PSM

LARGE SCALE ROCK MODULUS TEST
LUCAS HEIGHTS, SYDNEY

A large scale rock mass modulus test was performed on the Hawkesbury Sandstone bedrock at the Replacement Research Nuclear Reactor, Lucas Heights, Sydney. Extremely movement-sensitive instruments are to be used within the reactor building. The movement of these instruments was dependent on the stiffness of the foundation bedrock and a test was devised to measure this parameter.

The main difficulty in the assessment of mass modulus lies in the fact that the deformation behaviour of the rock mass is dominated by defects within it.

Small intact specimens of rock (termed the rock substance) will exhibit a significantly larger modulus than the overall rock mass. Therefore any accurate measurement of the mass modulus needs to encompass a sufficiently large volume to include a representative proportion of defects.

The mass modulus of Hawkesbury Sandstone is a parameter seldom measured because even very conservative estimates of this parameter usually give rise to computed settlements well within the acceptable range for most structures.

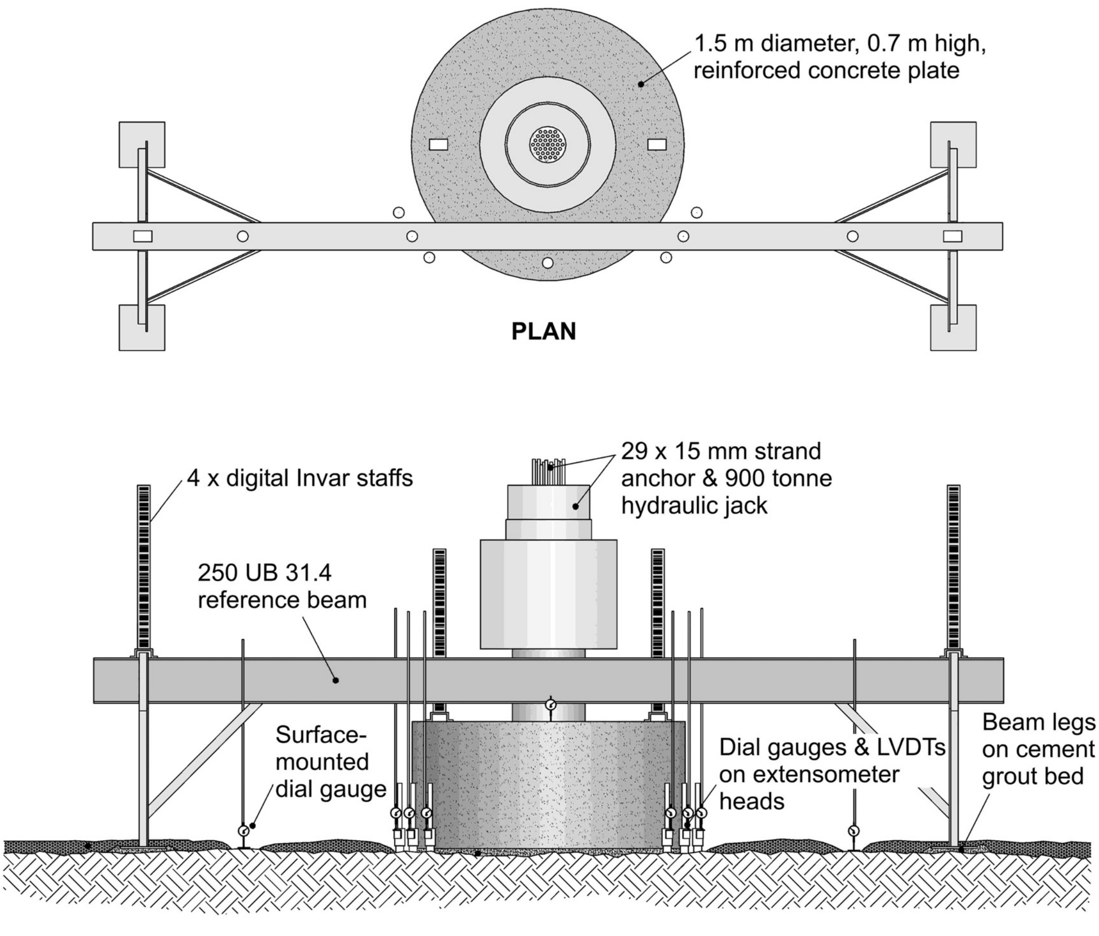

Figure 1 Sketch of test configuration (below ground components not shown).

