X           |          |            |
| Blast timing (time of day)         |             | X        |            |

Table 3. Uncontrollable Parameters in Blasting Operations (Rosenthal & Morlock, 1987)

| Parameter                                               | Significant | Moderate | Negligible |
|---------------------------------------------------------|-------------|----------|------------|
| General topography                                      | X           |          |            |
| Atmospheric conditions                                  | X           |          |            |
| Rock type (especially structures with joint interfaces) |             | X        |            |

## 2.3. Impacts of Flyrock

Flyrock occurs when explosive energy, particularly the expansive force of detonation gases, escapes violently into the atmosphere and propels rock fragments outward. This phenomenon can take place during both the primary and secondary blast phases.

In primary blasts, flyrock incidents often result from insufficient burden or inadequate stemming length, or when blast holes are detonated out of sequence. Although blasting parameters, such as burden, spacing between boreholes, and hole row arrangements, are usually calculated appropriately, deviations during field implementation, such as drilling errors or incorrect borehole inclination, can cause actual burden values to differ from the

design specifications. If the burden is too large, fragmentation efficiency decreases while ground vibration increases. Conversely, when the burden is too small, the likelihood of excessive noise, air overpressure, and flyrock significantly increases.

Flyrock events during blasting operations can lead to serious injuries or fatalities if rock fragments strike workers. Moreover, in projects located near residential areas or transportation routes, flyrock incidents may induce fear and concern among local communities, thereby impacting project safety perception and social acceptance.

### **3. Mitigation Measures for Blasting Impacts**

#### **3.1. Determination of Blast Scale, Maximum Instantaneous Charge, and Optimal Drilling-Blasting Parameters**

The safe distance regarding blast-induced ground vibration for the surrounding environment and structures is determined in accordance with the National Technical Regulation on Safety in the Manufacture, Testing, Acceptance, Storage, Transportation, Use, and Disposal of Industrial Explosives and Storage of Explosive Precursors – QCVN 01:2019/BCT.

The safe vibration distance for structures and protected objects in the case of a single concentrated blast is calculated using the following formula (QCVN 01:2019/BCT, 2019):

$$R_c = K_c \times \alpha \times \sqrt[3]{Q_T}, \text{ m} \quad (1)$$

Where:  $R_c$  is the safe distance (in meters);  $K_c$  is a coefficient dependent on the geotechnical characteristics of the foundation of the protected structure, typically ranging from 3 to 20;  $\alpha$  is a coefficient related to the blast impact index  $n$ ,  $n$  generally ranging from 0.6 to 1.2;  $Q_T$  is the total concentrated explosive charge (in kilograms).

When the distance from the blasting site to the protected structure is known, the permissible scale of a simultaneous blast can be determined based on Equation (1) as follows (QCVN 01:2019/BCT, 2019):

$$Q = \left( \frac{R}{K_c \alpha} \right)^3 \quad (2)$$

In the case of delay blasting, the total permissible explosive charge can be increased and is determined using the following formula (Nhu Van Bach et al., 2015):

$$Q_{vs} = \frac{2}{3} Q \sqrt{N} \quad (3)$$

Where:  $N$  is the number of delay intervals, applicable when the inter-delay time is no less than 50 milliseconds.

According to the National Technical Regulation on Safety in the Manufacture, Testing, Acceptance, Storage, Transportation, Use, and Disposal of Industrial Explosives and Storage of Explosive Precursors (QCVN 01:2019/BCT), when blasting is conducted in areas near residential zones, cultural and historical monuments, national critical infrastructure, or other structures not owned by the organization or individual using industrial explosives, the user is required to monitor the effects of ground vibration and air overpressure on humans and structures under the following circumstances:

- When there are complaints from property owners regarding the impacts of ground vibration or air overpressure;
- When the scaled distance coefficient ( $D_s$ ) does not meet the minimum requirements specified in Table 4.

