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TOWARDS QUALITY DECISION MAKING FOR SUBSOIL INVESTIGATION; SITE CLASS AND POTENTIAL SURFACE MOVEMENT RESULTANTS CRACKING BUILDINGS IN PERTH, WESTERN AUSTRALIA

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Abstract**: The issues impacting the modern buildings cracking have many folds ranging from physical attributes to geological factors. The literature reveals that the expansive soil is widely spread all over Australia that causes great anxiety in house owners and technical industries for sustainable building development, protecting structural failure based on sound structural and geotechnical principles (Sun et al., 2017 p. 3960). To mitigate these nationwide challenges, a national standard, AS2870, was established in 1986 to provide a guide for the building industry(AS 1996, p.7). Although a standard was adopted, quality decision making is inevitable along with this Standard for the best outcome that promotes a comprehensive outlook in envisaging safety measures. Nonetheless, To accommodate an extra 1 million population by 2050, targeting 50% urban infill, the Perth Metropolitan Area has enormous pressure on releases new urban buildings and corridors (WAPC, 2010). Moreover, due to the current Pandemic, Australian Federal Government offered various stimulus packages to keep running the building industry, leading to more infrastructure development (ABC, 2020), where there are aggravated risks without comprehensive decision making, policy and practices. Responsive, quality decision-making and context-sensitive geotechnical investigation are critical to lowering the probability of structural, financial, and life-threatening risks. The results show that without quality decision making at an early stage and without proper investigation, it can create significant risks in infrastructure development. In many cases, it is almost impossible to rectify or reinstate the cracks without a new build or to adopt expensive technology in a dense suburban area that is unbearable in most cases for building owners. To explain such a scenario, the study is brought a single case study due to limited text. However, authors have significant experience, warranted similar challenges on many occasions in the past two decades. The study concludes that the findings will be helpful to understand towards quality decision making for subsoil investigation through a context-sensitive approach, where the site classification and the potential surface movement due to cyclic soil shrinkage and swelling arising from soil moisture variation result in cracking the lightweight structure (residential buildings) in Perth, Western Australia.

Keywords- Subsoil Investigation, geology and geotechnical, Quality decision making, ground movement, Sustainable buildings

I. INTRODUCTION

In Australia, the building materials in residential development varies from bricks, timber, plasterboards, where expand and shrinks generally occurs due to various reason such as seasonal variations, climate changes and many more. Moreover, foundation movement and crack also occurs due to soft, non-uniform and reactive soils. It is highlighted that soft, reactive soils are wide spreadly in Australian state and territory where moisture contents are rapidly fluctuating that can cause the very flexible slab same way deformation of foundation, where some locations may occur tensile membrane action **(AS 1996)** as shown in the figure. Although some measures are in design consideration, it is impossible to protect cracks without knowing the extreme moisture change or investigation in many cases. Therefore, at clay site governs additional costs and risks of housing.

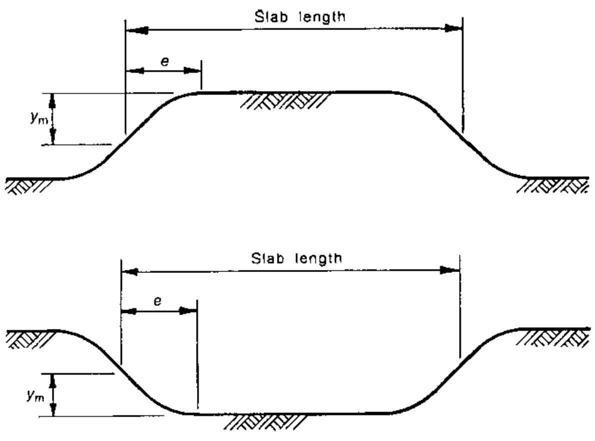


Figure 1: idealized ground movement patterns for footings and slabs on clays (walsh shapes)

There is evidence that the construction materials for residential buildings continuously have contraction and expansion, e.g. bricks (expand), timber and plasterboard (shrink). Consequently, these phenomena result in cracking in residential construction, which is unavoidable and is independent of foundation movement. Besides, the foundation movement adds to this tendency to crack due to reactive and soft or non-uniform soils. From the literature review and geological data analysis, it is revealed that a large number of houses in Australia are constructed on clays due to geological reform that moves with changes of soil moisture conditions arising from the imposition of the house on the ground. Generally, the ground movements were observed moderate, and the recommended designs in the Standard is resilient enough to cope with the movement. When unknown extreme moisture conditions occur, which may have been avoided with a reasonable level of site maintenance, significant damage will be more likely and probably more severe. To design for such conditions on every clay site required improvement concerning groundwater, subsoil profile, neighbouring infrastructure, and drainage facilities, which would finally add housing cost throughout Australia (AS 1996, p.7).

According to Vazirani (Vazirani and Chandola 1980), p.1-83), the cause of moisture content can occur for various reasons;

- Seepage of water into the subgrade from the higher ground adjacent to the lot due to high groundwater or a lower rate of soil infiltration
- By raising or fall in the level of the watertable due to various weathering and climate change context
- Percolation of water through the surface of the road due to wearing course is not enough waterproofing
- Transfer of moisture either to or from the soil in the verges as a result of the difference in moisture content.
- Transfer of moisture to: or from lower soil layers.
- Transfer of water vapour through the soil.

