Laboratory Shear Testing of Weakness Planes in Diamond Drill Core

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SUMMARY.- The importance of the frictional properties of joints in determining the stability of mine openings in rock has been well documented. Both in situ and laboratory testing are at present being used to estimate these properties, but often these methods require considerable specimen preparation. Diamond drill core taken for geological or geomechanical purposes offers readily prepared specimens on which a great number of tests could be conducted. To this end a machine was designed and constructed in the Mining Department of the University of Melbourne, enabling shear testing of cores up to 3.5 inches in diameter. Both open and intact joints through the core can be tested for peak and residual strengths, providing the angle of intersection between the joint plane and core axis is greater than 30°. Also, testing can be conducted along the joint plane in any direction relative to slickensiding. Calibration testing using teflon and brake lining specimens has been conducted, and the results of joint samples tested are discussed.

I.- INTRODUCTION

In recent years considerable interest has been shown in the frictional properties of the joints and weakness planes within rock. Where these planes are unfavourably oriented to the excavation, failure is more likely to occur along these weaknesses than through the rock matrix. Normal testing techniques use intact specimens which may not represent a rock mass dissected by weakness planes. However, this deficiency can be partially overcome by shear testing for peak and residual frictional resistence along particular weakness planes. These measurements, combined with a knowledge of the orientation and the surface properties of the joint, will enable stability predictions to be made.

Several shear testing techniques are in use at the present time. Triaxial apparatus can be used on solid cores with weakness planes within them, providing the planes intersect the core axis at angles between 30° and 60°. Direct shear testing has been conducted on joints or weakness planes both in situ and in the laboratory. In situ tests involve considerable time, expense and effort to arrange, but can be of real value where sampling would influence the results. Laboratory direct shear tests can be conducted under uniform conditions and at a lower cost than in situ tests. Well designed machinery is necessary to allow shear movement and riding over any surface irregularities which may occur, whilst preventing rotation. Specimens are usually chosen from surface outcrops or exploratory openings and require careful preparation before testing can be conducted. Tests on artificial surfaces are used to predict modes of failure rather than absolute values of friction.

These Direct Shear Testing methods involve time consuming work reducing the numbers of specimens which could be economically tested. Also, selecting samples from near excavated openings could impose restrictions on the results achieved. Machinery could be designed to improve testing of frictional properties of selected surfaces while overcoming the deficiencies of these methods.

II.- AIMS OF EQUIPMENT

(a) Rapid testing of a large number of samples, enabling statistical analysis.

(b) Testing of exploration drill cores.

(c) Testing of various diameter core.

(d) Loading to simulate in situ conditions.

(e) Testing in any direction to striations or slickensiding along joints intersecting the core.

(f) Separation of joint surfaces if riding over asperities occurs.

(g) Measurement of the loading applied and the resulting deformation to the specimen will determine the peak and residual strengths along the tested plane.

III.- DESIGN AND MANUFACTURE OF THE UNIVERSITY OF MELBOURNE DIRECT SHEAR TESTING MACHINE

The machine was designed and constructed within the Mining Department with the manufacture of major items being conducted by engineering firms. The loading capacity of 20 tons allows pressures of up to 10,000 p.s.i. to be applied to the surface area of the joint. Tests can be conducted on various core diameters to a maximum of 3.5 inches, with an allowable shear displacement of 1 inch in each direction and a normal displacement of .5 inch. A photograph of the machine is shown in Fig. 1.

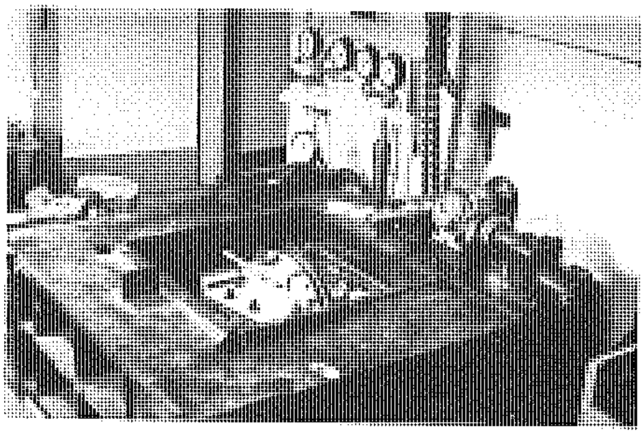

Fig.1 The Shear Testing Machine.