The formula for calculating the scaled distance  $D_s$  is defined as follows (William Hustrulid, 1995; QCVN 01:2019/BCT, 2019):

$$D_s = \frac{D}{\sqrt{Q}} \quad (4)$$

Where:  $Q$  is the maximum instantaneous charge (kg) used in a single blast event. Explosive charges detonated within a time interval of less than 8 milliseconds are considered simultaneous (instantaneous) detonation.  $D$  is the distance from the blasting site to the nearest structure (in meters).

Table 4. Scaled Distance Coefficient  $D_s$  (QCVN 01:2019/BCT, 2019)

| Distance from Blasting Site to Nearest Structure (m) | $D_s$           |
|------------------------------------------------------|-----------------|
| 0 – 92                                               | $D_s \geq 22.6$ |
| > 92 – 1524                                          | $D_s \geq 24.9$ |
| > 1524                                               | $D_s \geq 9.4$  |

### 3.2. Determination of Optimal Drilling and Blasting Parameters

Based on the blasting objectives and technical requirements, as well as the engineering geological conditions, hydrogeology, geomechanical properties of the rock and soil mass, site-specific construction conditions, and available equipment, the optimal drilling and blasting parameters are selected accordingly (Nguyen Dinh An et al., 2010; Nhu Van Bach et al., 2015).

### 3.3. Selection of Appropriate Initiation Point and Blasting Sequence

The selection of a delay blasting pattern involves determining the appropriate initiation point and blasting sequence based on the specific distribution of explosive charges on the bench.

The location of the first charge and the firing sequence of subsequent charges govern the direction of detonation wave propagation and the resulting ground vibrations. A well-designed initiation point and blasting sequence ensure optimal rock fragmentation while minimizing blast-induced vibrations and other adverse effects. For this project, the blasting scheme was selected based on the following criteria:

- The use of a fully non-electric delay blasting method was prioritized, as it is considered the most effective approach for minimizing environmental impacts, particularly ground vibrations.
- The non-electric initiation network allows for a highly flexible and adjustable blast configuration, enabling control over both the direction of detonation propagation and vibration transmission. This flexibility is critical for ensuring the safety of nearby structures.

In blasting operations, the strongest vibrations typically occur at the far end of the blast, while the weakest occur near the free face. Therefore, maximizing the number of free faces in the blast layout is desirable. The optimal initiation point is the one located closest to the protected structure, allowing the blast energy and vibration waves to propagate away from it.

### 3.4. Other Mitigation Measures

In addition to the aforementioned methods, practical experience shows that to minimize flyrock and air overpressure during blasting, it is effective not only to reduce the specific charge and increase the stemming height beyond that of standard blasting, just enough to fracture and pile the rock without projecting fragments, but also to apply physical coverings over the blast area prior to detonation. These coverings serve to restrain rock fragments from being ejected beyond the blast site.

Commonly used covering materials include B40 steel mesh, loose sand, and sandbags. Based on prior blasting experience using such protective measures, we found them to be highly effective in enhancing safety.

After charging is completed, B40 steel mesh is laid over the blast surface. Sandbags or soil bags weighing approximately 20–25 kg each are then placed on top, covering at least 0.3 meters of each borehole collar. The steel mesh sheets are securely tied together using wire to form a connected barrier capable of containing flyrock.

## 4. Implementation of Trial Blasting and Results

### 4.1. Technical Characteristics of the Project

The Ha Giang Provincial Sports and Cultural Complex Project (Phase 1) includes, under Package No. 08 of the construction technical design documents, blasting operations for site leveling of the stadium, rock excavation for platform preparation, and foundation blasting for structural bases, specifically the foundation for Stand A of the stadium. This stand is located approximately 40 meters from Stand B, which has already been constructed. The project site is situated in Group 9, Phuong Do Commune, Ha Giang City, Ha Giang Province. Therefore, strict control of the adverse effects of blasting is critically important to avoid any impact on the structural integrity and quality of the adjacent facilities.