To mitigate these challenges, The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has published a guide called ‘Guide to Home Owners on Foundation Maintenance and Footing Performance’ to guide owners, builders and designers to minimize the consequences in such extreme context. (AS 1996, p.7). The next section detail the objective of this study.

This research aims to highlight the quality decision making for site classification and the best practice in residential development that could contribute to the literature gap by examining (a) how the private and public building design investigates the subsoil investigation. These movements can damage lightly loaded structures due to reactive sites consisting of clay soils that swell on wetting and shrink on drying. (b) to what extent the probability of damage can occur on reactive sites due to abnormal moisture conditions.

In this regard, this study explained a case example as a piece of evidence for academics and practitioners. The first section describes the desktop study from available information, The factual data (field test results), including test pit logs as per AS1726. The second section describes the interpretation of the subsurface conditions across the site, groundwater table information whether it was encountered, and Site classification according to AS2870-2011. The third and fourth sections describe investigation results and analysis, the action taken in practices explained by the authors for the purpose of the remedial process of context-sensitive site preparations and compaction requirements, earthworks classifications as per AS1170. The fifth and sixth section describes the survey results laboratory certifications, and the final section provides a conclusion and recommendation. In these circumstances, the study has highlighted a project where the investigation was carried out for a residential building by the Perth Geotechnics (PG). The Perth Geotechnics (PG) was engaged by the building owner, Lot 22 (66) Royal Street, Kenwick, WA, due to significant cracking at various locations of this property and taking remedial measures. The project location is situated in the City of Gosnells in Kenwick Suburb in Perth, capital of Western Australia. The next section reviews the literature reports from various projects to summarise the techniques with application examples to carry out this study.

Figure 2: Australian Map showing States and Territories

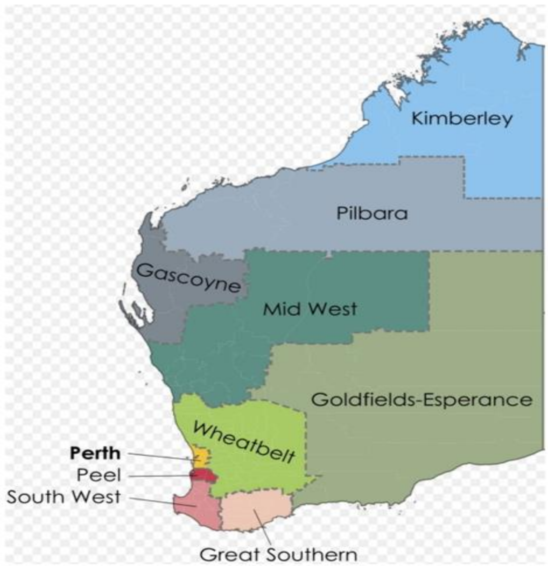


Figure 3: Location of Perth in Western Australia

Figure 4: Perth Metro Councils

Figure 5: City of Gosnells, South East Metropolitan

The Owner also highlighted that due to such damage and vulnerable condition of this existing property, he was informally advised by Builders (Developer) to demolish the existing property, and the proposed development at the site can be a maximum of double-storey residential dwellings. The next section has described for desktop study.

II. DESKTOP STUDY

A) SITE HISTORY

A review of Landgate Information and aerial photography of the site indicates that the site is situated in a residential area. Royal Street bounds the site at the northern side, Canning river at the western and southern side, Gospel Methodist Church and bushland at the eastern side. Currently, there is an existing house and few sheds at the site. Few cracks were observed in the existing house wall at the time of the investigation. There are some small to big size trees at the site. The site level is found flat at the northern and eastern side, and the western and southern side slopes up to Canning River. Geomatics Australia conducted a topographic Survey (Feature Survey) on 8 October 2020, tying with Perth Coastal Grid (PCG94) projection linking to Australian Height Datum (AHD). The site photograph was taken during the field investigation are shown in figure 7 and 8 below.

Figure 6: Location of Lot 22 (66) Royal Street, Kenwick WA City of Gosnells, South East Metropolitan
Tests Locations: Bore Hole (BH), Dynamic Cone Penetration (DCP) and Field Permeability Test (FPT)

