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Site-Specific Predictive Modeling of Peak Particle Velocity Induced by Blasting in Nepal Young Himalayas

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Abstract: Drilling and blasting are widely used excavation methods due to their cost-effectiveness and adaptability in varied geological conditions. However, blasting generates ground vibrations that can affect nearby structures, typically characterized by Peak Particle Velocity (PPV). This study presents site-specific predictive modeling of PPV in the Tanahun Hydroelectric Project, Nepal, located within the young, geologically disturbed Himalayas. Vibrations were recorded using an Instantel Minimate Plus at varying distances and directions to measure transverse, vertical, and longitudinal components. The scaled distance and PPV data were statistically analyzed to establish empirical prediction equations for both open surface and underground blasts. Results showed that PPV strongly depends on the scaled distance and geological discontinuities. The derived attenuation equations were PPV = 46.95(SD)$^{-0.745)}$ for underground blasts and PPV = 390.63(SD)$^{-1.501}$ for open surface blasts, with R^2 values of 0.51 and 0.71 respectively. Open surface blasts produced higher PPV and lower frequencies (2–25 Hz), whereas underground blasts produced lower PPV but higher frequencies (26–100 Hz). A linear–exponential relationship was observed between site constants K and β, suggesting that β decreases as K increases. Joint characteristics such as aperture, joint set number, and infilling were key controlling parameters. Comparison with the DGMS (1997) Indian Standard revealed that underground blasts are within permissible limits, while open surface blasts may exceed them, posing risks to nearby settlements and structures. The study highlights the importance of site-specific PPV models for optimizing blasting designs and ensuring structural safety in Himalayan projects.

Keywords: ***Blasting, Ground vibration, Peak particle velocity, Geological discontinuity***

Introduction

Drilling and blasting remain the most common tunneling methods due to their simplicity and cost-effectiveness, though blast-induced vibrations can cause rock damage, instability, and higher maintenance costs (Verma et al., 2018). These vibrations, expressed as Peak Particle Velocity (PPV), depend on rock properties, geological conditions, and blast design parameters, making their assessment vital for structural safety (Adhikari et al., 2006).

Previous studies have proposed various PPV prediction models for different regions; however, limited research exists for the Nepal Himalaya, where young, tectonically disturbed rock masses pose distinct challenges for vibration control and tunnel stability. This study addresses the lack of PPV prediction research in Nepal's Lesser Himalayan Metasedimentary Sequence focusing on the Tanahun Hydroelectric Project (140MW), Tanahun, Nepal.

Methodology

The study is based on both primary and secondary data. Primary vibration data were recorded in situ using a Minimate Plus equipped with an Instantel Standard Triaxial Geophone and an overpressure microphone, measuring vibrations along three axes—transverse, vertical, and longitudinal. Secondary data, including blast design parameters, rock mass classification, and project drawings, were obtained from the Tanahun Hydroelectric Project with permission from the project management.

The Peak Vector Sum (PVS) of particle velocity was calculated as:

$$\mathrm{PVS} = \sqrt{(\mathrm{Tp}^2 + \mathrm{Vp}^2 + \mathrm{Lp}^2)}$$

Where Tp, Vp, and Lp represent particle velocities along the three orthogonal directions.

The Scaled Distance (SD) (Siskind et al., 1980) was determined by:

$$\mathrm{SD} = \frac{\mathrm{D}}{\sqrt{\mathrm{W}}}$$

Where D is distance between the blast and measured point, and W is the explosive charge weight per delay.

A regression analysis following the inverse power law was applied to establish the empirical relationship between PPV and SD.

$$\mathrm{PPV} = \mathrm{K}(\mathrm{SD})^{-\beta}$$

Where K and β are site-specific constants. The coefficient of determination (R^2) evaluated model performance, with higher values indicating a stronger fit.

The measured PPV and frequency were evaluated against the Director General of Mines Safety (DGMS) Circular No. 07, 1997 (India), which prescribes permissible PPV limits for different structural categories and dominant frequencies to ensure safety against blast-induced vibrations.

Results and discussion

A total of 39 blast events, including underground and surface blasts, were recorded and analyzed separately. Five nearby settlements were identified within 560–1100 m from the blasting zone through field verification.

