

### Ground-borne Vibrations Arising from Pile Driving and Similar Operations

Pile driving (including pile withdrawal) operations and the like generate vibrations which, if not properly controlled, may have adverse effects on, or cause damage to, adjacent buildings and structures, in particular, non-structural elements therein. For the purpose of this PNAP, such operations are termed as "pile driving operations".

2. This practice note aims to provide guidelines on the control of ground-borne vibrations generated from pile driving or similar operations with a view to minimizing possible damage to adjacent properties and streets. Authorized Persons (AP)/Registered Structural Engineers (RSE) are reminded that under the Buildings Ordinance, it is their responsibility to ensure that the building works carried out will not impair the stability of, or cause damage to any building, structure, land, street or services. They should also exercise their professional judgment in choosing suitable and safe construction methods and provide vigilant supervision over the works throughout the construction period.

#### Piling Plan Submission

3. Piling plans submitted for approval should, in general, follow the requirements laid down in PNAP 66. AP/RSE's particular attention should be paid to the monitoring requirements and the required appraisal report at items 4(k) and 4(o) therein respectively for adjacent buildings/structures. Depending on the structural condition of the adjoining buildings/structures, the Building Authority (BA) may require the following details to be included in the appraisal report :

- (a) Pre-construction condition survey with a full set of photographic record of the external and common areas of the buildings/structures that are vulnerable to vibration damage. If access to some internal areas can be gained, the condition therein should also be recorded.
- (b) Recommended vibration control limits (with due consideration of the recommendations given in Appendix A of this practice note) and vibration monitoring proposal. Critical locations for vibration monitoring should be identified by the RSE and included in the monitoring proposal.
- (c) Preliminary appraisal of the stability of the structural and non-structural elements of adjacent buildings/structures under the expected ground-borne vibrations.

- (d) If vibration control limits greater than those given in Appendix A are to be adopted, a detailed assessment of the magnitude of the ground-borne vibrations generated by the piling operations should be made. Under such circumstances, reference could be made to Technical Note 142 published by CIRIA of the UK for such assessment or to any other relevant references acceptable to the BA. Consideration should also be given to the cumulative effects from the driving of all piles at the site. The structural stability of all adjoining buildings/structures due to the effects of ground-borne vibrations in item (c) above should also be appraised by detailed engineering analyses.
- (e) A monitoring proposal to monitor the movements of adjoining grounds and buildings/structures.
- (f) If the site is situated close to buildings/structures that are vulnerable to damage caused by the piling operations, a trial pile proposal to confirm the accuracy of the vibration assessments and the effects of the piling works on adjacent buildings/structures (see paragraphs 6 to 8 below).

#### **Required actions from the RSE prior to consent application for piling works**

4. Prior to consent application, the RSE is required to confirm with the Registered Specialist Contractor the method of construction including the maximum number of piles to be driven concurrently and the relevant details of the construction plants. In case there are changes from the approved details, the RSE should submit an amendment plan together with a re-assessment of the ground-borne vibrations and, if necessary, revise the appraisal report for item 3(c) above. Final reports for items 3(b) & (c) above shall be submitted together with the amendment submission.

5. It should be noted that certain types of piles installed by vibratory equipment may cause significant damage to vibration sensitive buildings/structures such as those mentioned in paragraph 7 below. Such method will not normally be accepted by the BA unless it can be satisfactorily demonstrated to him by means of trial piling as described below. Prior to the installation of the trial piles, precautionary measures such as the provision of shoring for temporary support to cracked structural members of adjacent buildings may need to be provided.

#### **Test/Trial Pile(s) for Vibration Control**

6. If the adjoining buildings/structures are not vulnerable to the effects of vibration from the piling works, the magnitude of ground-borne vibrations as assessed at item 3(b) or the re-assessed values at paragraph 4 above, as appropriate, can be verified during the driving test of piles. Ground-borne vibrations should be measured during the driving of the test pile(s) as detailed in paragraph 8 below. The RSE will be required, under BO section 17 and in conjunction with PNAP 242, to supervise personally the driving of at least the first test pile to ensure that the upper limits of the ground-borne vibration will not be exceeded. The effects of the piling works on the adjoining buildings/structures should also be assessed by the RSE during the driving of the test pile(s).

7. In cases where buildings or structures that are particularly vulnerable to the effects of vibration, such as masonry buildings, are in the proximity of the piling site, the AP/RSE should submit for approval a trial pile proposal to confirm the magnitude of ground-borne vibrations assessed at item 3(b) or the re-assessed values at paragraph 4 above, as appropriate, at each critical ground condition where generation of maximum ground-borne vibrations will be expected (usually at the highest founding level or at location of obstruction at shallow depth). The number of such trial pile(s) would depend on the actual site condition. The RSE will be required, under BO Section 17 and in accordance with PNAP 242, to supervise personally the driving of the trial pile(s) to ensure the upper limits of the ground-borne vibration will not be exceeded.

