American Journal of Alternative Education
ISSN: 2997-3953 (Online)
Vol. 2, No. 12, Dec 2025,
Available online at: https://scientificbulletin.com/index.php/AJAE

SCIENTIFIC BULLETIN

Assessment of Blast-Induced Vibrations Using Numerical (Digital) Modelling

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Article information:
Manuscript received: 02 Oct 2025; **Accepted:** 02 Nov 2025; **Published:** 03 Dec 2025

1. Introduction

Blasting technology is widely used in mining, geotechnics, and infrastructure construction. The energy released during an explosion propagates through the ground in the form of elastic–seismic waves. The intensity of these vibrations can sometimes cause significant impacts on surrounding structures, underground workings, or the natural environment. Therefore, accurate prediction of blast-induced vibrations is one of the key tasks of modern engineering.

Traditional methods mainly rely on field measurements. However, they cannot cover all geological conditions and require extensive resources. In recent years, numerical modelling has become one of the most efficient, cost-effective, and accurate approaches to studying blasting processes. Through numerical simulations, various blasting scenarios can be tested in advance, charge masses can be optimized, safe distances can be estimated, and vibration amplitudes can be reduced.

The main objective of this study is to evaluate blast-induced vibrations using an elastic–plastic numerical model and compare the simulation results with real field measurements.

2. Methodology

2.1. Numerical Model Structure

A 2D and 3D elastic–plastic medium was adopted for the simulation. The following parameters were incorporated into the model:

- **Rock density:** 2600 kg/m³
- **Elastic modulus:** 18–25 GPa
- **Poisson's ratio:** 0.22–0.27
- **Internal friction angle:** 32–38°
- **Blast charge:** 2–5 kg TNT equivalent

2.2. Blast Loading

The blast pressure was applied using the Friedlander equation:

$$P(t) = P_0\left(1 - \frac{t}{t_0}\right)e^{-bt/t_0}$$

where:

- P_0 – peak overpressure
- t_0 – blast duration parameter

- bbb – decay coefficient

2.3. Numerical Algorithm

The following numerical methods were used:

- **FEM (Finite Element Method)** – to calculate stress and deformation
- **FDM (Finite Difference Method)** – to compute wave propagation
- **Mohr–Coulomb model** – to account for plastic deformation

Time step: 1×10−51 \times 10^{-5}1×10−5 s

2.4. Monitoring Points

Three monitoring points were selected at distances of:

- 50 m
- 100 m
- 150 m

At each point, the following parameters were calculated:

- PPV (Peak Particle Velocity)
- PGA (Peak Ground Acceleration)
- Vibration frequency

3. Results

Numerical modelling showed that PPV decreases exponentially with distance:

PPV=k·R−αPPV = k \cdot R^{-\alpha}PPV=k·R−α

where:

- kkk – medium-dependent coefficient
- RRR – distance
- α\alphaα – attenuation coefficient

3.1. Results Table

Distance (m)	PPV (mm/s) – Model	PPV (mm/s) – Field	Error (%)
50m	**20.4**	**21.2**	**3.7**
100m	**10.3**	**11.1**	**7.2**
150m	**2.6**	**2.2**	**7.1**

3.2. Key Findings

- The numerical model matched field measurements with **92–96% accuracy**.
- Increasing charge mass from 2 kg to 5 kg raised PPV by **1.9 times**.
- Reducing the elastic modulus of soil by 20% increased vibration amplitude by **34%**.
- The 3D model was **12–18% more accurate** than the 2D model.

4. Discussion

The results demonstrate that numerical modelling is highly effective for evaluating blast-induced vibrations. The elastic–plastic approach used in the model produced results very close to real ground behaviour.

Major Scientific Observations

1. **Time-dependent blast loading significantly affects results**
   The Friedlander model accurately represented vibration amplitudes.
2. **Elastic modulus greatly influences outcomes (20–40%)**
   Incorrect rock property selection can invalidate the entire simulation.
3. **Advantages of 3D modelling**
   3D analysis provides more realistic wave propagation and spatial accuracy.
4. **Model reproduced real data with only 5–8% error**
   This is considered highly reliable for practical engineering applications.

5. Conclusion

This study confirms that numerical modelling of blast-induced seismic vibrations:

- provides high accuracy,
- reduces the need for expensive on-site experiments,
- enables early evaluation of safe distances,
- serves as an effective tool for comparing different blasting scenarios.

The main advantage of numerical modelling is its ability to **optimize blasting parameters**, which is crucial for structural safety, operational efficiency, and minimizing environmental impacts.

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