



Planning of geotechnical investigations for existing buildings

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ABSTRACT

This paper discusses challenges to geotechnical investigations for existing buildings and offers a summary of investigation constraints and relevant mitigation options that can be considered as part of investigation planning.

Over the past few years, we have worked closely with structural engineers, architects, owners, investigation contractors and other stakeholders on redevelopment of a number of existing sites in Wellington; the vast majority of those projects were seismic strengthening of existing structures. Many investigations were carried out within the existing buildings. Those investigations were limited by technical and non-technical constraints. Some green field investigation techniques were not suitable for indoor investigations. Communication and collaboration between all parties was critical to ensure investigation progress. Lessons learnt from those projects have provided valuable input to this paper.

1 INTRODUCTION

Geotechnical investigations for existing buildings may be required for detailed seismic assessment and mitigation design. Such investigations often involve examining dimensions and conditions of existing foundations, verifying assumed ground conditions and addressing other uncertainties identified in the building assessment. Compared to geotechnical investigations in open space, geotechnical investigations for existing buildings is complex, expensive, takes significantly longer and possesses many challenging constraints due to its inherent nature. Those constraints are not specifically discussed in the geotechnical investigation guideline: Module 2 (NZGS/MBIE.2016), however they are critical to investigation planning and delivery. This paper aims to raise awareness of such constraints to geotechnical investigations for existing buildings and offers options to mitigate associated risks.

2 CONSTRAINTS AND MITIGATIONS TO INVESTIGATIONS FOR EXISTING BUILDINGS

Constraints to investigations for existing buildings are primarily inherited from features of the site/building of interest. They are expected to be different for each project and could be only applicable to part of the site. Some constraints could halt the projects if they cannot be resolved. Table 1 below briefly summarises a range of constraints and the possible mitigation options that can be considered in developing a site investigation plan. The mitigation options can be adopted individually or combined where suitable.

Table 1: Summary of constraints to investigations for existing buildings and associated mitigations.

Identified Constraints	Mitigation Options
Cost: high cost of investigations due to the constraints and mitigation measures discussed below	<ol style="list-style-type: none"> 1. Geotechnical and structural engineers collaboratively challenge what matters for the building assessment and if any physical investigations are necessary. If necessary formulate an investigation targeted at informing those uncertainties which are critical for the assessment. Refer section 2.1. 2. Stage the targeted investigations and challenge the value of proceeding to the next stage.
Access: physical limitations of access to, around and within the building (width, available head room and length)	<ol style="list-style-type: none"> 1. Consider alternative investigation locations or access routes. 2. Choose compact and portable investigation equipment. Refer section 2.2. 3. Undertake enabling works: <ul style="list-style-type: none"> - Modification to equipment. Refer section 2.3. - Modification of existing buildings. Refer section 2.3.
Access: ability of existing access and building to support equipment weight and test loads	<ol style="list-style-type: none"> 1. Consider alternative investigation locations or access routes. 2. Choose light and portable investigation equipment and consider limiting test loads. Refer section 2.2. 3. Undertake enabling works to improve strength/capacity of access and buildings. Refer section 2.3.
Access: presence of services or lack of services information	<ol style="list-style-type: none"> 1. Obtain plans for underground and overhead services then carry out visual check during a site walkover inspection. 2. Scan surface to detect underground services. 3. Physically locate services, carry out jet vac excavation to clear services, protect and/or relocate identified services.
Access: investigation from outside the building may be constrained by: available space, traffic and underground services	<ol style="list-style-type: none"> 1. See above mitigations listed related to access for indoor investigations, such as, consider alternative test locations or access routes and consider compact and portable investigation equipment.

Identified Constraints

Mitigation Options (continuation of Table 1)

Disruption to buildings: modification to the structure or its foundation to allow access and/or investigation potentially compromising structural stability

1. Work collaboratively with the structural engineer to identify suitable alternative investigation location away from unstable structures.
2. Undertake demolition or enabling works to improve structural stability, e.g. install steel props to support undermined structural elements.

Disruption to buildings: the need to preserve building heritage features

1. Keep investigation away from identified heritage features.
2. Consult heritage protection authority on protection, monitoring and reinstatement required.

Disruption to buildings: the need to avoid complex and expensive architectural/ structural reinstatement

1. Choose investigation methods and equipment that cause less disruption to the building.
2. Undertake investigations at locations with less disruption to the building or where reinstatement works can be completed easily and economically.