8. For the vibration monitoring of trial/test pile(s), the maximum ground-borne vibrations, measured in terms of peak particle velocity (ppv), should be recorded at every meter length of penetration of pile, at final set and at levels where obstructions are encountered. The monitoring work should be carried out using a properly calibrated device under the direction of the RSE. If the measured ground-borne vibrations have been found to exceed the allowable values or if damage to either the structural or non-structural elements of the adjacent buildings/structures has been observed, all piling works should be stopped and the agreed precautionary measures referred to at item 4(o) of PNAP 66 should be reviewed and revised as necessary, and submitted by the RSE to the BA for agreement. The suspended piling works should not be resumed without the prior agreement of the BA.

9. A condition survey of all adjacent buildings/structures should be carried out after the completion of the trial piles for confirmation of the effects of the piling works. Two sets of trial piling report on ground-borne vibrations and their effects on adjacent buildings/structures should be submitted to the BA for consideration/record prior to the commencement of the driving of the working piles.

#### **Required actions from the RSE during the driving of working piles**

10. The vibration monitoring work should be under the supervision of the RSE or his representatives throughout the piling process. The RSE should review the site situation from time to time and if found necessary, suspend the piling works, revise the precautionary measures and/or vibration monitoring proposal and submit them to the BA for agreement prior to the resumption of the piling works.

#### **Requirements for controlling vibrations arising from site formation and excavation and lateral support works**

11. The installation of temporary pile walls such as steel sheet piles, pipe piles or steel channel planks are often included in site formation and excavation and lateral support works. Such temporary pile walls, if installed by percussive or vibratory methods, are likely to generate vibrations that may cause damage to adjoining buildings/structures, particularly those that are vulnerable to vibrations. Excessive vibrations are also likely to be experienced during the removal of underground obstructions. Due consideration should thus be given to the recommendations in Appendix A for the vibration control limits to various types of structures. A detailed vibration and settlement monitoring proposal on all adjoining

buildings, structures, land, streets or services should be included in the site formation or excavation and lateral supports plans to be submitted to the BA for approval/acceptance. If there are vibration sensitive buildings in the proximity of the site, the AP/RSE should exercise vigilance during the driving of the first few piles and closely monitor the effects of such driving on all adjoining grounds and properties. If the measured ground-borne vibrations have been found to exceed the allowable values or if damage to either structural or non-structural elements of the adjacent buildings/structures has been observed, the driving of elements of the temporary pile walls should be stopped and the agreed/approved installation method and precautionary measures should be reviewed and submitted by the RSE to the BA for agreement/approval. The suspended temporary pile wall works should not be resumed without the prior agreement from the BA. Vibration monitoring should be carried out during the installation of the remaining elements of the temporary pile walls. Likewise, vibration monitoring should be carried out during the removal of the temporary pile walls.



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Vibration  
Peak Particle Velocity

## Vibration Measurement and Recommended Ground-borne Vibration Limits Resulting from Piling and Similar Works

### Vibration measurement

The effect of ground-borne vibration from piling works on adjacent structures should be assessed by the maximum peak particle velocity (ppv). The maximum ppv should be evaluated from the peak particle velocities at three orthogonal axes measured at ground levels of the structures in question. All such measurements should be made by properly calibrated device and under the supervision of the RSE or his representatives.

### Recommended Ground-borne vibration limits

2. For the detailed assessment of the effects of ground-borne vibrations on adjacent buildings/structures, an engineering analysis should be carried out. Reference could be made to BS 7385 Part 1 : 1990 or similar references.

3. In the absence of an engineering analysis, the following empirical guidelines may be used for reference :

Targeted Results	Upper limit on maximum ppv (mm/sec)
To avoid damage to buildings, sewerage tunnel structure and major public utilities in general	15
To avoid damage to MTR & KCR structures	Refer to PNAP 77 and PNAP 279
To avoid damage to water retaining structure/water tunnels/masonry retaining wall and dilapidated buildings	7.5

4. The above upper limits of maximum ppv are suggested to give minimal risks of vibration-induced damage. Due attention should also be paid to sensitive buildings close to the piling site such as hospitals, academic institutes, buildings installed with sensitive equipment etc. A lower value of the upper limit of ppv for these buildings may have to be specified based on site and building conditions.

5. The AP/RSE is also required to fulfill the requirements imposed by other government departments.

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