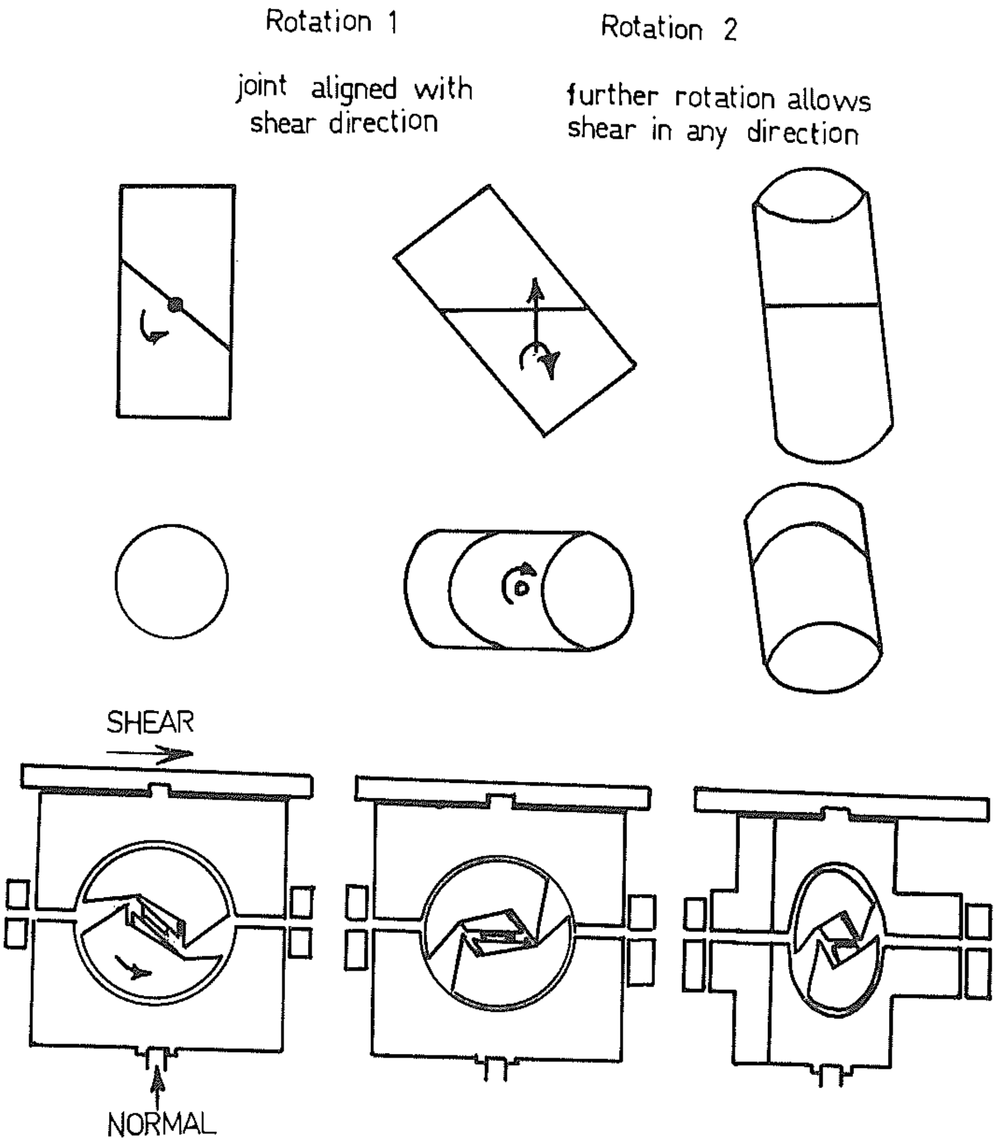

Fig.2 Rotations required prior to a test which aligns the joint with the shear direction.

The design is such that:

(a) Prior to a test the core specimen can be rotated relative to the loading points. This allows testing in any direction along the joint plane, providing the joint intersects the core at angles greater than 30°. Two rotations are required. The first is around the line perpendicular to the core axis and parallel to the joint plane. This aligns the joint with the direction of shear loading. Secondly, rotation around the line perpendicular to the joint plane allows shearing movement in any direction on that plane. These pre-test adjustments are shown in Fig.2.

