# Guidance Note No. GN 10
# Vibration Monitoring

**Mines Division, Geotechnical Engineering Office**
**Civil Engineering and Development Department**

## 1. Scope and Objective

1.1 This Note provides general guidance on the specifications and use of seismographs[1] (also known as vibrographs) for routine site monitoring of vibrations affecting structures, slopes, retaining walls and utilities, generated from blasting works.

## 2. Minimum Specification

2.1 The sensors/geophones in seismographs should meet the following minimum general specification requirements, based on ISEE, 2017 "Performance Specifications for Blasting Seismographs":

| | |
|---|---|
| Frequency range | 2 to 250 Hz |
| Accuracy | 2 to 4 Hz …. +5 % to -3 dB of an ideal flat response<br>4 to 125 Hz …. +/- 5 % or +/- 0.5 mm/s, whichever is larger<br>125 to 250 Hz …. +5 % to -3 dB of an ideal flat response |
| Transducer density | < 2.4 g/cc |
| Digital sampling | 1000 samples/sec or greater, per channel |
| Operating temperature | -12 to 49°C |

## 3. Calibration Requirements

3.1 Calibration should be undertaken at least annually by the manufacturer or its authorised agent, or by a laboratory accredited by HOKLAS to carry out calibration. A properly calibrated seismograph should meet the minimum accuracy requirements given in para. 2.1 above.

3.2 A seismograph without a built-in geophone should, as far as practicable, be calibrated as a set, i.e. the recording unit, triaxial geophone and connecting cables. Once calibrated, the set should be used together for site monitoring.

3.3 To ensure full compliance with ISEE specifications, the amplitude and frequency response of each geophone and the phase response of the three ground vibration channels must be tested at sufficient points to verify their response across the entire ISEE specified frequency range of 2 to 250 Hz. The presentation of the results for the frequency, amplitude and phase response tests should follow the specific tabular or graphical format, as shown in Annex A.

3.4 A calibration certificate should include:

(a) the name of the calibration laboratory;

[1] A seismograph comprises a recording unit/data logger and at least one triaxial geophone. For some models, the geophone is built into the recording unit, whilst for others, the geophone is attached to the recording unit using a cable.

(b) the model, type and serial number of the seismograph (the recording unit and the geophones);

(c) the date of issue and validity period of the calibration certificate;

(d) the calibration procedures adopted;

(e) information on the reference standard and equipment used for calibration and traceability to national standards;

(f) the results of the calibration process and information on any adjustment made to the seismograph in order to comply with the specification;

(g) a statement to express that the seismograph calibrated meets the ISEE 2017 (or latest version) Performance Specifications for Blasting Seismographs; and

(h) the name and signature of the laboratory's representative authorised to approve calibration certificates.

## 4. Comparative Monitoring

4.1 At the beginning of a project involving blasting, comparative monitoring should be carried out on the seismographs to be used by the blasting permit holder (normally, the contractor) and those to be used by CEDD's Mines Division, i.e. the regulatory authority. Additional comparative monitoring tests should be undertaken at appropriate stages during the project. The geophones from both parties should be mounted side by side on the same monitoring station, using the same mounting procedures where practicable; the recording units should also be configured to the same trigger level, sampling frequency, etc. The difference in results between the seismographs for the same blast should generally not exceed twice the maximum accuracy limit given in para. 2.1 above. In cases where there is dispute over the results of comparative monitoring, vibration measurements should be repeated using the same seismographs over several blasts, until the matter is resolved.

## 5. Monitoring Personnel

5.1 The blasting permit holder should engage a Blasting Engineer to take overall responsibility for the blast monitoring team. The Blasting Engineer should ensure that only competent personnel, who have adequate knowledge or training and experience of blast vibration monitoring and who are familiar with the operation of the seismographs, are engaged on site to set up monitoring instruments, collect and manage data, and report results. At the beginning of a project, the Blasting Engineer should ensure that all personnel engaged in vibration monitoring receive suitable training from the seismograph manufacturer or its authorised agent. A copy of the manufacturer's operation manual for the seismographs should be kept on site for reference.

## 6. Monitoring Locations and Set up of Monitoring Stations

6.1 All monitoring stations required for regulatory control purposes should be agreed with the site supervisory staff and Mines Division prior to the commencement of blasting.