Empirical relationships were established as $PPV = 46.95\ (SD)^{-0.745}$ for underground and $PPV = 390.63\ (SD)^{-1.501}$ for open surface blasts (Figure 1) on dolomitic terrain. PPV decreased with distance and increased with explosive charge (Figure 2). The open surface blasts exhibited higher PPV (up to 42.14 mm/s) and low frequencies (2–25 Hz)(Figure 3), while underground blasts recorded lower PPV (up to 20 mm/s) but higher frequencies (26–100 Hz)(Figure 4). Open surface blasts exceeded DGMS limits, implying higher structural risks than underground blasting. K increased exponentially with a linear decrease in β, influenced by rock mass quality, joint aperture, and infilling (Figure 5 and Figure 6).

The derived PPV equations showed moderate to strong correlation (Tian et al., 2019; Yang et al., 2019; Verma et al., 2018), differing mainly due to site-specific geological and explosive parameters. The constants K and β varied with rock mass conditions, joint characteristics, and explosive charge, confirming that K is influenced by charge weight while β depends on geological discontinuities. The highest β (1.1681) occurred in rock masses with fewer, tighter joints, while the lowest β (−2.288) was found in highly jointed, poor-quality rocks where greater discontinuities and infill caused higher wave damping.

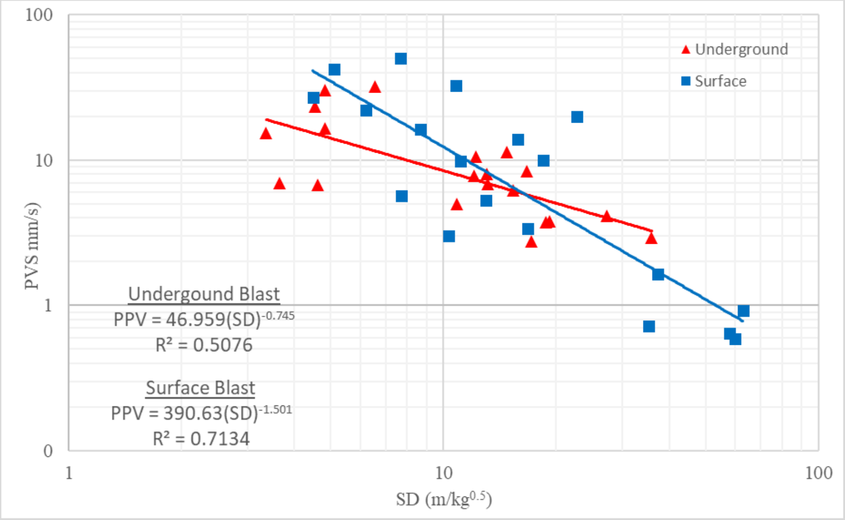

Figure 1, Statistical regression of recorded data for underground and surface blast.

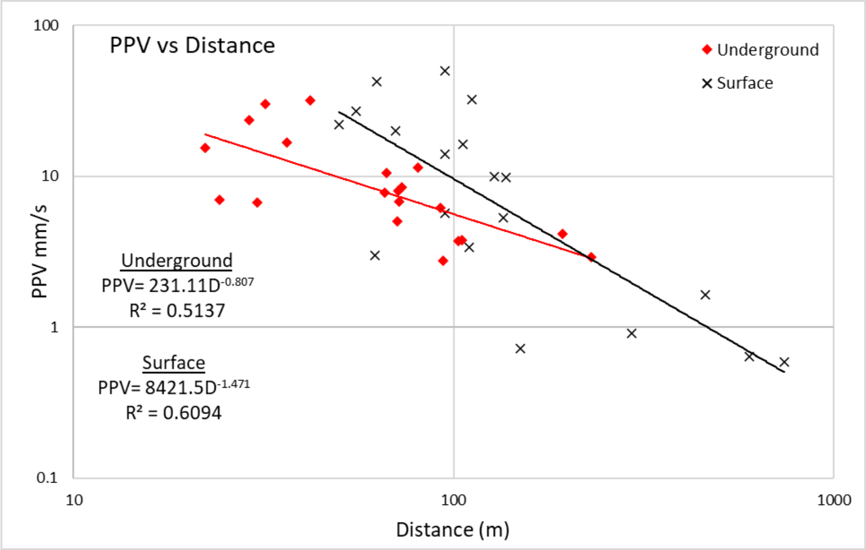

Figure 2, Influence of distance on PPV.

