Laboratory Test Determing Rock Shear Strength

ASTM D 5607-16 Rock Direct Shear Strength | *By Bowei Yu PhD, MEng BEng*

1. Introduction

The shear strength and the stress parameters (e.g., apparent cohesion and friction angle) of an intact rock or a rock with discontinuities are important designing parameters in geotechnical engineering. Those parameters are highly dependent on histories and stress conditions of each individual rock entities, such as its lithology, geological characteristics, and the stress conditions. Therefore, laboratory tests play an important part in providing accurate rock shearing parameters to assist engineers designing safely and economically when they are running into rock-engineering projects.

(a) Kalgoorlie Super Pit, WA. credit: Jon Gollings

(b) Blue Mountains, NSW.

Fig. 1 Examples of rock slope stability applications in engineering practices

Due to the simplicity and versatility, direct shear tests are commonly used in the laboratory to determine the rock shear strength and pertinent parameters. Test methods such as ASTM D5607-16 provide shear test methods for both intact rock and rock with discontinuities.

(1) Intact shear strength test

The intact rock sample is subjected to a vertical load and then sheared until a failure develops. In this fashion a suite of specimens can be tested subjected to various vertical confining pressures. The failed sample is then testable for further sliding friction test. engineers designing safely and economically when they are running into rock-engineering projects.

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(2) Sliding friction test on rock with discontinuities (joints or bedding planes)

The specimen with a discontinuity, such as joints or bedding planes, is encapsulated in both top and bottom specimen holder, with the shear force being exerted in the same plane as the discontinuity. The specimen is then subjected to a vertical stress for consolidation and then sheared until residual friction force is obtained (refer to Fig. 2a). The sample is then consolidated and sheared at a higher vertical stress a couple of times until a failure envelop can be obtained from the results (Fig. 2b).

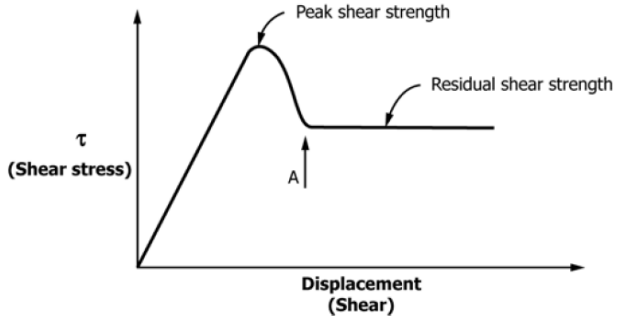
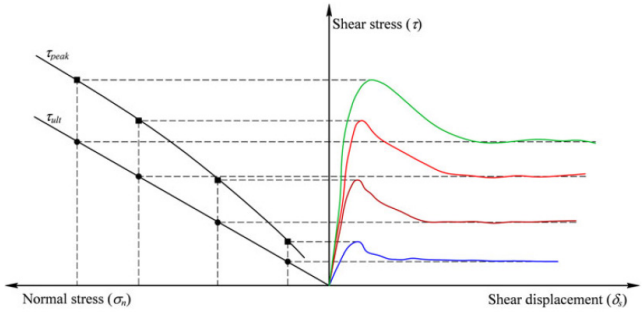


FIG. 1 Generalized Shear Stress and Shear Displacement Curve



(a) Generalized shear stress and shear displacement curve (adopted from ASTM D5607-16)

(b) Interpretation on the peak and ultimate/residual shear stresses (adopted from Muralha et al. 2014)

Fig. 2 Example of curves and interpretations from the sliding friction tests on rock discontinuity

2. Equipment and Test Methods

The specialist laboratory in Alliance is accredited with ASTM D5607-16 (Performing laboratory direct shear strength tests of rock specimens under constant normal force). Following the method the laboratory can provide peak shear strength for intact rock samples, peak and residual shear strength for rock discontinuities, and sliding friction parameters (e.g., c and ϕ) from multistage tests. Depending on the requirements on specimen size, rock strength, stress conditions, etc., the laboratory uses a variety of shear/rock shear equipment to provide accurate tests with fast TATs.

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Table 1 Various equipment available tailoring specific test requirements for the client

Equipment	Load Capacity	Specimen Size
Shearmatic EMS	Vertical-10 kN Shear Load-10 kN	Up to 100x100 mm Up to 100 mm diameter core
Rock Shear Box	Vertical-50 kN Shear Load-50 kN	Up to 115x125 mm Up to 102 mm diameter core
Shearmatic 300	Vertical-100 kN Shear Load-100 kN	Up to 150x150 mm Up to 150 mm diameter core

The equipment mentioned above can also be used in the shear strength tests on concretes/aggregates, soil-geosynthetic and geosynthetic-geosynthetic interfaces, etc. The test procedures are in general similar, with the shear strength of the interface being measured at various vertical confining stresses. The detailed test conditions (dry or saturated, drained or undrained, single stage or multi stages) may vary between those tests, depending on the site conditions and engineering designs.