6.2 The location of monitoring stations should be consistent, as far as practicable, with the locations at which the permissible vibration limits are derived. For example, the critical PPV values calculated from GEO Report No. 15 (Wong & Pang, 1992) for a soil slope relate to the rock vibrations at the base of the slope; therefore monitoring should be undertaken of the blasting vibrations affecting the rock at the base of the slope, when it is feasible to do so. For buildings, vibration limits generally relate to the ground adjacent to the building, so the ground rather than the building is monitored. Also, when choosing a location, account should be taken of ease of access and risk of damage or loss of monitoring equipment.

6.3 The following locations should be avoided, wherever possible:

(a) areas where voids could affect the monitoring results, e.g. a hollow area beneath a concrete pavement; and

(b) areas where loose/poorly compacted fill could affect the monitoring results, e.g. on the berm of a slope, or close to concrete steps or surface drainage channels.

6.4 Typical monitoring stations and mounting details for geophones are given in Figure 1. Based on local experience, the following practice should be adopted:

(a) Spiking (i.e. spikes screwed into the base of a geophone) is not recommended as it is difficult to ensure that the geophone is properly coupled with the ground surface.

(b) Reliable monitoring results can be achieved, even for near field monitoring of high velocities/accelerations, by bolting or “gluing” (using a 2-part plastic putty, such as “plasti-bond”) the geophone to the monitoring station (details given in Figure 1).

(c) Where it is not feasible to bolt or glue the geophone to the monitoring station, and where the acceleration expected from blasting is less than 1.0 g, a sandbag can be used to hold the geophone in place (see Figure 1). However, when monitoring critical sensitive receivers where the level of vibration is likely to approach the agreed limit or, where a dispute could arise over the reliability of monitoring results, every effort should be made to secure the geophone by bolting or gluing to a well prepared monitoring station.

(d) The geophone should be placed on a clean level surface.

(e) The longitudinal direction of the geophone should generally point directly at the centre of the blast and the bearing should be recorded. For cases where a geophone is being used to record multiple blasts from different locations, the bearing of the chosen longitudinal direction should still be recorded.

(f) The position and level of all monitoring stations should be surveyed to a minimum accuracy of +/- 100 mm and shown on a plan at a suitable scale for the size of the site. The permissible PPV limits for each monitoring location should also be shown on the plan or on an accompanying table.

6.5 ISEE (2015) presents details of other mounting methods, the suitability of which will depend on the magnitude of the vibrations and accelerations to be monitored. Additional guidance is also given in ISO (1998). Segarra et al (2015) have shown that significant errors in vibration measurement can arise when geophones are freely placed or held in place using a sandbag; they also recommend securely anchoring geophones.

## 7. Records

7.1 Details of the instrumentation, measurement procedure, location, date and time of recording must be recorded for each blast.

7.2 Records of the results of all blast vibration monitoring, including other relevant information e.g. videos of the blasts, must be kept until satisfactory completion of the works contract, or as specified under the contract, whichever is later.

7.3 Copies of records shall be made available to Mines Division, upon request.

7.4 An example of a data summary sheet for surface blasting is given in Annex B. The format can be modified to suit particular site conditions and monitoring requirements.

## 8. Vibration Limits

8.1 A list of vibration limits commonly adopted in Hong Kong is given in Annex C (OAP, 2014). This list is for reference only. Project consultants and contractors must ascertain specific limits from relevant stakeholders for individual projects.

## 9. References

ISEE (2015). Field Practice Guidelines for Blasting Seismographs. International Society of Explosives Engineers, Standards Committee, Final Standard 31 July 2015.

ISEE (2017). Performance Specification for Blasting Seismographs. International Society of Explosive Engineers.

ISO (1998). ISO 5348-3: 1998, Mechanical vibration and shock – Mechanical mounting of accelerometers.

Ove Arup & Partners HK Ltd (2014). Long-term Strategy for Cavern Development – Feasibility Study Working Paper 8: Blasting Vibration Limits in Hong Kong. Agreement No. CE 12/2012 (GE), Geotechnical Engineering Office, Civil Engineering and Development Department.

Segarra, P., Sanchidrián, J. A., Castedo, R., López, L. M. and del Castillo, I. (2015). Perfomance of some coupling methods for blast vibration monitoring. Journal of Applied Geophysics, Vol. 112, p. 129-135.