Disruption to building occupants and others affected: disruption can be caused by traffic, noise, vibration, fumes, dust, water and mud runoff. Disruption can also be an interruption to daily life or business operations

1. Choose investigation locations and methods that cause less disruption.
2. Consult the building occupants and others affected about the proposed investigation including control measures to minimise disruption and keep them informed.
3. Carry out investigation at agreed time/period/locations.
4. Relocate building occupants and others affected.

Consent requirements: the need to comply with all consent requirements, e.g. drilling investigation within Lower Hutt groundwater aquifer zone

1. The project team to consult a planner.
2. Check with relevant regional and district consenting authorities. For older buildings recorded on ArchSite (NZAA.n.d.), consider heritage protection authority.

Health and safety requirements: working in high risk environments, such as earthquake prone buildings with evacuation notice and work operation in progress with high impact machinery

1. Consult the client or relevant authority who is in charge of the site about health and safety hazards and mitigations.
2. Consult with structural engineer on stability and risk associated with earthquakes.
3. Remove, isolate or separate the investigation area from high risk areas.

Health and safety requirements: working with potentially contaminated soils, e.g. asbestos in soils

1. Ask client for any existing information on soil contamination. If necessary consult a ground contamination specialist. Complete a ground contamination assessment to advise risks and possible mitigations of ground contamination.
2. Undertake a ground contamination investigation prior to or concurrently with the geotechnical investigation. Revise risks as project progresses.

Identified Constraints

Mitigation Options (continuation of Table 1)

Health and safety requirements: working in buildings with asbestos containing materials (ACM)

1. Ask client for any existing asbestos survey information. If necessary consult an ACM specialist. Have an asbestos building survey completed to advise risks.
2. Undertake a building material investigation prior to or concurrently with structural investigations or as part of enabling works for geotechnical investigations. Revise risks as project progresses.

Restricted space within existing building: limited air flow. Exhaust fumes generated by equipment

1. Keep investigation in open space with good air flow (keep windows and doors open).
2. Use equipment which does not emit exhaust fumes inside.
3. Undertake enabling works to create good air flow (create openings or use extraction fans).

2.1 Challenge if geotechnical investigation is necessary

In light of the complex, expensive and time-consuming nature of geotechnical investigations for existing buildings, the geotechnical and structural engineers should take full advantage of available desktop information to challenge the need for investigations; and if necessary ensure it is targeted to resolve the critical matters for the building assessment. It may not be practical, or necessary, to carry out investigations to resolve all uncertainties identified in the assessment process. This challenge can be achieved as described in “Seismic assessment of existing buildings – Section C4: Geotechnical considerations” (refer Sections 4.3 and 4.4. MBIE. 2017) and summarised below:

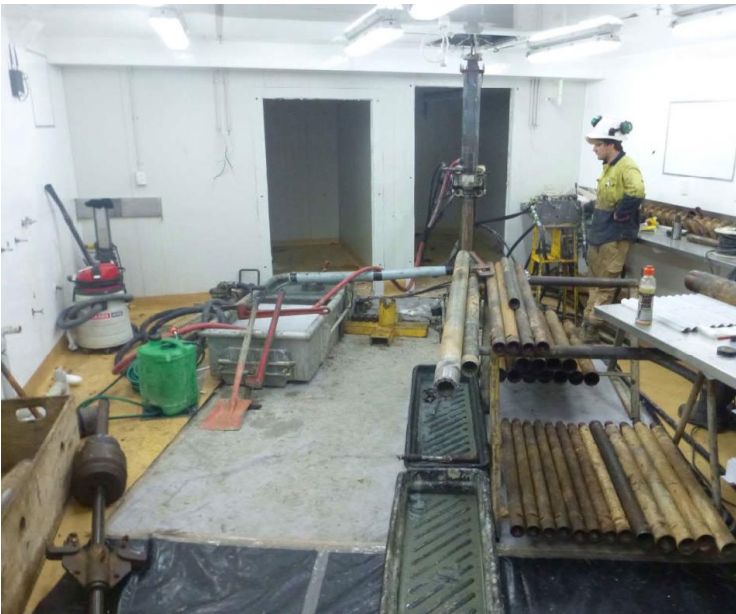
- Initial geotechnical and structural desktop assessments undertaken.
- Structural and geotechnical engineer meet, identify issues which may be material to the assessment.
- Test the need for and value of investigations to inform these potentially material issues by:
 1. Testing assessment assuming “pessimistic” geotechnical parameters which can be relied on without further site investigation. If the assessment concludes the structure can tolerate predicted deformation, then site investigation may not be necessary.
 2. Testing assessment assuming “optimistic” geotechnical parameters which could be proved by targeted site investigations. If this second run of the assessment returns a favourable outcome, undertaking a targeted site investigation could be justified. If the outcome is unfavourable the value of the investigations may be challenged.
- Stage the targeted investigations. Before proceeding to a subsequent stage of investigations challenge the value of proceeding considering the conclusions and implications of the previous stage.