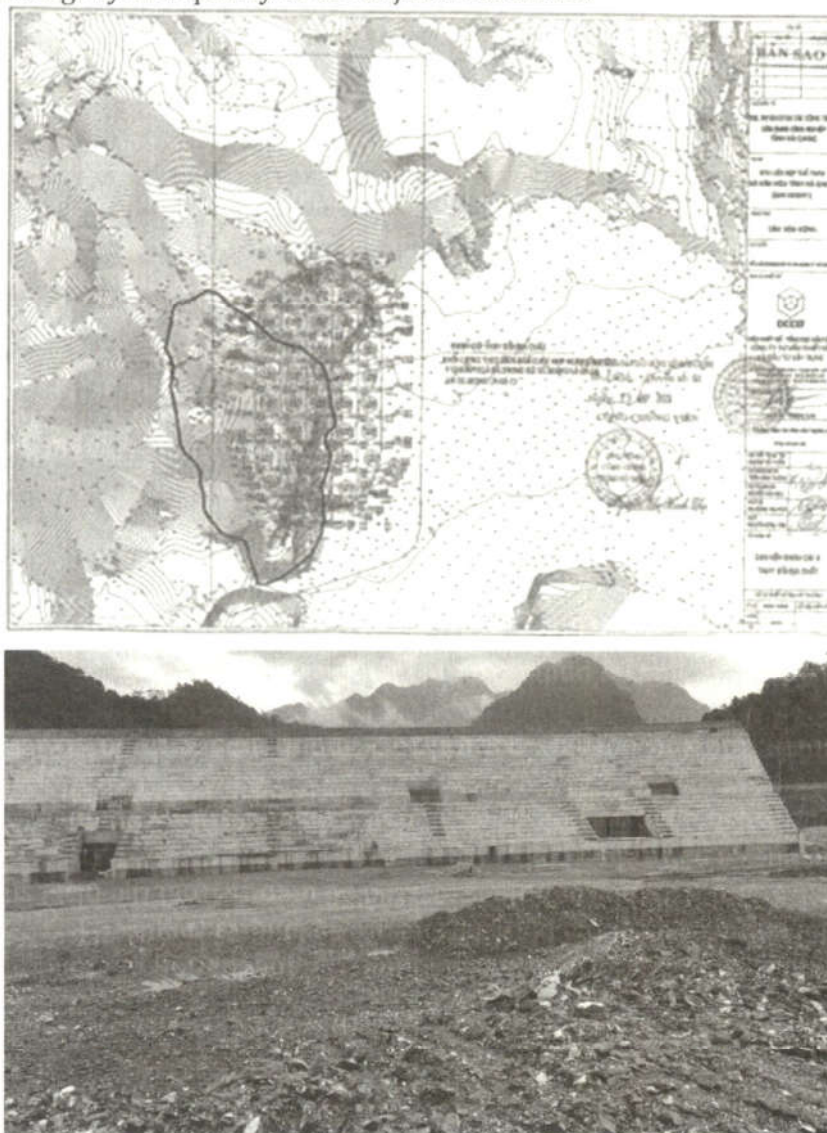


*Figure 1. Site Layout of Package No. 08*

Unlike open-pit mines or infrastructure projects where blasting has previously been conducted and monitoring data is available for subsequent blast design and adjustment, this is a new construction site. For this particular project, blasting for site leveling, platform preparation, and foundation excavation, no prior field monitoring data exists for vibration, air overpressure, or flyrock. This constitutes a significant difference from existing sites with established data, and introduces greater complexity and risk when determining the initial blast scale and methodology.

Package No. 08 includes the construction of the stadium and access roads (Routes DD3 and DD5) within the Ha Giang Provincial Sports and Cultural Complex (Phase 1), located in Group 9, Phuong Do Commune, Ha Giang City. The blasting area covers approximately 10,000

m<sup>2</sup>, corresponding to the platform of the stadium, the foundation of Stand A, and the track area. The spatial boundaries of the blasting site are as follows (Figure 1):

- To the east, Stand B of the stadium is located 50 meters from the blast site;
- To the west lies a natural soil hill;
- To the southwest, a power pole is located at a distance of  $\geq 200$  meters from the blast area;
- To the north, the site borders natural rock mountains with no structures requiring protection;
- The blast area contains no underground facilities.