Wong, H.N. & Pang, P.L.R. (1992). Assessment of Stability of Slopes Subjected to Blasting Vibrating, (GEO Report No. 15). Geotechnical Engineering Office, Civil Engineering Department, Government of Hong Kong.

**Mines Division**
**August 2019**

***General guidance is provided in this Note. Specific requirements may be imposed by the Commissioner of Mines to suit the conditions and characteristics of the site. Any feedback on this document should be sent to the Chief Geotechnical Engineer/Mines, Geotechnical Engineering Office, Civil Engineering and Development Department.***
***Telephone: (852) 3842 7210 Facsimile: (852) 2714 0193 E-mail: mines@cedd.gov.hk***

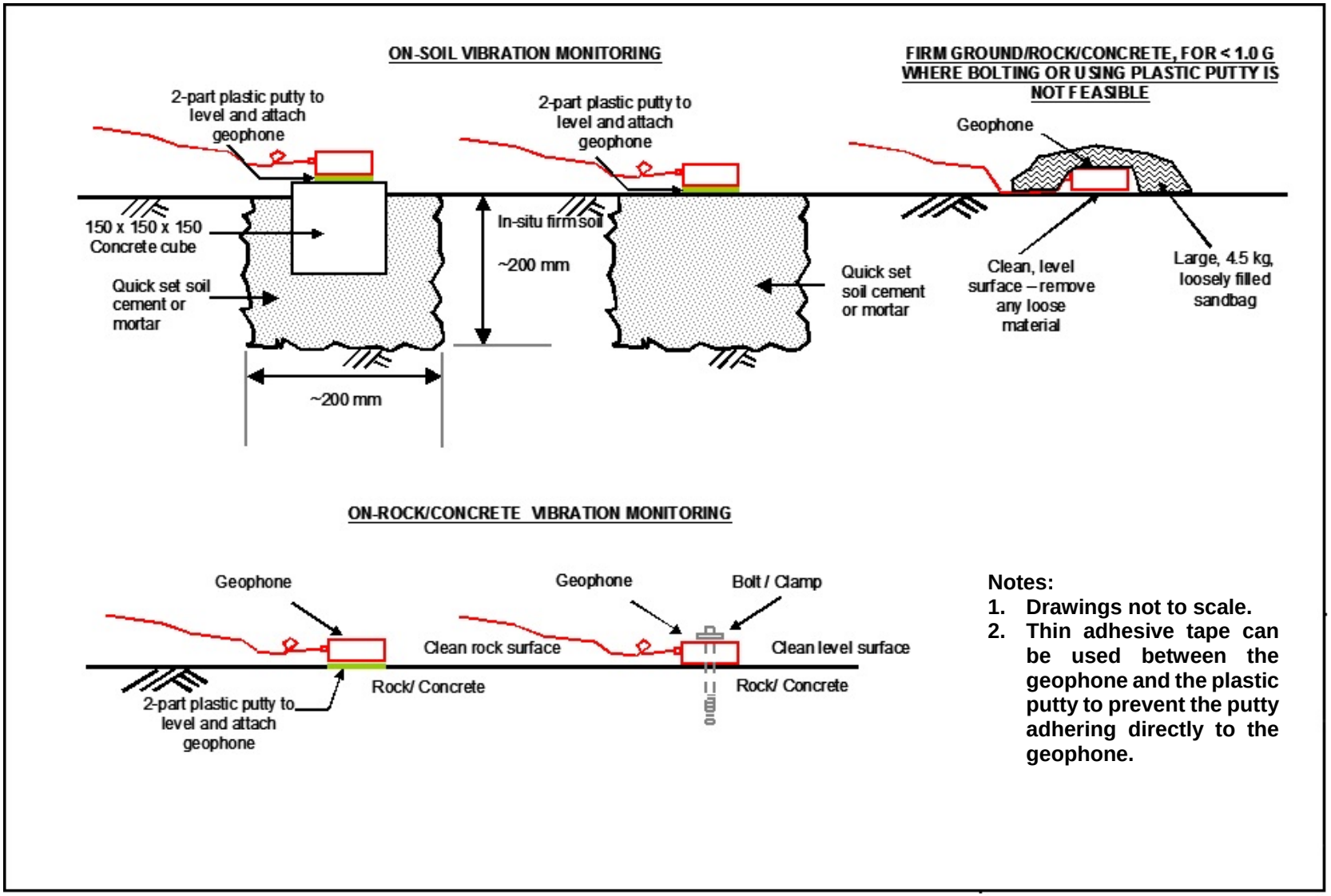


**Figure 1 – Typical Monitoring Station and Mounting Details for Horizontal Geophones**

# Annex A

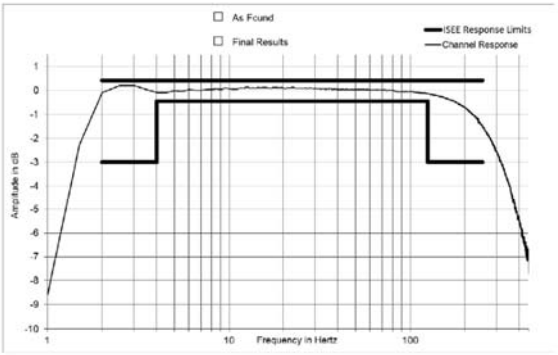


**Figure 1.** Sample amplitude-versus-frequency response graph.

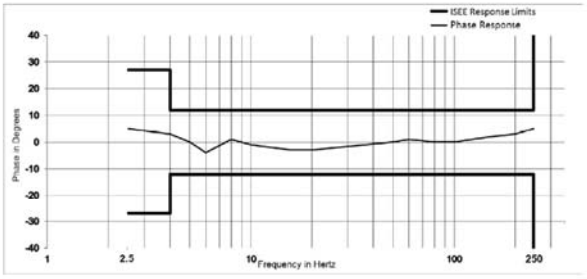


**Figure 2.** Sample phase-versus-frequency response graph.

| Frequency | Reference Signal | Amplitude Response □ As Found or □ Final Results | | | | |
|---|---|---|---|---|---|---|
| Hertz | Amplitude | Transverse | Vertical | Radial/ Longitudinal | Tolerance | Pass/Fail |
| 2 | | | | | +5% to -3 dB | |
| 4 | | | | | +/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger | |
| 10 | | | | | +/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger | |
| 30 | | | | | +/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger | |
| 60 | | | | | +/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger | |
| 125 | | | | | +/- 5 % or +/-0.5 mm/sec (+/-0.02 in/sec) whichever is larger | |
| 200 | | | | | +5% to -3 dB | |
| 250 | | | | | +5% to -3 dB | |