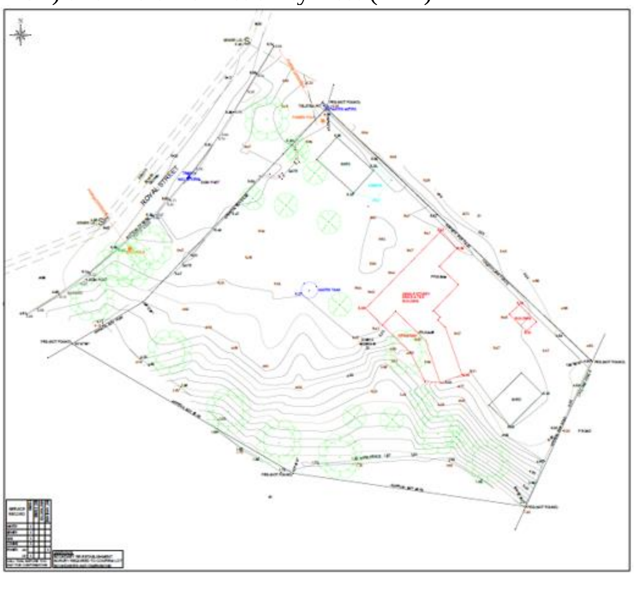


Figure 7: Topographic Survey (Feature Survey) for the site

FIGURE 8: A LOCATION OF EXISTING BUILDING CRACKS

Figure 9: Type of Soil observed from test pit

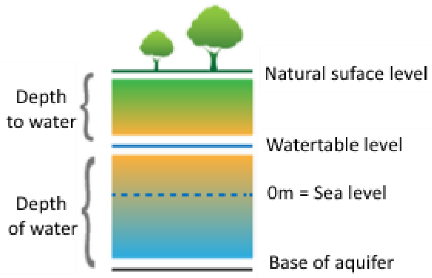
a) Site Geology

A review of Environmental Geological Western Australia survey Map of Armadale 1:50,000 (part sheets 2033 I and 2133 IV) revealed that the site consists of Sandy Clay- white grey to brown, fine to coarse-grained, sub-angular to rounded sand, clay of moderate plasticity, gravel and silt layers near scarp, Guildford formation. The Environmental Geological Map of Armadale also revealed that the site soil has low permeability, Low corrosion potential, low to medium slope stability, low bearing capacity. Sand pads are required beneath foundations, and high logs may require pile support, permanent cuts unstable, prone to seasonal flooding, interferers with Sc to west and colluvium to east.

FIGURE 10: GEOLOGICAL MAP

b) Groundwater

The groundwater table was not observed at any of the boreholes up to the investigation depth of 2.0 m. A review of the 'Online Perth Groundwater Atlas' of the Department of Water was carried out for this site. "Perth Groundwater Atlas" revealed that natural surface elevation is 3.8 m AHD and the annual average groundwater table is at 1.0 m AHD. That means the depth of the groundwater table is approximately 2.8 m AHD from the ground level. The groundwater level contours are estimated based on the recorded groundwater levels measured in May of 2003 (end of summer).



Groundwater Depth Information (below)

Depth from ground level to:	
Watertable:	2.8 meters
Base of Aquifer:	13.8 meters
Levels relative to AHD (~sealevel)	
Natural Surface:	3.8 meters
Watertable:	1.0 meters
Base of Aquifer:	-10.0 meters

Water Quality Information (below)	
Groundwater Salinity	**1000-1500** mg/L
Surface Geology Type	**Guildford Clay: alluvium (clay, loam, sand and gravel)|Qpg**
Iron Staining Risk	**Low risk**
Garden Bore Suitability	**Unsuitable**
Acid Sulfate Class	**Moderate to low risk**
Public Drinking Water Source Areas (PDWSA)	**N/A**

Figure 11: Groundwater Information from Perth Groundwater Atlas

III. DETAIL SITE INVESTIGATION

The geotechnical site investigation was undertaken on 22 October 2020 in the full-time presence of a geotechnical engineer from PG. The site investigation comprised of the following:

- Site walkover and taking photographs.
- Excavation of four (4) boreholes (BH1 to BH4) by hand auger up to a depth of 2.5 m or refusal.
- Logging of the site soil profile as per AS1726.
- Conducting four (4) Dynamic Cone Penetrometer (DCP1 to DCP4) tests adjacent to boreholes to a depth of 1.0 m or refusal.
- Conducting one (1) Field Permeability Test (FPT1) by Guelph permeameter.
- Recording of the locations of BH, DCP and FPT by handheld GPS.

A site plan showing the locations of the borehole, DCP and Field Permeability Tests are detailed in the following figures

c) Test Pit and Bore Hole Logs

Four (4) Bore Holes (BH1 to BH4) were conducted at the site by using a hand auger to a depth of 2.5 m or refusal.

Boreholes BH1 to BH4 revealed a similar soil profile and consists of Clayey Sand/Gravelly Clayey Sand- fine to medium-grained, dark grey, dark red, reddish-brown, brown, dry, loose to medium dense, low to medium plasticity, with gravel up to 15 mm (TOPSOIL) to a depth up to 0.3 m overlying Sandy Clay- high plasticity, reddish-brown, red, yellowish-brown, yellow, dry to slightly moist, firm to very stiff, fine-grained sand to a depth of 2.0 m. A groundwater table was not observed at any of the boreholes up to the investigation. BH1, BH2, BH3 and BH4 were terminated at a depth of 2.0 m due to hand auger refusal. Bore Hole logs are attached below;

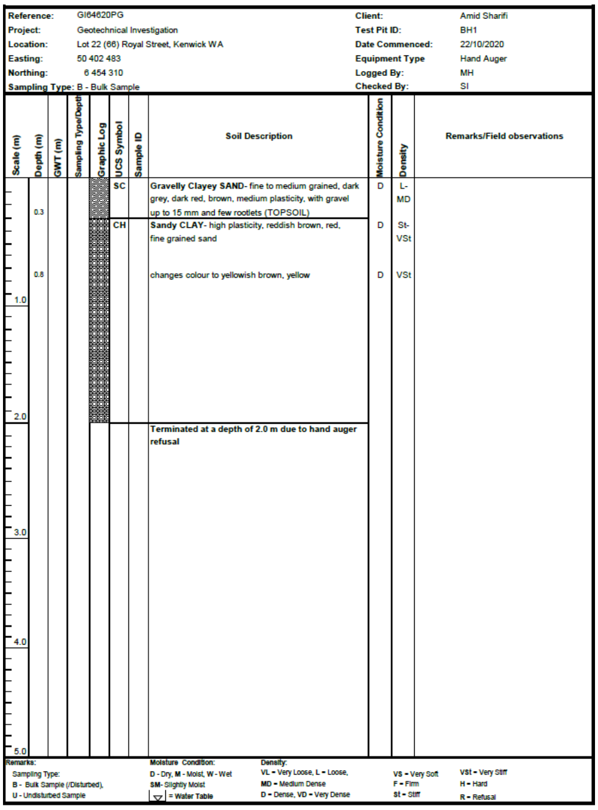


Figure 12: Bore Hole (BH1)