(b) The core is rigidly held in sleeves, ensuring uniform loading to the specimen on each side of the joint plane. The sleeves are of various sizes to allow testing of core up to 3.5 inches in diameter. Also, the ends are cut at angles between 30° and 90° to the core axis so that specimens with weak plane intersections in this range may be tested with support to within .25 inch of the joint plane. The core and sleeve are held neatly in the specimen holder with packers and a screw adjustment. (Fig. 3). A keyway in the holder prevents axial rotation.

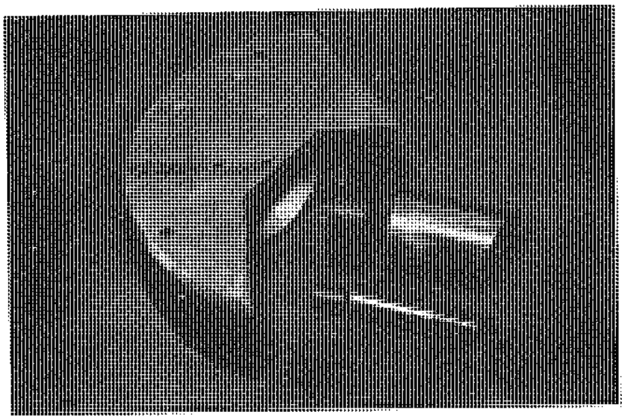

Fig. 3 The specimen holder and sleeve, showing the specimen location.

Each specimen holder is clamped between the upper and lower parts of one of the two universal loading frames. The specimen holder and the universal loading frame have circular mating surfaces for rotation prior to testing to orient the joint surfaces. (Fig. 4). Flat teflon-surfaced bearings on the outside of the universal loading frame control the movement of the two sides of the specimen. One frame can move parallel to the joint with the other perpendicular to this direction, so that riding over irregularities may occur.

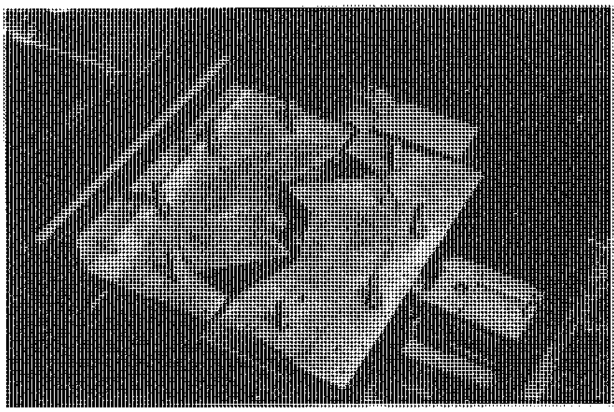

Fig.4 The Universal Loading Frame and the Specimen Holders, showing how rotations can be conducted.

(c) Shear loading can be applied in either direction to allow reversal of the test, and reach the residual strength. Loading is applied by hydraulic rams between the main frame and the universal loading frames. A constant normal load was applied by using a loaded lever arm, while a constant volume displacement oil pump provided the shear load. The shear system allowed pressure to build up at a uniform rate, reaching the resisting strength developed along the weakness plane before failure occurred. This compares with the situation found in situ where the forces causing sliding are thought to build up after each slip. The hydraulic circuits are shown in Fig. 5.

(d) Measurement of the loading applied to the specimen was made using pressure gauges in the hydraulic circuits. Displacements of the specimen were measured by using Linear Variable Differential Transformers (L.V.D.T.'s) between the two universal loading frames. The loading and resultant displacements were recorded using a four track Watanable continuous recorder.

(e) Using an overhead block and tackle system, it was found that a specimen could be tested and replaced within two hours.