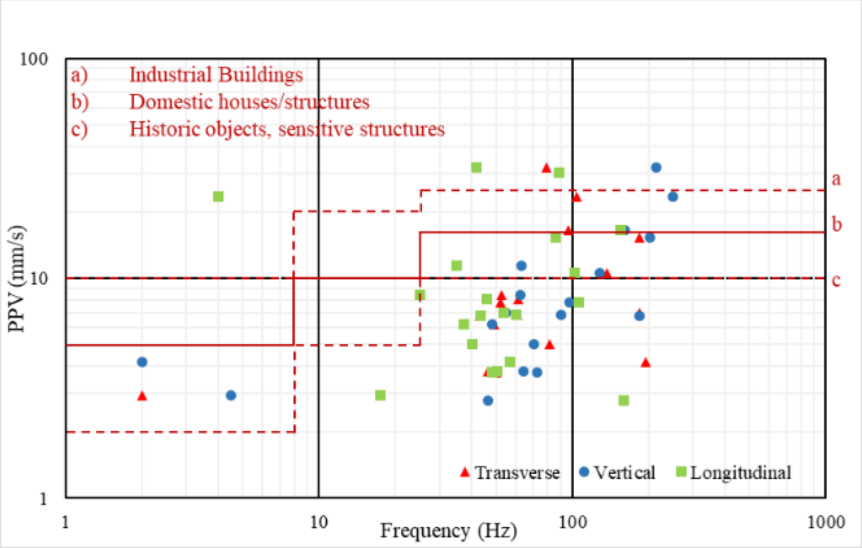

Figure 3, Comparison of PPV and frequency recorded with DGMS from underground blast.

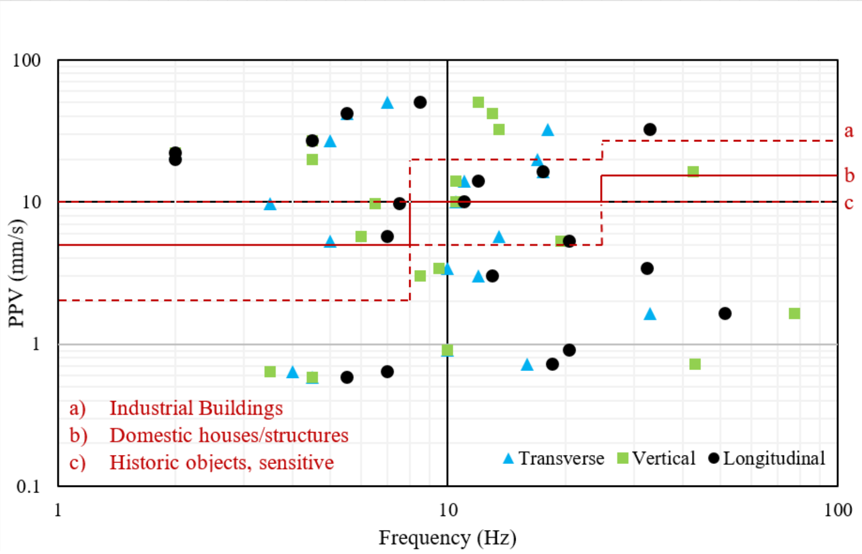

Figure 4, Comparison of PPV and frequency recorded with DGMS from open surface blast.