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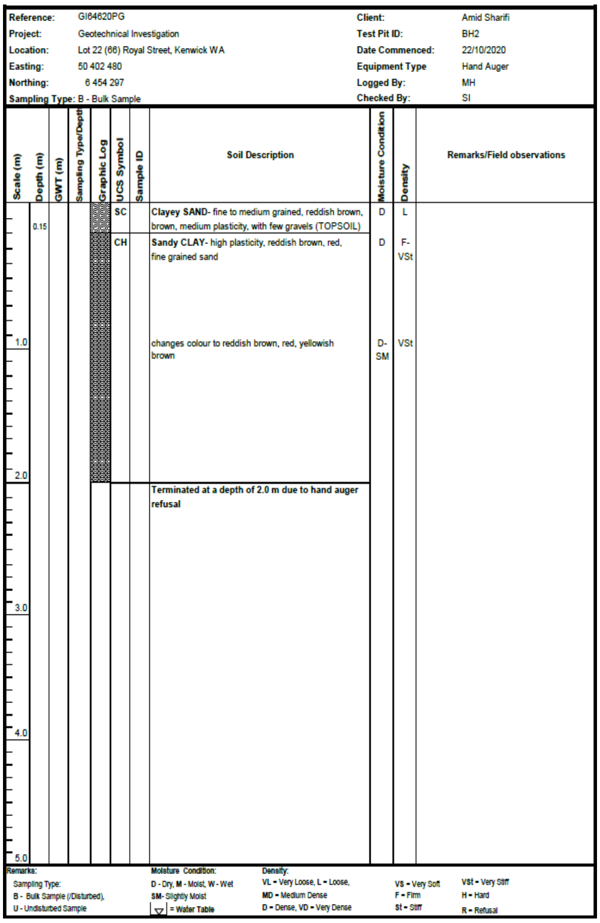


Figure 13: Bore Hole (BH2)

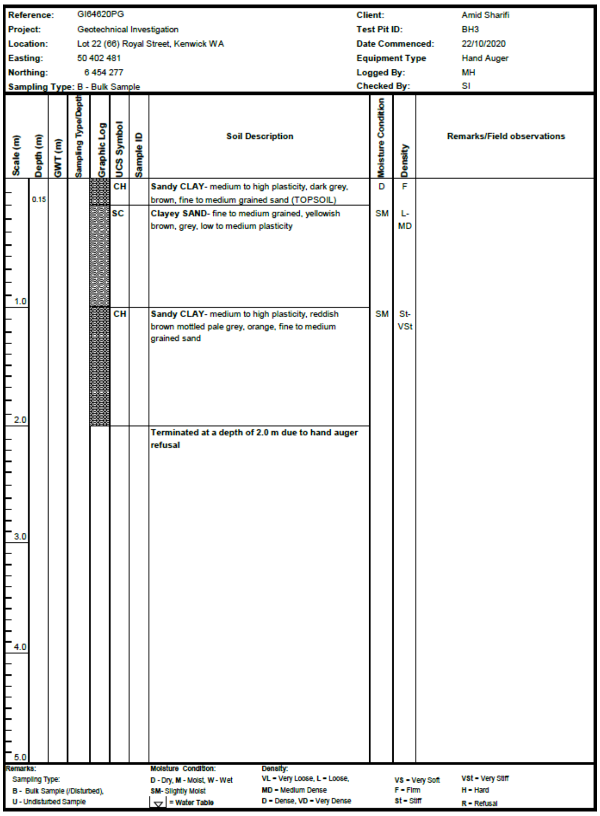


Figure 14: Bore Hole (BH3)

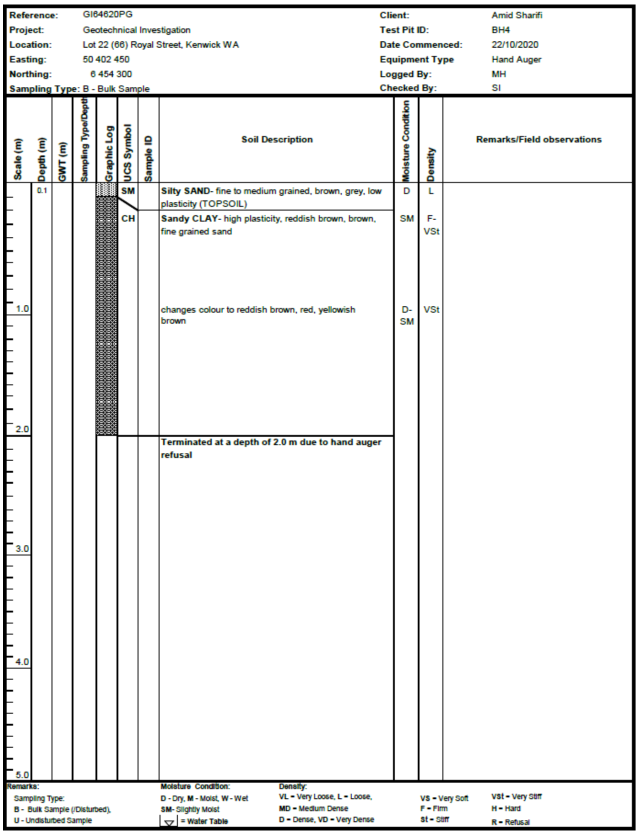


Figure 15: Bore Hole (BH4)