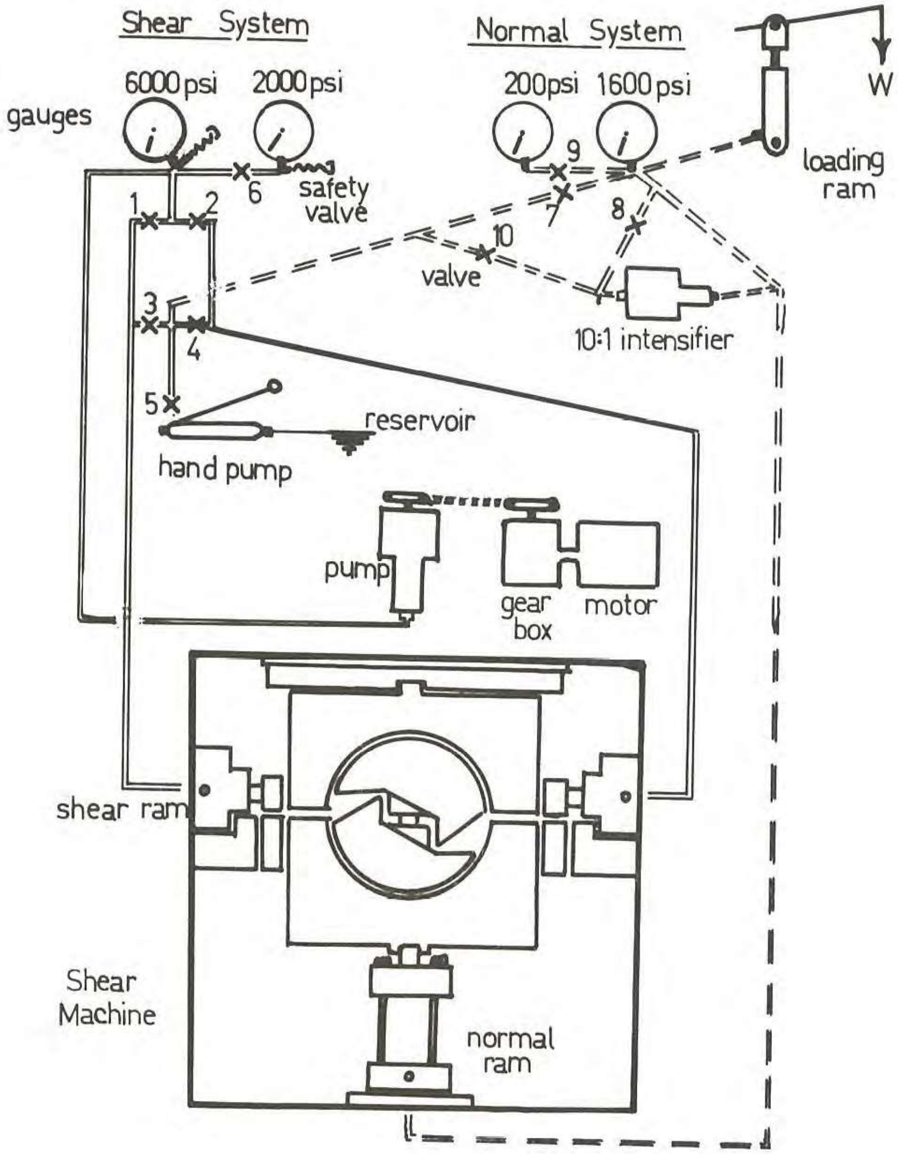

Fig.5 Shear and Normal loading circuits

IV.- CALIBRATION AND TESTING

Calibration was considered necessary because of the large component weight and the friction at the bearings. Samples were prepared of teflon against teflon and of cast iron against brake lining material, as both have relatively consistent frictional properties. It was found that a reduction of 320 lb. to the shear load produced accurate repetitive results. A more complete assessment could probably be achieved by using loadcell devices but this test has not been conducted at this stage.

Testing has been conducted on core provided by King Island Scheelite (1947) Ltd., Western Mining and the M.M.B.W. Both intact and open joints have been tested, and these have shown that the peak and residual shear properties can readily be achieved. A tested joint is shown in Fig.6.

Fig.6 A tested specimen showing joint surfaces.

The reversing procedure will show a different shear resistance if the failure surface is not accurately aligned with the load application. Correction for this error can be applied by averaging the forward and reverse values. An example of the results of two tests is shown in Fig. 7. Of the hornfels rock samples tested, the residual friction depended greatly on the surface properties on the line of failure. For example:- bedding plane joint (smooth, slightly curved surface) -: 40° to 45°.
smooth flat joints -: 38° to 42°.
rough joints -: 45°.