The blast area is located in a low mountainous terrain, with elevation levels to be graded from +130 m down to +104 m. The rock mass in the area primarily consists of black-colored burnt limestone, with occasional occurrences of white calcite-bearing limestone. The rock is highly fissile and water-saturated.

Survey results indicate that the entire blast zone lies on a limestone foundation characterized by signs of burning and thin-layered stratification. The rock is subjected to compressive forces, resulting in directional fabric and layering, with a fine- to micro-grained texture. According to the approved design documents, the limestone in this area is classified as rock type grade III and grade IV in terms of hardness.

Given the geological features of the blast site and the presence of nearby structures requiring protection, the research team conducted a preliminary blast risk assessment and proposed appropriate control measures, as summarized in Table 5.

Table 5. Preliminary Risk Assessment for Blasting Operations – Package No. 08

| Hazard                 | Affected Object                      | Severity (S) (1-5) | Probability (P) (1-5) | Risk Level (R = S × P) | Proposed Control Measures                                                                        |
|------------------------|--------------------------------------|--------------------|-----------------------|------------------------|--------------------------------------------------------------------------------------------------|
| Ground vibration (PPV) | Structure of Stand B (40 m distance) | 5 (Very Severe)    | 4 (High)              | 20 (Very High)         | Perform PPV calculations and monitoring, conduct trial blasts, apply QCVN 01:2019/BCT guidelines |
| Flyrock                | Workers, equipment, Stand B          | 5 (Very Severe)    | 3 (Moderate)          | 15 (High)              | Limit charge per row, use B40 steel mesh and sandbags as shielding                               |
| Air overpressure       | Residential glass windows            | 3 (Moderate)       | 4 (High)              | 12 (High)              | Monitor air overpressure [dB(L)], increase stemming, cover blast surface                         |
| Noise / Dust           | Local community, environment         | 2 (Minor)          | 5 (Very High)         | 10 (Medium)            | Notify in advance, use dust suppression measures (fogging), apply temporary shielding            |

#### 4.2. Blasting site

Based on the theoretical framework discussed above and the specific blasting conditions for site leveling, rock excavation, and foundation preparation of the stadium under Phase 1 of the Ha Giang Provincial Sports and Cultural Complex Project, the research team conducted experimental blasts. The distance from the blast site to the protected structures and foundations was known, and conservative safety coefficients were applied in the calculations, exceeding the actual conditions of the site to ensure higher safety margins.

A total of five trial blasts were carried out. For each blast, three monitoring devices were installed at designated protection points. The blasting parameters for each test, summarized in Table 6, were designed based on theoretical calculations and then validated through field measurements. All blasting sites were carefully monitored throughout the entire process—from borehole passport preparation and blast passport documentation to execution of the blast itself.

The blasts were conducted at different positions, with distances greater than 40 meters from the protected structures, and arranged in sequence from farther to closer locations. The layout and sequence of these trial blasts are illustrated in Figure 2.