d) Dynamic Cone Penetrometers (DCP) Test

Four (4) Dynamic Cone Penetrometer tests (DCP1 to DCP4) were conducted adjacent to borehole locations. All DCP tests were conducted to a depth of 1.0 m or refusal. The tests were conducted in accordance with test method AS1289.6.3.2, Ref Table 6.4.6.1 (A) & (B) HB 160- 2006. The DCP tests revealed that the site is in loose to medium dense and firm to very stiff condition. Based on the Dynamic Cone Penetrometer test results, the foundation material cannot support an allowable bearing pressure of 100 kPa in its current condition. The DCP test certificates are attached.

DYNAMIC CONE PENETROMETER (DCP)
TEST CERTIFICATE

(AS 1289.6.3.2)
Correlation of Sand Density - Table 6.4.6.1 (A) & (B) HB 160-2006

Client	Amid Sharifi	Project	Geotechnical Investigation
Reference	GI64620PG	Location	Lot 22 (66) Royal Street, Kenwick WA
Date Tested	22/10/2020	Tested By	MH

References:	DCP1	DCP2	DCP3	DCP4	DCP5
Depth below ground level test commenced	Penetration Resistance - Blows/100mm				
0-100	2	2	1	2	
100-200	2	2	2	2	
200-300	3	2	2	4	
300-400	3	3	2	5	
400-500	4	4	2	5	
500-600	5	5	2	6	
600-700	5	6	3	6	
700-800	6	6	2	6	
800-900	7	7	3	7	
900-1000	7	8	3	8	
Depth below ground level test commenced					
0-100	L	L	F	L	
100-200	L	F	L	F	
200-300	MD	F	L	St	
300-400	St	St	L	VSt	
400-500	St	St	L	VSt	
500-600	VSt	VSt	L	VSt	
600-700	VSt	VSt	MD	VSt	
700-800	VSt	VSt	L	VSt	
800-900	VSt	VSt	MD	VSt	
900-1000	VSt	VSt	MD	VSt	

Remarks:

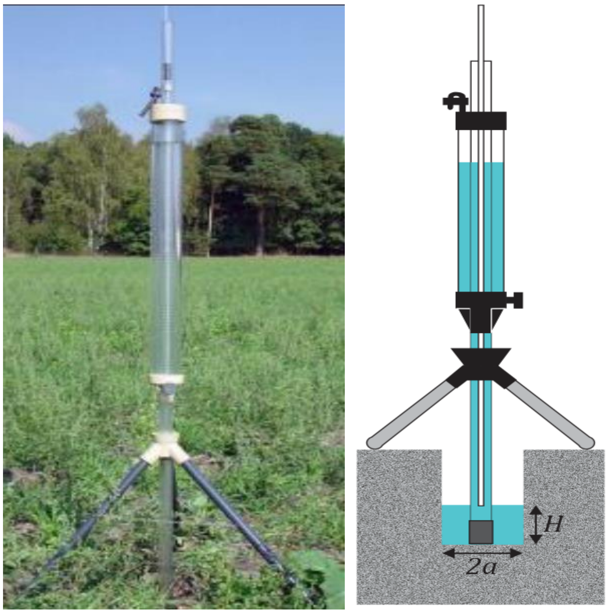
Table A: H = Hard >10, VSt = Very Stiff, 5 – 10, St = Stiff, 3 – 4, F = Firm, 1 – 2, VS = Very Soft < 1

Table B: VD = Very Dense > 8, D = Dense, 4 – 8, MD = Medium Dense, 2 – 3, L = Loose, 1 – 2, VL = Very Loose < 1

Figure 16: Dynamic Cone Penetration (DCP)

e) Field Permeability Test

One (1) Field permeability test (FPT1) was conducted by using Guelph permeameter as per ASTM D 5126 – 90. The test was conducted at a depth of 0.5 m below ground level (bgl). The Guelph Permeameter is a constant head device that operates on the Mariotte siphon principle. It provides a straightforward way of determining the field saturated hydraulic conductivity, matrix flux potential and soil sorptivity. The following figure has shown the typical arrangement;



(a) Field Set-up (b) Field Testing

FIGURE 17: FIELD PERMEABILITY TEST BY GUELPH PERMEAMETER

Table 1. Summary of Field Permeability Test Results

Permeability Test ID		FPT1
Co-ordinates (GDA94)	**Easting**	402 485
	Northing	6 454 307
Per meability rate	**cm/sec**	9.9×10^{-4}
	m/day	0.86
Soil Description		Sandy Clay
Test Depth (m)		0.5

IV. LABORATORY TEST

Laboratory tests were conducted at Western Geotechnical Laboratory WA, a NATA accredited laboratory located at Welshpool WA. The following laboratory tests were undertaken:

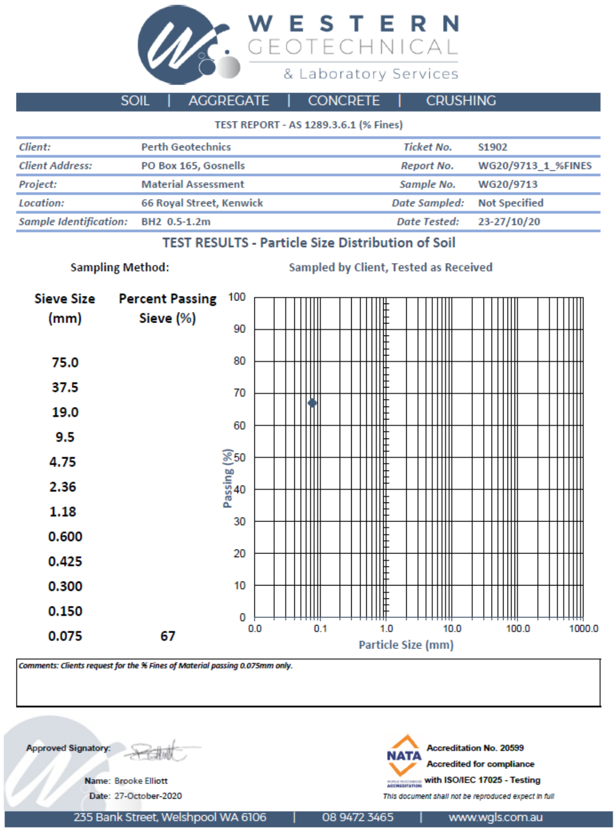
- Percent Fines (% Fines) (Test Method: AS 1289 3.6.1)
- Atterberg Limits Test or PI test (Test Method AS1289. 3.9.2, 3.2.1, 3.3.1,3.4.1)

Laboratory test revealed that site consists of highly reactive clay. The laboratory test results are presented in Table 2, and test certificates are included in Appendix C.

Table 2. Summary of Laboratory Test Data

Soil Properties	**Soil Sample from BH2 (0.5 m to 1.2 m)**
Particle Size Distribution	
Sand (%)	33
Fines < 75µm (%)	67
Atterberg Limit Test	
Liquid Limit (%)	51
Plastic Limit (%)	19
Plasticity Index (%)	32
Linear Shrinkage (%)	11.0

Percent Fines from Western Geotechnical Laboratory Services


WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.6.1 (% Fines)

Client:	Perth Geotechnics	Ticket No.	S1902
Client Address:	PO Box 165, Gosnells	Report No.	WG20/9713_1_%FINES
Project:	Material Assessment	Sample No.	WG20/9713
Location:	66 Royal Street, Kenwick	Date Sampled:	Not Specified
Sample Identification:	BH2 0.5-1.2m	Date Tested:	23-27/10/20

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	
19.0	
9.5	
4.75	
2.36	
1.18	
0.600	
0.425	
0.300	
0.150	
0.075	67

Comments: Clients request for the % Fines of Material passing 0.075mm only.

Approved Signatory: Name: Brooke Elliott Date: 27-October-2020

NATA Accreditation No. 20599 Accredited for compliance with ISO/IEC 17025 - Testing

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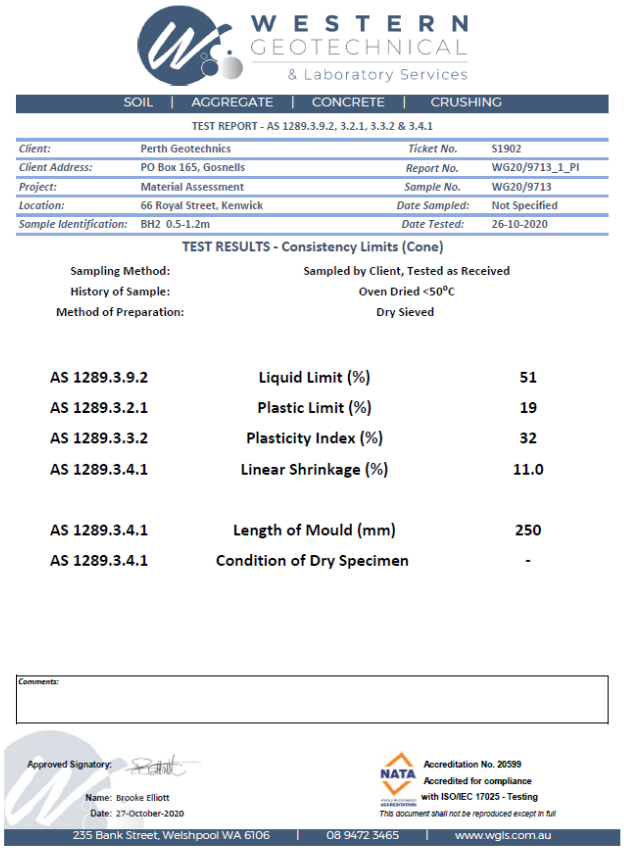
Figure 18: Percent Fines Lab Test Results

Atterberg Limits Test from Western Geotechnical Laboratory Services


WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.9.2, 3.2.1, 3.3.2 & 3.4.1

Client:	Perth Geotechnics	Ticket No.	S1902
Client Address:	PO Box 165, Gosnells	Report No.	WG20/9713_1_PI
Project:	Material Assessment	Sample No.	WG20/9713
Location:	66 Royal Street, Kenwick	Date Sampled:	Not Specified
Sample Identification:	BH2 0.5-1.2m	Date Tested:	26-10-2020

TEST RESULTS - Consistency Limits (Cone)

Sampling Method: Sampled by Client, Tested as Received
History of Sample: Oven Dried <50°C
Method of Preparation: Dry Sieved