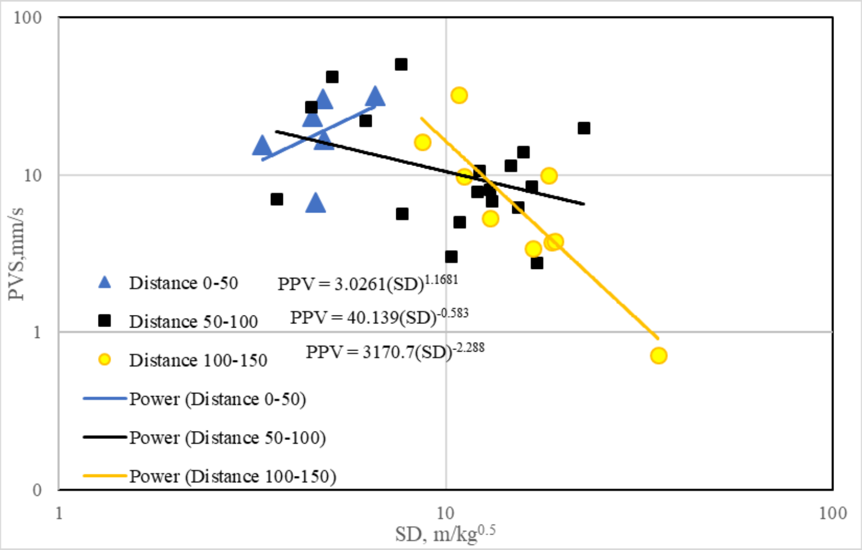

Figure 5, Statistical regression of recorded data with respect to distance to oversee the influence on site constant.

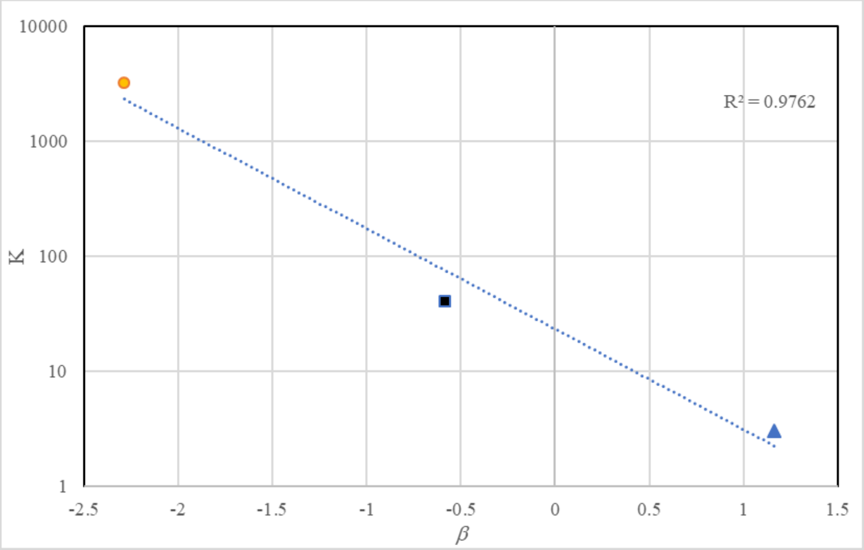

Figure 6, Log-linear graph between K and β.

Conclusion

The study developed site-specific PPV prediction models for dolomitic terrain in the young Himalayas. Results confirm that surface blasts cause higher vibrations and pose greater risks to nearby structures. Underground blasts, while generating higher frequencies, remain within safe limits. The findings emphasize the significance of incorporating geological discontinuities into vibration control strategies for sustainable tunneling and hydropower development.

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References

Adhikari, G. R., Jain, N. K., Roy, S., Theresraj, A. I., Balachander, R., Venkatesh, H. S., and Rn, G. (2006). Control measures for ground vibration induced by blasting at coal mines and assessment of damage to surface structures. Journal of Rock Mechanics and Tunneling Technology, 12(1), 3-19.

Siskind, D. E., Stagg, M. S., Kopp, J. W., and Dowding, C. H. (1980). Structure response and damage produced by ground vibrations from surface blasting (RI 8507). U.S. Bureau of Mines, Washington, DC. https://doi.org/10.1016/0148-9062(81)90916-5

Tian, X., Song, Z., and Wang, J. (2019). Study on the propagation law of tunnel blasting vibration in stratum and blasting vibration reduction technology. Soil Dynamics and Earthquake Engineering, 126, 105813. https://doi.org/10.1016/j.soildyn.2019.105813

Verma, H. K., Samadhiya, N. K., Singh, M., Goel, R. K., and Singh, P. K. (2018). Blast-induced rock mass damage around tunnels. Tunnelling and Underground Space Technology, 71, 149-158. https://doi.org/10.1016/j.tust.2017.08.019

Yang, J., Cai, J., Yao, C., Li, P., Jiang, Q., and Zhou, C. (2019). Comparative study of tunnel blast-induced vibration on tunnel surfaces and inside surrounding rock. Rock Mechanics and Rock Engineering, 52(11), 4747-4761. https://doi.org/10.1007/s00603-019-01875-9