3. Parameter Reported

The parameters one can obtain directly or interpret from the test include intact rock shear strength (peak shear stress), peak and ultimate or residual shear stress for rock with discontinuities. When multiple shear stages are conducted, using a linear Mohr-Columb model can provide stress parameters such as apparent cohesion and friction angle. Additional information may also be obtained from the rock shear tests, such as the dilation angle, etc. A sample report is given below.

Report Number: P212569-1 Sample Number: Sample 1

alliance Specialised Testing - 1800 288 188 | Direct Shear Strength Tests of Rocks Test Method: ASTM D5607-16

Report Number: N/A
Sample Number: 18548A
Sample Source: BH234, Depth: 20.31 - 20.58m
Borehole Angle: Vertical
Sample Date: 23/03/2022
Test Date: 12/04/2022
Report Date: 19/04/2022
Sampled by: N/A

Project Name: Geotechnical Investigation
Client: Alliance Geotechnical (Environmental)
Sample Description: SANDSTONE
Specimen Storage Method and Envrionment: Rock core received from client wrapped in wet cloth in sealed plastic bags. Stored in laboratory at room temperature.
Method of Preparation: -
Tested by: IG
Test Type: Sliding Friction Test-Multi Stage, Peak

Specimen Details	
Number of Specimens Tested	1
Initial Shape	Round
Moisture Condition:	Saturated
Type of Encapsulating Material	Plaster of Paris
Physical Description	Single Rock Specimen – Open Discontinuity (Saw Cut)
As Received Moisture Content (%)	2.5
*Joint Roughness Before Test	JRC 0-2, SANDSTONE
*Joint Roughness After Test	JRC 0-2, SANDSTONE

*Refer to Figure 1

Test Stage	Test 1: 250kPa	Test 2: 500kPa	Test 3: 1000kPa
Specimen Cross Sectional Shape	Round	Round	Round
Specimen Diameter (mm)	51.8	51.8	51.8
Nominal Cross-Sectional Area (mm^2)	2110	2110	2110

Data Interpretation	Peak Shear Strength
Apparent Cohesion (kPa)	61.6
Angle of Shearing Resistance (°)	29.7

Results	Test 1: 250kPa	Test 2: 500kPa	Test 3: 1000kPa
Normal Stress (kPa)	250	500	1000
Peak Shear Strength (kPa)	201	351	630
Horizontal Displacement at Peak Shear Strength (mm)	0.79	0.39	0.97
Residual Shear Strength (kPa)	-	-	-
Horizontal Displacement at Residual Shear Strength (mm)	-	-	-

Approved Signature:
Ian Goldschmidt
Specialised Testing Manager

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Observations of the top cap and box during test and after test description	No pronounced tilting

Specimen Photos
Before Test Specimen

After Test Specimen

Comments
Location and orientation of discontinuities: n/a.
Description of failure: n/a.

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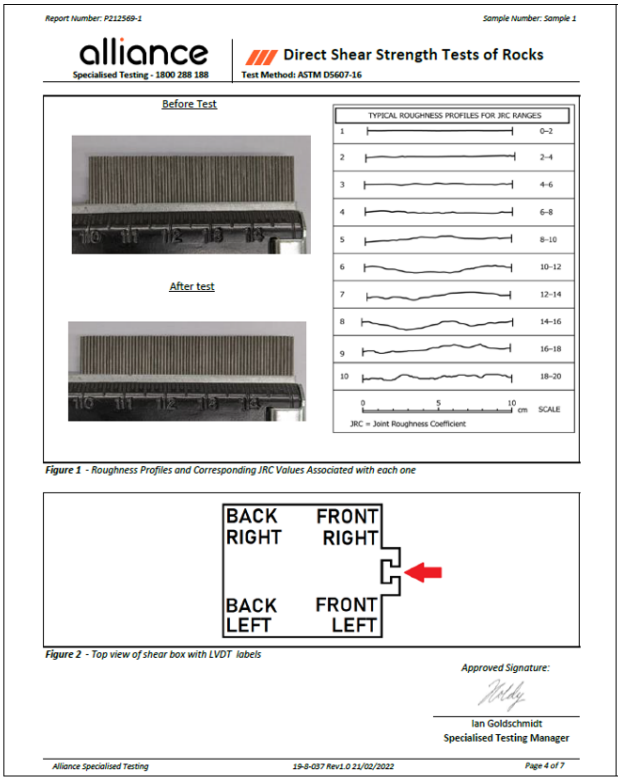