Table 6. Summary of Drilling and Blasting Parameters for Trial Blasts

| No | Parameter                         | Symbol          | Unit              | HC01                         |              |              |              |              |
|----|-----------------------------------|-----------------|-------------------|------------------------------|--------------|--------------|--------------|--------------|
|    |                                   |                 |                   | 76                           | 76           | 76           | 76           | 76           |
| 1  | Borehole diameter                 |                 | mm                |                              |              |              |              |              |
| 2  | Bench height                      | H               | m                 | 5                            | 5            | 5            | 5            | 5            |
| 3  | Sub-drilling depth                | L <sub>kt</sub> | m                 | 0.5                          | 0.5          | 0.5          | 0.5          | 0.5          |
| 4  | Total borehole depth              | L <sub>k</sub>  | m                 | 5.5                          | 5.5          | 5.5          | 5.5          | 5.5          |
| 5  | Burden                            | W               | m                 | 2.5                          | 2.5          | 2.5          | 2.5          | 2.5          |
| 6  | Spacing between holes             | a               | m                 | 2.5                          | 2.5          | 2.5          | 2.5          | 2.5          |
| 7  | Spacing between rows              | b               | m                 | 2.5<br>(2.2)                 | 2.5<br>(2.2) | 2.5<br>(2.2) | 2.5<br>(2.2) | 2.5<br>(2.2) |
| 8  | Explosive charge density          | q               | kg/m <sup>3</sup> | 0.35                         | 0.35         | 0.35         | 0.35         | 0.35         |
| 9  | Charge per hole                   | Q <sub>lk</sub> | kg                | 11 (9.5)                     | 11<br>(9.5)  | 11<br>(9.5)  | 11<br>(9.5)  | 11<br>(9.5)  |
| 10 | Charge column height              | L <sub>t</sub>  | m                 | 3.3                          | 3.3          | 3.3          | 3.3          | 3.3          |
| 11 | Stemming height                   | L <sub>b</sub>  | m                 | 2.2                          | 2.2          | 2.2          | 2.2          | 2.2          |
| 12 | Number of blast holes             | n               | holes             | 25                           | 24           | 20           | 18           | 18           |
| 13 | Total charge per blast            | Q               | kg                | 275<br>(237.5)               | 264<br>(228) | 220<br>(190) | 198<br>(171) | 198<br>(171) |
| 14 | Maximum charge per delay interval | Q <sub>vs</sub> | kg                | ≤12                          | ≤12          | ≤12          | ≤12          | ≤12          |
| 15 | Initiation system                 | –               | –                 | Non-electric delay detonator |              |              |              |              |
| No | Parameter                         | Symbol          |                   |                              |              |              |              |              |