**Table 1.** Sample Ground Vibration Sensor Amplitude and Frequency Test Results.
**Calibration Remarks:** This is a sample of a tabular test report for the ground vibration sensor.

**Annex B**

# An example of a vibration monitoring data summary sheet for surface blasting
## (Appropriate modifications should be made for tunnel and shaft blasting)

**Consultants:** **Contractor:**

**Table 1a Summary of Blasting Parameters**

| Blast No. | Date | Time | Centre of blast location | | | Bench height (m) | Total no. of blastholes | No. of rows of blastholes | Hole dia. (m) | Hole depth (m) | Subdrill (m) | Stemming/ (Inter-stemming for deck loading) (m) | Burden (m) | Blasthole spacing (m) | MIC (kg) | Type of rock blasted | Total vol. of rock blasted ($m^3$) | Types of initiation system | Type(s) of explosives used | Total amount of explosives (kg) | Powder factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Northing | Easting | Level (mPD) | | | | | | | | | | | | | | | | |
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Notes:
1. MIC - Maximum Instantaneous Charge

**Consultants:** **Contractor:**

**Table 1b Summary of Monitoring Data**

| Date | Blast No. | Sensitive Receiver & reference no. | Monitoring Station | | | Distance from blast (m) | Seismograph serial no. | Bearing of longitudinal direction of seismograph | Trigger level, PPV (mm/s) | Permissible PPV ( mm/s) | | | Predicted PPV (mm/s) | Measured PPV (mm/s) | | | | Frequency (Hz) | | | Remarks (misfire/signs of distress/ exceedance of AAA levels, actions taken) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Northing | Easting | Level (mPD) | | | | | Alert | Alarm | Action | | Trans. | Vert. | Long. | Resultant | Trans. | Vert. | Long. | |
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Notes:
1. A standard "Event Report" for each geophone location and a digital copy of the full time history waveform should be submitted to CoM upon request.
2. Location plans showing the monitoring stations should be provided.
3. The "Distance from blast (m)" should be the distance that results in the highest predicted PPV for the monitoring point (generally the minimum straightline distance between the location of the nearest blast hole containing the MIC to the monitoring point).