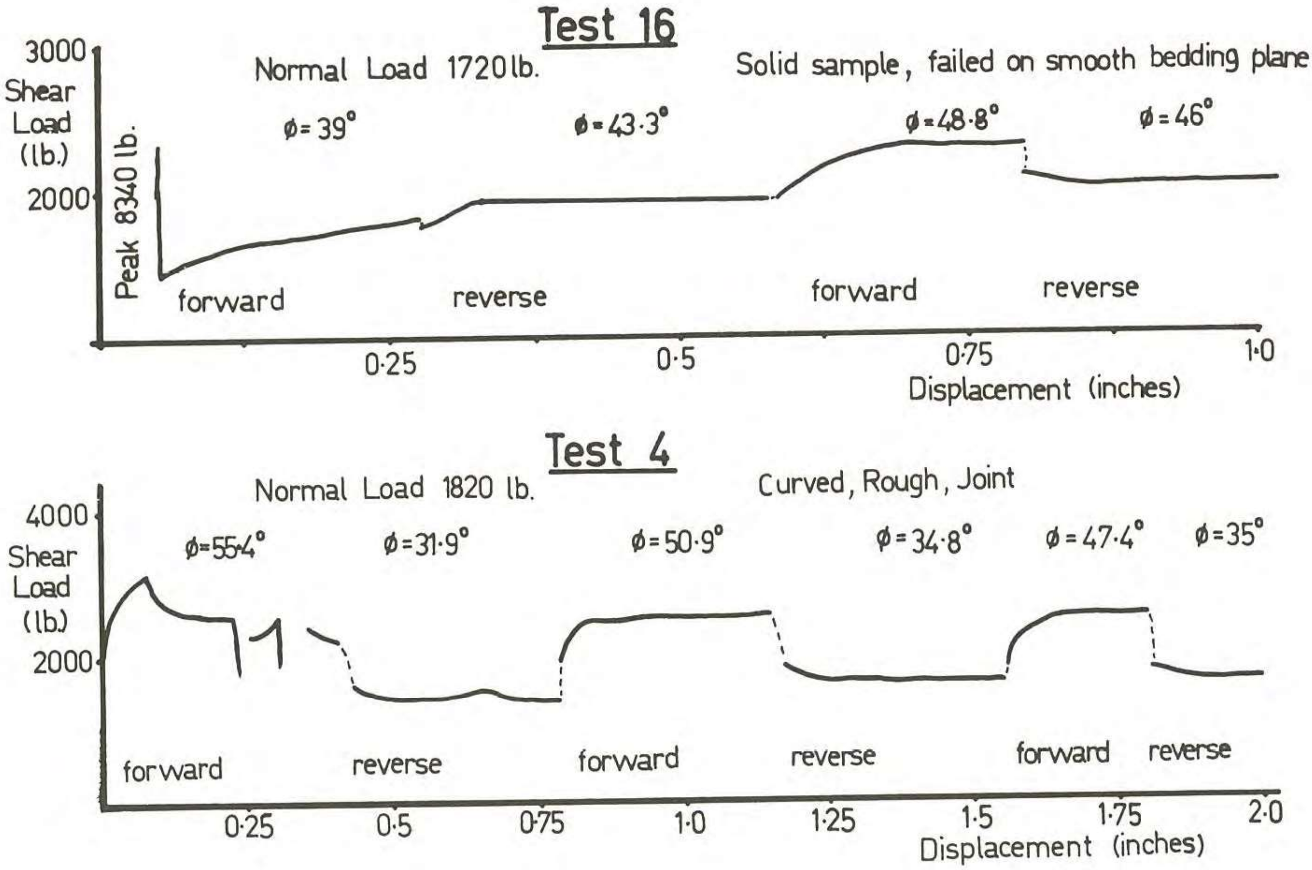

Fig.7 Load-displacement Curves for two tests.

V.- CONCLUSIONS

It is considered that this machine has fulfilled the requirements of providing measurements of peak and residual frictional properties of joints. The design has accomplished a degree of rapidity and versatility not present in other testing machines, allowing core samples from depth to be tested.

VI.- ACKNOWLEDGEMENT

The machine was designed and constructed with considerable aid from the academic and technical staff at the University of Melbourne. In particular, acknowledgement should be made to Messrs. Bamford, Dyson, Lawson and Ogden; and also for the generous assistance provided by King Island Scheelite (1947) Ltd., and the Western Mining Corporation.

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