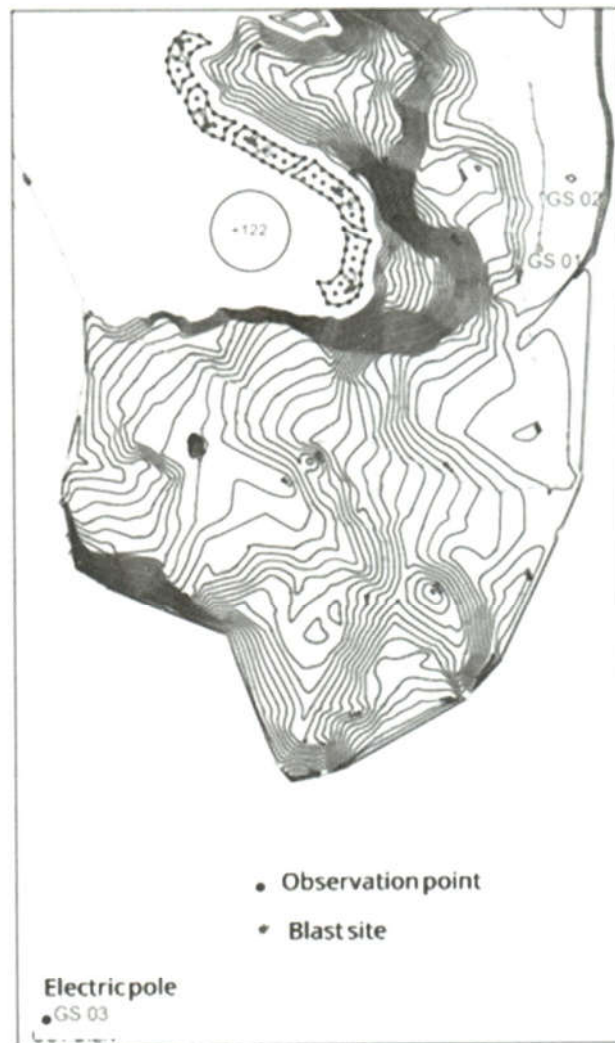


*Figure 2. Locations of Blast Sites and Monitoring Points*

#### **4.3. Blasting Monitoring Instruments**

To monitor blast-induced ground vibrations, the research team employed Blastmate III and Micromate devices (Figure 3), manufactured by Instantel – Canada. These instruments are equipped with integrated printers, allowing for immediate on-site printing of monitoring results. The recorded data include vertical, transverse, and longitudinal vibration waveforms, air overpressure signals, and peak particle velocity (PPV) graphs.



*Figure 3. Equipment Used for Monitoring Blast-Induced Ground Vibrations*

#### 4.4. Results

The monitoring results from five trial blasts at fifteen monitoring points are presented in Table 7.

Table 7. Summary of Blasting Monitoring Results from Five Trial Blasts

| Blast ID        | Explosive Load (kg/delay) | Monitoring Location          | Distance (m) | PPV (mm/s) | PPV Limit (mm/s) | Air Overpressure (dB) | dB Limit |
|-----------------|---------------------------|------------------------------|--------------|------------|------------------|-----------------------|----------|
| 01/2023/HCNMV B | 270 (10)                  | Location 01                  | 76.7         | 8.4        | 31.75            | 115                   | 133      |
|                 |                           | Location 02                  | 59.1         | 11.7       | 31.75            | 121                   | 133      |
|                 |                           | Location 03 (Power pole)     | 228.87       | 4.05       | 25.4             | 116.2                 | 133      |
| 02/2023/HCNMV B | 96 (8)                    | Location 01 (Stone Workshop) | 65.6         | 4.64       | 31.75            | 111.5                 | 133      |
|                 |                           | Location 02                  | 85.19        | 12.07      | 31.75            | 117.5                 | 133      |
|                 |                           | Location 03 (Power pole)     | 121.89       | 4.49       | 25.4             | 106                   | 133      |
| 03/2023/HCNMV B | 160 (8)                   | Location 01 (Stone Workshop) | 84.42        | 7.45       | 31.75            | 113.1                 | 133      |
|                 |                           | Location 02                  | 112.83       | 7.055      | 25.4             | 119.4                 | 133      |
|                 |                           | Location 03 (Power pole)     | 122.43       | 4.3        | 25.4             | 111                   | 133      |
| 04/2023/HCNMV B | 104 (8)                   | Location 01 (Stone Workshop) | 56.38        | 5.27       | 31.75            | 111.8                 | 133      |
|                 |                           | Location 02                  | 75.51        | 6.226      | 31.75            | 117                   | 133      |
|                 |                           | Location 03 (Power pole)     | 146.61       | 2.1        | 25.4             | 103                   | 133      |
| 05/2023/HCNMV B | 248 (10)                  | Location 01                  | 51           | 14.9       | 31.75            | 123.9                 | 133      |
|                 |                           | Location 02                  | 45           | 24.8       | 31.75            | 122                   | 133      |
|                 |                           | Location 03 (Power pole)     | 214          | 4.983      | 25.4             | 114.9                 | 133      |

Based on the vibration waveform records (Table 7), the following evaluations can be made:

The drilling and blasting parameters calculated theoretically were relatively consistent with the actual field conditions. Adjustments were made after each trial blast to ensure that all blasts were conducted both efficiently and safely using the non-electric delay blasting method.

For the five blast sites with total charge weights of 270, 96, 160, 104, and 248 kg, the maximum recorded peak particle velocity (PPV) was 24.8 mm/s, which remains below the regulatory limit of 31.75 mm/s for the corresponding distance class, as specified in QCVN 01:2019/BCT. This confirms that all recorded PPV values across the five trials were within permissible limits.

Although the PPV remained within safety thresholds, Scalise et al. (2021) noted that PPV is an indirect indicator of structural response. A more direct measurement, such as displacement using radar, could offer a more comprehensive assessment. Nevertheless, under the constraints of this project, strict PPV monitoring and procedural compliance proved to be effective in ensuring the safety of Stand B.