Report Number: P212569-1 Sample Number: Sample 1

alliance Specialised Testing - 1800 288 188 | Direct Shear Strength Tests of Rocks Test Method: ASTM D5607-16

Before Test

After test

TYPICAL ROUGHNESS PROFILES FOR JRC RANGES

1 0–2
2 2–4
3 4–6
4 6–8
5 8–10
6 10–12
7 12–14
8 14–16
9 16–18
10 18–20

0 5 10 cm SCALE

JRC = Joint Roughness Coefficient

Figure 1 - Roughness Profiles and Corresponding JRC Values Associated with each one

Figure 2 - Top view of shear box with LVDT labels

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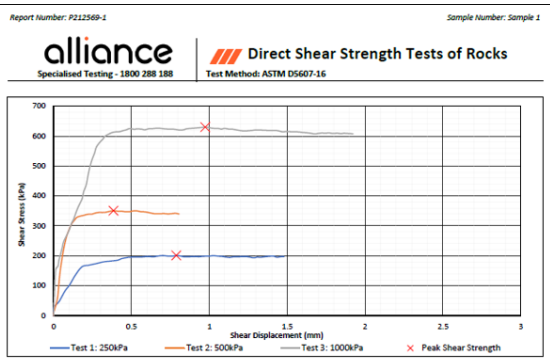

Figure 3 - Shear Stress vs Shear Displacement Sample ID: 18548A

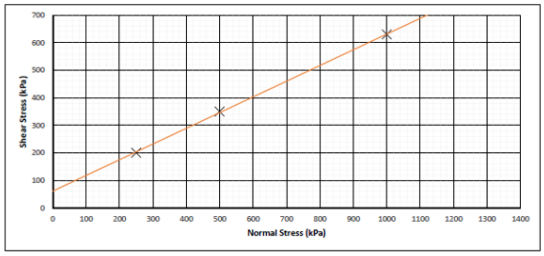

Figure 4 - Shear Stress vs Normal Stress: Condition at Peak Shear Strength Sample ID: 18548A

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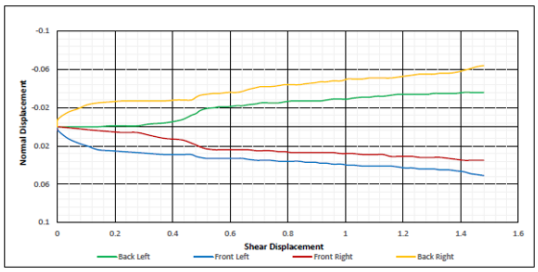

***Figure 5* - Normal Displacement and Shear Displacement (@ 250 kPa) Sample ID: 18548A

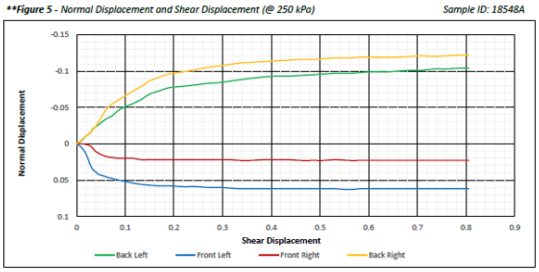

***Figure 6* - Normal Displacement and Shear Displacement (@ 500 kPa) Sample ID: 18548A

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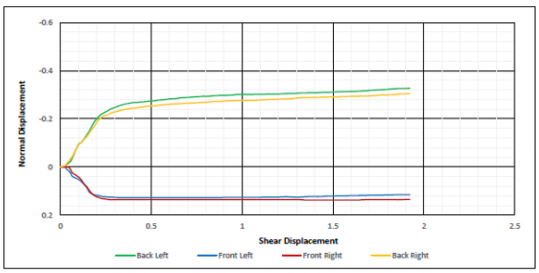

***Figure 7* - Normal Displacement and Shear Displacement (@ 1000 kPa) Sample ID: 18548A

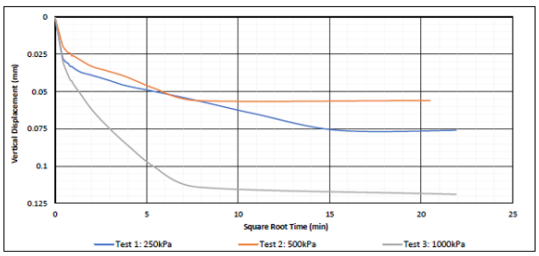

Figure 8 - Vertical Displacement vs Square Root Time Sample ID: 18548A
** Refer to Figure 2

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