**Annex C**

# Vibration Limits Commonly Adopted in Hong Kong (OAP, 2014)

| Current Hong Kong Vibration Limits | PPV Limits (mm/sec) | PD Limit (mm) |
|---|---|---|
| **MTRC** | | |
| - Railway Structures / Permanent Way | 25 | 0.2 |
| - Q Relays | 40 | 0.2 |
| - Insulators and Overhead Lines | 50 | 0.2 |
| - Overhead Line Mast | 10 | ns |
| **WSD** | | |
| - Water Retaining Structures/Water Tunnels | 13 | 0.1 |
| - Water Mains/Pipes | 25 | 0.2 |
| **Towngas** | | |
| **Towngas Transmission/Distribution Network** | | |
| - All installations/Pipes | 25 | 0.2 |
| - Gas Governors | 13 | 0.1 |
| - Gas Tunnels | 13 | 0.1 |
| - Off-take stations/Above Ground Gas Pipes | 13 | 0.1 |
| **Towngas Production Facilities** | | |
| - Gas Holders | 5 | 0.1 |
| - Naphtha Tanks | 5 | 0.1 |
| - Switch Rooms/Control Room Containing Electrical Switchgear (with protection relays) | 5 | 0.1 |
| - Gas Production Plant & Corresponding Facilities | 5 | 0.1 |
| - Gas Production Plant Columns and Stacks | 5 | 0.1 |
| - Water Tanks & Vessels etc. | 5 | 0.1 |
| - Major Gas and Naphtha Pipelines | 15 | 0.2 |
| - DG Stores | 15 | 0.2 |
| - Buildings | 15 | 0.2 |
| - Boundary Wall | 15 | 0.2 |
| **CLP** | | |
| - Power Stations | 6.28 - 11 | 0.02 - 0.1 |
| - Major Sub-Stations | 13 | 0.1 |
| - Minor Sub-Stations | 25 | 0.2 |
| - Underground Cable Joints | 13 | 0.1 |
| - Underground Cable and Pylon Foundations | 25 | 0.2 |
| - Cable Tunnel | 13 | 0.1 |
| **HKE** | | |
| - Transmission / Distribution facilities (electrical protection equipment, transformer & HV / LV switchgear) | 0.2g | 0.02 |

**Annex C**

| Current Hong Kong Vibration Limits | PPV Limits (mm/sec) | PD Limit (mm) |
|---|---|---|
| - Transmission (275/132kV) cable & joint | 12mm/s/0.223g | 0.1 |
| - Building Structures of Primary Substation | 0.07g | ns |
| - Submarine Cable Landing Point and associated structures | 0.07g | ns |
| - Pylon Foundations | 0.07g | ns |
| **HKE (continued)** | | |
| - Cable Tunnel / Portal | 0.07g | ns |
| - Power Station Building & the Associated Facilities | 0.07g | ns |
| **DSD** | | |
| - All structures | 25 | Ns |
| **Highways Department** | | |
| - All Structures and Road Drains | 25 | 0.2 |
| **Buildings** | | |
| - Schools/Residential Buildings/Private Property | 13 - 25 | 0.2 |
| - Historical Buildings and Monuments | 5 - 10 | 0.2 |
| **Green Concrete (GEO Report No. 102 – Time Based)** | | |
| ≤ 4 Hours Age | 10 | ns |
| 6 to 8 Hours Age | 20 | ns |
| 10 - 12 Hours Age | 30 | ns |
| 18 Hours Age | 40 | ns |
| 24 Hours Age | 70 | ns |
| 3 Days Age | 100 | ns |
| 7 Days Age | 125 | ns |
| > 28 Days Age | 150 | ns |
| **Green Concrete (GEO Report No. 102 – Compressive Strength Based)** | | |
| 3.0 MPa | 77 | ns |
| 5.0 MPa | 88 | ns |
| 10.0 MPa | 106 | ns |
| 20.0 MPa | 126 | ns |
| 30.0 MPa | 140 | ns |
| 40.0 MPa | 151 | ns |
| 50.0 MPa | 160 | ns |
| **Hong Kong Tramways** | | |
| - All facilities | 25 | 0.2 |
| **Shell** | | |
| - LPG utilities / equipment / structures | 5 | - |