

**GEO Technical Guidance Note No. 54 (TGN 54)
Guidelines on Ground Deformation Control Mechanism for
Geotechnical Works**

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1. SCOPE

- 1.1 This Technical Guidance Note (TGN) provides technical guidance on ground deformation control mechanism for geotechnical works.
- 1.2 Any feedback on this TGN should be directed to the Chief Geotechnical Engineer/Mainland East of the GEO.

2. TECHNICAL POLICY

- 2.1 The technical recommendations promulgated in this TGN were agreed by GEO Geotechnical Control Conference via circulation on 4 January 2024.

3. RELATED DOCUMENTS

- 3.1 BD (2018). *Ground-borne Vibrations and Ground Settlements Arising from Pile Driving and Similar Operations (Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers PNAP APP-137)*. Buildings Department, HKSAR Government, 7 p.
- 3.2 BD (2022). *Railway Protection under Railways Ordinance, Mass Transit Railway (Land Resumption and Related Provisions) Ordinance and Area Number 3 of the Scheduled Areas in Schedule 5 to the Buildings Ordinance (Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers PNAP APP-24)*. Buildings Department, HKSAR Government, 16 p.
- 3.3 GEO (2023). *Deep Excavation Design and Construction (GEO Publication No. 1/2023)*. Geotechnical Engineering Office, Civil Engineering and Development Department, HKSAR Government, 144 p.

4. BACKGROUND

- 4.1 Geotechnical works such as piling, deep excavation and soft ground tunnelling works need to be cautiously carried out together with the implementation of a prudent control mechanism on the induced ground deformation. This is to ensure that the impact arising from the geotechnical works on nearby sensitive receivers is kept within an acceptable level. Geotechnical designs are often made with certain degree of simplification and assumptions. The performance of the geotechnical works should be regularly checked based on the monitoring data obtained during construction. Project team should conduct design reviews at suitable stages of works and implement necessary precautionary measures to reduce any adverse impact on nearby sensitive receivers.
- 4.2 GEO Publication No. 1/2023 (GEO, 2023) puts forward an enhanced empirical approach (5A Approach) for ground deformation control mechanism. The 5A Approach consists

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of five trigger levels (i.e. Alert, Alarm, Action Levels 1, 2 and 3) for ground, services and building monitoring markers, each comes with a set of explicit response actions after exceedance of the trigger values based on the specific nature and conditions of different sensitive receivers. The principles in setting various trigger levels are based on the consideration of the tolerable limits of the affected sensitive receivers that prompt the serviceability and safety concerns, as well as the ground deformation that should be anticipated in well planned and executed excavation and lateral support (ELS) works based on local experience. The 5A Approach also counts on the proper execution of the response actions, that put emphasis on the early involvement of relevant stakeholders (e.g. maintenance departments, utility undertakers) and prompt implementation of remedial works (e.g. repaving, open trench repair, grouting) to mitigate the serviceability and safety issues of the sensitive receivers due to ground deformation. Relevant stakeholders (e.g. owners, maintenance parties, utility undertakers) should be consulted on the adequacy of monitoring stations for assessing possible impacts on nearby sensitive receivers, the proposed trigger values and the corresponding response actions. Where utilities are laid in the vicinity of the excavation, the relevant stakeholders should be consulted regarding tolerable limits of total settlement, and any precautionary measures and specific response actions required.

- 4.3 Similar to ELS works, other geotechnical works such as piling and soft ground tunnelling using tunnel boring machine (TBM) will also induce ground deformation that requires prudent control. Given the same nature of sensitive receivers being affected, the 5A Approach for ELS works can also be applied to other geotechnical works. In this connection, it is necessary to establish the corresponding empirical limits for setting trigger levels for Action Level 2 and Action Level 3 of ground monitoring marker that are realistic and practical for the geotechnical works.

5. TECHNICAL RECOMMENDATIONS

- 5.1 The empirical 5A Approach for control of ground deformation induced by ELS works recommended in GEO Publication No. 1/2023 (GEO, 2023) can be applied to other geotechnical works affecting roads, services, buildings and structures that are not particularly sensitive to settlement. For particularly sensitive receivers (e.g. historical buildings, dilapidated structures and services, hospital, railway structures, tunnels, service reservoirs), engineering approach can be adopted to assess the tolerable limits of the sensitive receivers, as well as total settlement of services and building if necessary, with consultation of the relevant stakeholders and authority on a case-by case basis.
- 5.2 For piling works, the maximum ground settlement induced by the construction of common pile types (e.g. sheet pile, pipe pile, bored pile, diaphragm wall) seldom exceeded 30 mm based on local experience. As such, the lower bound empirical limits of ground settlement for Action Level 2 (i.e. 25 mm) and Action Level 3 (i.e. 30 mm) can be adopted.
- 5.3 For soft ground tunnelling works using TBM, review of design standards and case histories of local TBM works indicates that the induced ground settlement is best

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estimated by correlation with the maximum tunnel excavation volume loss (VL). The commonly observed range of VL in TBM works varies between 1% and 2% and the maximum ground settlement is usually less than 100 mm, given the typical size of tunnels in Hong Kong. Hence, it is recommended to set 1% VL and 2% VL as the basis for determining the trigger levels of Action Level 2 and Action Level 3 of ground settlement.