AS 1289.3.9.2	Liquid Limit (%)	51
AS 1289.3.2.1	Plastic Limit (%)	19
AS 1289.3.3.2	Plasticity Index (%)	32
AS 1289.3.4.1	Linear Shrinkage (%)	11.0
AS 1289.3.4.1	Length of Mould (mm)	250
AS 1289.3.4.1	Condition of Dry Specimen	-

Comments:

Approved Signatory: Name: Brooke Elliott Date: 27-October-2020

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Figure 19: Atterberg Limits Test Results

Ground Movement: The expected free surface movement ys is determined as per AS2870, 2011 by estimating the movement of each soil layer within the depth of design suction change Hs and summing the movement for all layers, as follows:

$$y_s = \frac{1}{100}\sum_{n=1}^{N}\left(I_{pt}\,\overline{\Delta u h}\right)_n$$

Where, *Ipt is the instability index, which is indicating the degree of soil reactivity.*

It is defined as the axial strain of the soil under a unit logarithm suction change (Δ_u). Using this predictive technique, the ground movement results become more reliable by considering the expected values of the applied stress, degree of lateral restraint and the soil suction range. In addition, by multiplying a shrinkage index Ips by an empirical correction factor α (varying between 1 and 2) to allow for full or partial lateral confinement, depending on the depth within the soil layer and the expected depth of seasonal shrinkage cracking.

By using the above equation, a characteristic surface movement in the order of 17 mm to 47 mm has been calculated for the lot dependent on the soil profile, depth of fill, and depth to rock encountered at test locations. It is noted that the computed surface movement correlates to a site classification (Table below), Slightly reactive. However, the proposed site Class is recommended based on the potential for variable founding conditions at footing subgrade elevation

Site classifications provided above are based on test bores and laboratory testing of multiple layers over the depth of total soil suction change in the soil profile. It should be noted that individual lot development may include future geotechnical studies and care. Single laboratory results are not allocated to the full depth of the soil profile, as biased site classifications can result.

V. SITE CLASSIFICATION

f) Site Classification

Based on the subsurface, surrounding site condition during the investigation and laboratory test results, the existing site is classified with a Site Classification of 'H1' (characteristic surface movement of 40< Ys ≤ 60 mm) in accordance with the definitions provided in Australian Standard AS2870 - 2011, by conducting the remedial measures or site preparation as describing at Section VII-1. The general definition of 'Site Class' is shown in Table 3 (Source: AS 2870-2011).

Site Class	Soil Description	Characteristic Surface Movement (mm)
A	Most SAND and ROCK sites with little or no ground movement due to moisture content variation	little or no ground movement
S	Slightly reactive clayey or silty SAND, which will cause slight ground movement due to moisture content variation	0< Ys ≤ 20
M	Moderately reactive clayey or silty soil which will cause moderate ground movement due to moisture content variation	20< Ys ≤ 40
H1	Highly reactive clayey or silty soil which will cause high ground moved due to moisture content variation	40< Ys ≤ 60
H2	Highly reactive clayey or silty soil which will cause high ground moved due to moisture content variation	60< Ys ≤ 75
E	Extremely reactive clayey or silty soil which will cause extreme ground movement due to moisture content variation	Ys >75
P	Problematic sites, sites consisted of soft soils, soft clay or silt or loose sand; landfills, mine, subsidence, collapsing soils, very reactive soils, subjected to erosion and sites which cannot be classified as A to E.	-

VI. DISCUSSION

This research is based on conditions that existed at the time of the subsurface exploration; decisions should not be based on a report whose adequacy may have been affected by time. The authors urge ground movement matter during the investigation; however, after construction, the issue may be encountered because of differing compaction of foundation soil prior to construction and differing soil moisture content prior to construction (CSIRO, 2003).

From general practice, the existing soils below the topsoil in land zoned, primarily for residential buildings, can be divided into granular and clay. In many cases, the foundation soil is mix in a combination of both types of soils. The problem of clay soils occurs due to swelling/shrink problems (CSIRO, 2003).

This study highlights that the site investigation was identified the actual subsurface ground conditions only those points where the test pits were performed, and the samples were taken and when they were taken. Authors interpret data derived from literature and external data source review, sampling and subsequent laboratory testing to inform overall site conditions, context and likely impact on the proposed development and recommendation actions. The actual ground conditions may differ from those inferred to exist because it is difficult to discover the full depth of understanding and site scenarios. Moreover, it is difficult for professionals to reveal what is hidden by the earth, rock and time, without a comprehensive or sophisticated technology or action. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained during the test and investigation was made. It is evident that there is always minimal opportunity or nothing to be done to change actual site conditions. However, risks mitigation or remedial steps can be taken to reduce unexpected situations.

The study is also assumed that the site conditions revealed through selective point sampling indicate actual conditions throughout the area. This assumption cannot be substantiated until project implementation has commenced. Therefore the report recommendations can only be regarded as preliminary. Consequently, this study acknowledges that Quality decision-making (QDM) can have a severe impact of the building industry and homeowners, where a project takes place that will have consequences in Life Cycle Cost (LCC) of Infrastructure as well as leads design scope changes, reinstatement cost results increase project costs (Malik, 2015).

