

PROCEEDINGS  
2019 AUSTRALIAN GEOMECHANICS SOCIETY  
VICTORIAN SYMPOSIUM

**Geotechnical characterisation –  
managing design and construction risk**

Wednesday, 30 October 2019, 8:00am – 7:00pm  
Rydges Hotel, 186 Exhibition Street, Melbourne



AUSTRALIAN GEOMECHANICS SOCIETY  
**VICTORIA CHAPTER**



**IGS**  
Insitu Geotech Services Pty Ltd

# PREFACE

The Victorian chapter of the Australian Geomechanics Society invited academics and practitioners in the field of geotechnical and ground engineering to attend the 2019 Australian Geomechanics Society Victorian Symposium held on 30 October 2019.

In recent years Victoria has seen significant growth in the construction industry. Investment in both public infrastructure and commercial real estate is growing, and as our cities and infrastructure grow, so too does the need to develop parcels of land with challenging ground conditions. Economical and safe geotechnical design requires efficient and well thought through ground investigation and characterisation to identify and manage ground risks and opportunities.

The 2019 Australian Geomechanics Society Victorian Symposium presents an overview of current state-of-the-art practices, innovation, new research results and case studies relating to geotechnical characterisation with an emphasis on its implications for addressing and managing design and construction risk. The 2019 Symposium brought together professional engineers, researchers, specialist contractors, regulators, educators and students to share and discuss their experiences on the topic of ground characterisation.

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# Pressure selections for triaxial permeability testing

E. Gmehling<sup>1</sup>

<sup>1</sup>Ground Science Pty Ltd, 13 Brock Street, Thomastown VIC 3074; PH (03) 9464-4617; FAX (03) 9464-4618; email: [ernie@groundscience.com.au](mailto:ernie@groundscience.com.au)

## ABSTRACT

It is a common occurrence that geotechnical engineers, geologists and scientists request triaxial permeability testing from Construction Material Testing (CMT) laboratories without specifying the required pressures or detailing the application. This is generally as a result of a lack of understanding of the test procedures and how the pressure selection during the various stages affect the overall test result reported. Some specifiers may also nominate pressures which provide a result which potentially indicates a soil compliance under those test conditions, yet if it were tested under conditions reflective of the engineering application, would in fact fail the required specification. There are three stages of the test which require different pressure selections;

1. Saturation pressures based on soil type and plasticity;
2. Consolidation pressures to set the specimen equivalent to the insitu condition;
3. Running the test at the desired confining stress or the mean effective stress using pressures relevant to the soil type.

*Keywords: triaxial, triaxial permeability, pressure selections, saturation process*

## 1 INTRODUCTION

The triaxial permeability test AS1289 6.7.3 2016 is used extensively in civil / environmental industries for validating a soils suitability in a variety of applications. This may be as a water holding body, landfill leachate interface, landfill capping material or as a part of a subgrade replacement layer over reactive soils in road construction.

The test method allows the specifier to nominate the conditions in which the soil is to be tested which accurately reflects the application in the field. Typically, CMT labs are issued with a test requisition or a chain of custody to perform the test, yet commonly does not include the test pressures required, or a description of the application. This paper aims to provide specifiers with an understanding of the various processes within the test method that influence the performance of the material and how test pressures are to be nominated.

When testing a soil for triaxial permeability, we are not obtaining a value which is a set parameter for that soil type. The bulk density and moisture are variables in a project which influences the performance of the soil.

This paper aims to define how to provide the correct overburden pressures, define what the consequences of incorrect pressure selections are, provide case studies to demonstrate the variations, explain what can be done if a soil marginally fails to meet a permeability design specification but there are no alternatives to the supply and explain should the confining pressure be based on the inlet, outlet pressure or mean effective stress to reflect insitu conditions.

## 2 PRESSURE SET VARIATIONS

During a Site Investigation (SI), specific data is collected to assist the project engineer / scientist gain an understanding of the constraints and limitations of the works to better engineer the project. The sampling of the materials during this investigation may be sampled as bulk samples from near surface or at depths or as insitu undisturbed tube specimens. The depth at which the

sample was retrieved and the depth at which the material is to be used during the construction phase of the project is of great importance for the performance of the triaxial permeability test. Other contributing factors to the testing performance, are based on the liquids in which the materials are to be exposed to during its design life. These may include ground waters, landfill leachates, mine tailings or wastewater from sewage treatments.

A sample issued to a CMT lab may not have the project information available, to make the correct decision on the testing pressures and may adopt incorrect pressures.

### 2.1 Test pressure variations

During the performance of the triaxial permeability test, the test specimen will be subjected to three or more variations of the set pressures based on the following steps;

- Saturation of the test specimen (min 0.95 B-response);
- Consolidation pressures to replicate overburden pressures;
- Test pressures to ensure constant flow through specimen.