- 5.4 For other geotechnical works (e.g. slope works, ground improvement works), designer should refer to the principles adopted in GEO Publication 1/2023 (GEO, 2023) in deriving the reasonable range of settlements that will be induced by the works for setting trigger levels. Designer may consider adopting the lower bound empirical limits of ground settlement for Action Level 2 (i.e. 25 mm) and Action Level 3 (i.e. 30 mm) if significant ground settlement is not expected.
- 5.5 The recommended empirical limits for setting trigger levels in 5A Approach for geotechnical works are given in Table 1. Guidance on recommended response actions for exceedance of the trigger levels is given in Table 9.2 of GEO Publication No. 1/2023 (GEO, 2023). In case the geotechnical works may affect the groundwater table, designer should refer to the guidance on groundwater monitoring and the recommended response actions given in Chapter 9 of GEO Publication No. 1/2023 (GEO, 2023).

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Table 1 - Recommended Empirical Limits for Setting Trigger Values in 5A Approach for Geotechnical Works

Instrument	Criterion	Alert	Alarm	Action		
				Level 1	Level 2	Level 3
Ground monitoring marker ¹	Total settlement	10 mm	15 mm	20 mm	i. 25 mm (Piling) ii. 0.3% H _e (ELS)* iii. 1% VL (TBM)* *subject to the range of 25 mm to 60 mm	i. 30 mm (Piling) ii. 0.5% H _e (ELS)# iii. 2% VL (TBM)# #subject to the range of 30 mm to 100 mm
Services monitoring marker ²	Angular distortion	1:600	1:500	1:400	1:350	1:300
Building monitoring marker ³	Angular distortion	1:1000	1:750	1:600	1:550	1:500

where H_e is the maximum excavation depth of the ELS works and VL is the maximum tunnel excavation volume loss by using TBM. The calculated value of ground settlement should be rounded to the nearest integer value.

Notes:

1. Only for road pavements. For other less sensitive usage such as open space, carpark and playground, less stringent trigger values can be adopted with consent from stakeholders. If private roads are affected, the same trigger values could be adopted provided that agreement has been obtained from the private owners before commencement of the construction works. In the event that agreement from the relevant private lot owners is found difficult to obtain, the trigger values as given in PNAP APP-137 can be adopted for the Action Levels.
2. Trigger values on total settlement for individual services should be specified, if necessary, after consulting the relevant stakeholders.
3. Includes free-standing structures (e.g. fence walls, guard houses), earth retaining structures, highway structures and bridge abutments). Trigger values of total settlement for individual buildings or structures should be specified, if necessary, after consulting the relevant stakeholders.

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4. Special triggering conditions:

- (a) The “Action Level 1” response actions should be taken if the total settlement of the vulnerable components of those services that could pose a hazard to the public has reached 20 mm or there is over 20 mm heaving in any monitoring marker;
- (b) The “Action Level 2” response actions should be taken if there is any undue settlement as indicated by any monitoring markers (e.g. an increase of 5 mm between two consecutive daily readings), or significant seepage of groundwater;
- (c) The “Action Level 3” response actions should be taken if any obvious ground loss, excessive ingress of groundwater and sign of distress or damages are observed in any nearby sensitive receivers;
- (d) If the estimated maximum ground settlement or angular distortion of services/buildings is exceeded, a comprehensive design review should be carried out to investigate the causes, estimate further ground settlement and assess the likely impact to nearby sensitive receivers based on the performance of the geotechnical works (e.g. measured cumulative wall, tunnel and ground settlements). The impact assessment and review should demonstrate that the re-estimated maximum ground settlement and angular distortion of services/buildings are still within the tolerable serviceability limits of the sensitive receivers. Mitigation and remedial works should be implemented to minimise any excessive ground settlement and angular distortion. The findings of the design review should be reported to the responsible party/authority and included in the site supervision report; and
- (e) If any obvious damage to a road or pavement is observed, the relevant stakeholders should be immediately notified and consulted to identify any potential hazard and assess the need for urgent repair and repaving works. In such cases, no further construction activities that could aggravate the ground settlement, including further lowering of the excavated level, should be allowed.