Another important parameter is vibration frequency. According to Zhang et al. (2020), when blast waves propagate through fractured and strongly foliated rock masses (such as the limestone at the project site), the frequency spectrum may shift. The trial blasts utilized non-electric delay detonators, which help disperse energy and generate vibrations in the higher-frequency range, a range generally considered less harmful to civil structures with large mass and low natural frequencies.

The successful outcomes of the test blasts suggest that delay blasting not only reduces vibration amplitudes (PPV) but also shifts the dominant frequency away from the danger zone, thereby enhancing protection for surrounding structures.

Regarding air overpressure (blast air shock waves), the highest recorded value among all five trial blasts was 123.9 dB(L), which is also within the allowable threshold defined by QCVN 01:2019/BCT. This further confirms compliance with regulatory standards.

From the trial blasts, it was evident that the levels of ground vibration, air overpressure, and flyrock generated did not affect the integrity of any protected structures. Overall, the experimental blasts were executed with high safety and effectiveness, ensuring the structural stability of nearby facilities.

The use of B40 steel mesh and sandbags as flyrock shielding, though initially considered a provisional measure, proved to be highly effective in practice. This case exemplifies how the integration of scientifically designed parameters with simple, practical field techniques can lead to the successful execution of blasting operations in sensitive environments.

## **5. Conclusion**

This study successfully developed and validated a rational and effective blasting procedure for Package No. 08 (Ha Giang Stadium) to control the harmful impacts of blasting under conditions with no prior monitoring data. The procedure comprises four main steps:

- (1) Risk assessment and preliminary blast design based on regulatory standards;
- (2) Execution of trial blasts with gradually increasing scales;
- (3) Close monitoring of critical impact parameters; and
- (4) Adjustment and refinement of blast passports for subsequent operations.

This approach has been proven feasible, safe, and effective, and is potentially applicable to similar projects in complex and sensitive environments.

With five blast passports and fifteen monitoring records, the use of full-scale delay blasting (hole-by-hole delay) has demonstrated effective vibration control, ensuring that all measured values remained within the permissible limits defined by QCVN 01:2019/BCT. Key indicators such as peak particle velocity (PPV) and air overpressure levels were consistently maintained within safe thresholds, posing no adverse impact on adjacent structures. This confirms the high feasibility and effectiveness of the non-electric delay blasting method,

particularly in projects located near sensitive structures where baseline monitoring data is unavailable.

However, to ensure absolute safety and long-term structural stability, especially for projects with strict technical requirements such as stadium leveling and foundation excavation, the following principles must be strictly followed:

- Apply full delay blasting with a proper initiation diagram, selecting initiation points and delay intervals that minimize vibration propagation.

- When designing the blast passport, drilling and blasting parameters must be aligned with the site's geological conditions, rock and soil properties, explosive type, and initiation system.

- Blast layout should be designed to maximize the number of free faces, enhancing fragmentation efficiency while minimizing secondary effects such as airblast and flyrock.

- The scale of each blast round must be flexibly adjusted based on terrain conditions and the distance to protected structures to ensure acceptable safety margins for vibration and noise.

- In areas with a safety radius below 150 meters, deck charging techniques should be used. This includes reducing the specific charge and increasing stemming height to at least 35 times the borehole diameter, ensuring rock is fractured and heaped in place, avoiding flyrock hazards.

- Blasting operations must be conducted under strict supervision, adhering rigorously to the approved technical procedures and blast passport specifications.

The findings from this research and field trials contribute both to the scientific foundation for designing and controlling blasting in complex environments and to practical applications in similar projects. The approach ensures efficient, safe, and environmentally responsible construction through the use of optimized blasting technology.

### **Contributions of authors**

Tran Dinh Bao - writing & editing, supervision; Nguyen Dinh An - conceptualization, reviewing & corresponding.

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