A fundamental parameter of determining overburden pressures in soils is based around the specific gravity of the source and it is common to utilise 20kPa per meter of depth of soil. This is reduced to 10kPa where the soils are below the water table. For materials that have a very high (mine sites) or very low (high organics) specific gravity, variations to these overburden pressures shall be specified. These pressures are used to saturate, consolidate and permeate the soil specimen.



Figure 1: Typical Triaxial permeability setup

**2.2 Saturation stage**

Whether a sample has been trimmed from an in-situ sample or remoulded to replicate the proposed project conditions, the specimen shall be saturated to achieve a minimum pore pressure co-efficient (B-response) of 0.95 (commonly referred to as 95% saturation) for normally consolidated clays. Very Stiff clays may only indicate a B response of 0.91 even when fully saturated. This saturation process is important to replicate the true permeability of the soil under saturated conditions. Lower percentages of saturation typically result in slower permeability values reported.

This process is achieved by setting the confining pressure (cell pressure) (CP) approximately 10kPa – 15 kPa above the Back Pressure (BP). The ability to saturate a specimen depends on the initial moisture content and or saturation level if from an insitu specimen. As a guide, the saturation pressures need to be higher for soil types of higher

clay content and conversely lower for soils of low clay content. Table 1 provides some guidance on saturation pressures for clay soils. The ability to achieve the required saturation may be time consuming particularly for dry specimens of high clay content. The saturation process may take numerous days or weeks with daily monitoring to determine if the desired value has been achieved. It is not uncommon for a CMT lab to increase the saturation pressures mid process, if saturation cannot be achieved. This will aid in dissolving the air into

water and improving the saturation process, while maintaining the same low confining pressures.

Once a B-response of 0.95 has been achieved, the specimen shall then require the confining pressures to reflect the project conditions. This second step is commonly referred to as the consolidation stage.

**2.3 Consolidation Stage**

It is important to recognise that a sample prepared for testing is in a state that may not be reflective of the conditions in which the engineering application is to occur. It may reflect the in-situ state prior to sampling, but this may not be correct for the use in which the soil is to be used, particularly if the soil is to be recompacted in-situ.

Consolidation involves simulating the intended state prior to testing the permeability. The consolidation process allows the sample to compress and squeeze out water in the pore space, decreasing the voids ratio and increasing the bulk density. Incorrect pressures nominated at this stage will affect the result obtained and reported. The specifier is responsible for nominating the pressures to reflect the intended performance of the soil in the field.

Setting the consolidation pressures requires a clear understanding of the application to simulate the desire parameters and must be communicated to the CMT laboratory.

**2.4 Permeability stage**

It is appreciated that the consolidation process is likely to have changed the pore spaces and bulk density of the test specimen which is more common in remoulded specimens. While it is not a requirement of the test method, the specifier may wish to review the data from the consolidation stage to gain an understanding of the volume changes that may have occurred.

Setting the pressures for the performance of the permeability test, utilises three differing pressure selections, the cell pressure to confine the specimen, the inlet pressure and the outlet pressure

to induce flow across the specimen. Several case studies are presented below to provide guidance on how the pressures are selected and how variations to the pressures nominated can change the reported result.

Table 1. A guide to nominating saturation pressures

Soil Type	Recommended Back Pressures to aid in saturation
Clayey Sand	300 kPa
Sandy Clay / Clay (low to medium plasticity)	400 kPa – 500 kPa
Sandy Clay / Clay (medium to high plasticity) moist soils	500 kPa – 600 kPa
Sandy Clay / Clay (medium to high plasticity) dry/ damp soils	600 kPa – 800 kPa

## 2.5 Pressure Selections – Case Study 1 – Landfill Clay Liner

The sample to be tested is for the validation of a placed clay liner and will be subjected to leachate fluids. (The permeability test shall be tested with 50,000ppm saline solution). The completed landfill will contain 10m of waste. The specimen is obtained from soils which were compacted at or wet of Optimum Moisture Content (OMC) using a thin walled sampling tube.

Table 2 below provides the recommended test pressures for each stage of the triaxial permeability test. The specifier has the option of choosing the 100kPa overburden pressure to be used as the confining pressure or the Mean Effective Stress to be set at 100 kPa (refer to Table 3).