2.2 Examples of available equipment

Many of the constraints listed in Table 1 are related to difficult access and disruption to buildings which would be resolved by using compact and portable equipment. For example, a portable Cone Penetration Test (CPT) rig (photograph no. 1) and a portable drill rig (photograph no.2); both can be dismantled into portable pieces and assembled inside buildings. Another example is using extended Jet Vac equipment to carry out excavation around foundations inside buildings where an excavator cannot reach due to limited access.



Photograph no. 1: A portable CPT rig (1.2m wide, 1.6m long) operating within a 2m wide basement tunnel with a limited head room of 2.5m



Photograph no. 2: A modified portable drill rig is operating within a basement room with an opening in the ceiling under a limited head room of 2.7m

Compact and portable equipment could offer less capacity compared to the traditional equipment and such limitations should be carefully identified and considered in planning a geotechnical investigation. A common issue of using portable CPT rigs is its push capacity which is highly dependent on its tie-down method. The tie-down method may require specific design. For portable drill rigs, working under limited head room significantly slows down the drilling process: the greater the target depth, the slower the drilling process. In

addition to the time required to establish the site and set up the drill rig, drilling time for a certain depth under limited head room can be double or triple the time required to drill with an unrestricted head room. Furthermore, some portable drill rigs working under limited head room cannot perform Standard Penetration Tests.

2.3 Examples of enabling works

Enabling works are a critical part of geotechnical investigations for existing buildings and they could require a substantial amount of time and technical input from the project team. The enabling works can be modification to equipment and/or to structures. The benefits and implications of enabling works should be assessed and discussed with the project team during the planning phase.

2.3.1 Enabling works to equipment

Enabling works to equipment often require collaboration between the investigation contractors and the structural and geotechnical engineers. This type of enabling works is not substantially expensive to build and could be reusable for other locations. For example, a specifically designed steel reaction frame can be built and installed for a portable CPT rig to provide a stronger tie-down system; this can prevent early refusal of the CPT tests and hence minimising the risk of inconclusive results.

2.3.2 Enabling works to structures

Enabling works to structures could be expensive, complex and time-consuming and often require costly reinstatement works, especially for those buildings requiring preservation of heritage features. Structure stability and associated health and safety risks should be considered in the planning phase.

Enabling works to structures require the project team to work collaboratively and sometimes creatively. For example, for improving working head room for equipment, we have tried opening and utilising the ceiling space (photographs no. 2 and 3), trenching into the ground (photograph no.3), and coring through floors so that investigations can be undertaken at a higher floor level which has sufficient working head room.



Photograph no. 3: Enabling works to increase working head room via trenching into the ground and removing ceiling panels. Trenching works also exposed existing foundation pads for examination

3 CONCLUSIONS

Geotechnical investigation for existing buildings is often complex, expensive, disruptive and time-consuming; the project team should test the need for site investigations via geotechnical/structural collaborative assessments. When the geotechnical/structural collaborative assessments confirm the need for targeted site investigations, the project team should consider staging and prioritizing targeted site investigations to manage project uncertainties.

When planning geotechnical investigations for existing buildings, the project team should be aware of constraints to investigations listed in Table 1: access constraints, disruption to buildings, disruption to building occupants and others affected, consent requirements and health and safety requirements. Identifying and implementing such mitigations requires good collaboration among the project team members.

4 REFERENCES

- MBIE (revision 1). 2017. *Seismic assessment of existing buildings – Section 4: Geotechnical considerations*. Wellington, New Zealand: Ministry of Business, Innovation and Employment.
- NZGS/MBIE (revision 0). 2016. *Module 2: Geotechnical investigations for earthquake engineering*. Wellington, New Zealand: New Zealand Geotechnical Society and Ministry of Business, Innovation and Employment.
- ArchSite: New Zealand Archaeology Association: archaeological site recording scheme. n.d. Viewed 31 January 2019, URL: <https://archsite.eaglegis.co.nz/NZAAPublic>.