VII. CONCLUSION AND RECOMMENDATIONS

The purpose of this study was to examine the Quality Decision Making towards the explicit phases of residential infrastructure planning, design, construction and ongoing maintenance (the project had a certain length of defect liability) by examining a case from the city of Gosnells in Perth, Westen Australia. The study has uplifted the case as a lesson learn for industry and academics about the consequences of improper decision-making and policy compliance in the current development economy, where residential infrastructure influences social, land use, sustainable transport, and many more. Finally, the study has collated a few recommendations that could be considered for this particular projects and context as part of a quality checklist during decision making;

1. Site Preparation

- The earthworks should be carried out in a controlled manner in accordance with the recommendations given in Australian Standard AS 3798, "Guidelines on earthworks for commercial and residential developments".
- The site should clear uncontrolled fill, grasses, building rubbles, paved materials, tree with tree roots, demolition debris, soft clay materials or other harmful material.
- Based on the subsurface, surrounding site condition during the investigation and laboratory test results, the site is classified with a Site Classification of 'H1' (characteristic surface movement of $40 < Ys \leq 60$ mm) in accordance with the definitions provided in Australian Standard AS2870 - 2011, by conducting the remedial measures or site preparation as describing at Section VII-1.
- The site can be reclassified to 'M' classification, prepare sand pad of 700 mm over highly reactive clay and compact as per AS 3798 by conducting the remedial measures or site preparation as describing at Section VII-1. The characteristic surface movement can be considered up to ($20 < Ys \leq 40$ mm) in accordance with the definitions provided in Australian Standard AS2870 -2011. The soil suction change of 2.5 m is considering in this case.
- The site can be reclassified to 'S' classification, prepare sand pad of 1300 mm over highly reactive clay and compact as per AS 3798 by conducting the remedial measures or site preparation as describing at Section VII-1. The characteristic surface movement can be considered up to ($0 < Ys \leq 20$ mm) in accordance with the definitions provided in Australian Standard AS2870 -2011. The soil suction change of 2.5 m is considering in this case.
- Onsite disposal of stormwater via soakwell is not appropriate for this site. Authors recommend to disposal of stormwater or roof runoff to offsite of the property or to the council drainage system via a site-specific drainage system. The drainage system has to fulfil the requirements of the City of Gosnells.
- Compact the exposed, cleaned surface with a required number of passes of a heavy vibratory roller or a heavy plate compactor to a dense state (95% of MMDD in accordance with AS1289.5.2.1 or an equivalent minimum DCP blow count of 4 per 100 mm or an equivalent minimum PSP blow count of 8 for 150-450 mm, 9 PSP blows for 450-750 mm, and 10 PSP blows for 750-1050 mm.
- The material at compaction should be moisture conditioned within -1% to +2% of its optimum moisture content.
- The type of fill material used and the depth of fill may also affect the site classification.
- The retaining wall may be required to retain the filling sand and if the level difference is 0.5 m or as per city of canning requirements.
- The Owner needs attention regarding the CSIRO publication in Building Technology File Number 18 from "Guide to Home Owners on Foundation Maintenance and Footing Performance".
- It is highly recommended that during the course of construction, to verify site preparation and compaction prior to pouring of concrete checked by a geotechnical engineer.
- Conduct Dial Before You Dig (DBYD); All services shall be located prior to excavation and construction. Construction personnel obtain the latest service info and ensure due care and diligence be given to any new services not marked on these drawings.

2. **Structural Fill**

- Suitable materials for structural fill shall be a clean imported sand fill. The fill material at compaction should comprise sand that is free from oversized material (i.e. material > 50 mm in any dimension), less than 5% fines (material passing 0.075 mm sieve), foreign material, organic material or other deleterious material. It should also be free from industrial waste, solid waste, or construction and demolition debris.

3. **Site Subsoil Class and Earthquake hazard factor**

• The site sub-soil class may be classified as Class Ce - Shallow soil. This is based on the geotechnical investigation and is in accordance with the definitions provided in AS1170.4 - 2007, Structural design actions Part 4: Earthquake actions in Australia.

• The design criteria required for a structure considering the risk of being subjected to earthquake loads are provided in AS1170.4-2007. The Hazard Factor (z) for Perth is 0.09. This based on Figure 3.2(D), which provides the hazard factor for Western Australia.

4. **Stormwater Drainage**

• The site investigation revealed that the site comprises clayey sand overlying sandy clay to the maximum investigation depth of 2.0 m. The groundwater table was not observed at any of the boreholes up to the investigation depth. It is found from the field permeability test that the coefficient of permeability or hydraulic conductivity of the site is 0.86 m/day.

• All soakwells will set back from all buildings on the site, including any structure located on the boundary as per detail;

  - Minimum 1.0m from the side of the property line

- Minimum 1.0m from the corner junction peg.
- Minimum 0.5m to the side property line where a battle-axe driveway services a suitable block,
- For street furniture clarence: 1m for sep, 1.5m for street trees, 1m for utility boxes and 1m for street lights,

• Onsite disposal of stormwater via soakwell is not appropriate for this site. We recommend to disposal of stormwater or roof runoff to offsite of the property or to the council drainage system via a site-specific drainage system. The drainage system has to fulfil the requirements of the City of Gosnells.

5. **Bearing Capacity**

- Strip and pad footings should generally be a feasible foundation option for the proposed residential building structure.
- Based on the inferred state of natural soils as presented in Section III-c and DCP test results as presented in Section III-d, it can be concluded that the ground has not sufficient bearing capacity to support pad or strip shallow foundations for the proposed residential building structure.
- The authors estimated that the foundation material that is prepared following the recommended remedial earthworks/site preparation presented in Section VII-1 would be capable of withstanding an allowable bearing pressure of 100 kPa.

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