Table 2. Case Study 1 to 100 kPa confining pressure

Stage	Recommended Pressures
Soil type	CH Clay
Overburden load	Assume 10m fill x 10kPa = 100 kPa
Saturation pressures	CP = 615 kPa BP = 600 kPa
Consolidation pressures	CP = 600 kPa BP = 500 kPa
Test pressures	CP = 600 kPa IP = 500kPa OP = 450kPa MES = 125kPa

<sup>a</sup> CP = Cell Pressure, BP = Back Pressure, IP = Inlet Pressure, OP = Outlet Pressure, MES = Mean Effective Stress

Table 3. Case Study 1 to 100 kPa mean effective stress

Stage	Recommended Pressures
Soil type	CH Clay
Overburden load	Assume 10m fill x 10kPa = 100 kPa
Saturation pressures	CP = 615 kPa BP = 600 kPa
Consolidation pressures	CP = 600 kPa BP = 500 kPa
Test pressures	CP = 600 kPa IP = 550kPa OP = 450kPa MES = 100kPa

## 2.6 Pressure Selections – Case Study 2 – Bulk Sample taken from Green Field Site for the Construction of a Retarding Basin

It is common for geotechnical site investigations to sample soils from a variety of depths to assess the suitability of a clay source to be used for the construction of a retarding basin or similarly wetlands in new residential developments. These samples are remoulded to nominated compaction standards to reflect the site conditions. The challenge is for the specifier to consider whether the permeability test should be tested using an overburden pressure reflective of the deepest water depth or an arbitrary figure, even though the soils may typically remain dry for most part of the year.

If the mean effective stress is set too low, the sample may tend to swell under saturation. The ability to also obtain sufficient data points during the permeability test may extend the test for long periods, due to the low-pressure

Table 4. Case Study 2 – suggested mean effective stress

Stage	Recommended Pressures
Soil type	CH Clay
Overburden load	Assume 1m fill x 20kPa = 20 kPa
Saturation pressures	CP = 615 kPa BP = 600 kPa
Consolidation pressures	CP = 620 kPa BP = 600 kPa
Test pressures	CP = 620 kPa IP = 600kPa OP = 580kPa MES = 30kPa

<sup>a</sup> If data readings are too slow, the outlet pressure may be decreased by increments of 10kPa to improve flow rates.

head across the specimen. The commercial reality is that consultants require data quickly. Specifiers should be conscious of this limitation and nominate minimum pressures to use for these types of scenarios to meet their project timelines while understanding the effects of using a higher mean effective stress.

## 2.7 Pressure selections – Case study 3 – Purchasing clay soils from a soil merchant

A soil wholesaler or broker may have a supply of clay soils which are being considered for use to construct a compacted clay liner for a landfill cap. The material has been tested by the wholesaler and the results are submitted for review. The testing parameters detailed on the report are presented in Table 5.

Table 5. Case Study 3 – supplied permeability test report

Stage	Recommended Pressures
Permeability K	$1 \times 10^{-9}$ m/sec
Soil type	CL/CH sandy Clay
Remoulding criteria	100% SMDD @ OMC
Project specification	95% SMDD +/- 3% OMC
Confining pressure	650 kPa
Inlet pressure	600 kPa
Outlet pressure	570 kPa
Mean effective Stress	65 kPa

An engineer should consider these test results in relation to their specific project. The permeability results indicate the product is marginal and may not achieve this permeability rate if it were tested under lower mean effective stresses and remoulded at the lower compaction levels. Consideration is also required if the soil is compacted dry of OMC. In this situation the engineer would request a representative sample is supplied and the permeability testing repeated at the lower compaction level and at the variations of permitted moisture contents.

What is important to appreciate is the Specifier can modify the parameters to be used to run the permeability test to aid in the assessment of a materials suitability. It is not uncommon for a project to require a specific soil performance of permeability with supply limitations due to large transport costs and isolation from appropriate supplies. The use of a lower grade supply may be suitable by increasing the soils compaction level and the placement of tight moisture controls which may allow a soil type rejected at lower compaction levels to be used for the application.

### 3 CONCLUSION

It is important to consider that many civil applications using low permeability soils, may be exposed to the climatic cycles throughout each year. The consultant must consider the shrinking and swelling cycles of exposed soils when specifying the parameters for running a triaxial permeability test and the relevancy of the data obtained to the performance of the structure.

Performing a laboratory permeability test does not automatically translate to field performance. If the civil constructor does not perform the works to the desired standard required by the specification or if post construction, the placed fill is exposed to the elements for extended periods unprotected, then the in-situ permeability values may differ from the lab results.

It is imperative that a consultant reviewing triaxial permeability test results supplied by others, consider if the testing pressures and preparation methodologies used are appropriate to their application.

When ever possible the CMT lab should consult the client to obtain the test pressure parameters required.

### REFERENCES

AS1289 6.7.3-2016 Determination of permeability of soil – Constant head method using flexible wall permeameter

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