The test performed is a type of plate bearing test designed to provide a result representative of a large volume of rock. The force on the plate is provided by a cable anchored at shallow depth in the rock. The effect of the anchor being shallow is that the regions of stressed rock beneath the plate and around the anchor bond zone overlap, resulting in a single, large region of stressed rock.

Extensometers were used to measure displacements within the rock mass, in addition to measurement of movement of the plate itself and adjacent ground surface. The special feature of the test undertaken at the reactor site is that very small movements had to be measured accurately to provide confident calculation of a relatively stiff rock mass.

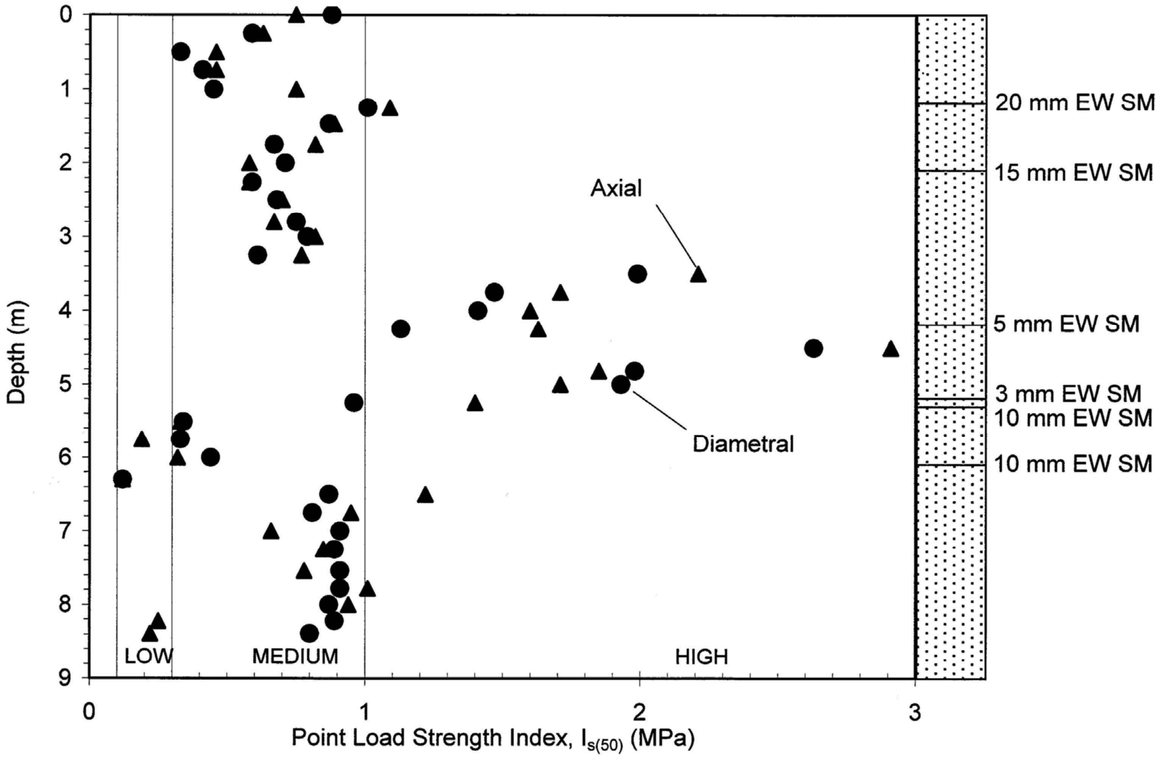

Figure 2 Summary of strength test results and major defects.

Geotechnical boreholes were drilled at the test site. Closely spaced point load testing was performed on the recovered core, as shown in Figure 2. The rock at the test location classifies as borderline between Class II and Class III Sandstone as per the Pells et al (1998) classification system.

The test was designed specifically to allow measurement of rock mass modulus up to a maximum value of 3000 MPa. Initial calculations showed that the maximum movement at a peak load of about 6000 kN would be at the plate itself and would be in the order of 0.9 mm, and would be significantly less at other measurement locations.

Therefore the emphasis in designing the test was on achieving accurate deflection measurements as well as providing sufficient measurement data to achieve a high level of redundancy.

The anchor was designed for a working force of 6000 kN, and was installed inside a 0.20 m diameter hole, 6.9 m deep.

During the test a 900 tonne capacity hydraulic jack was used to stress the anchor.

Figure 3 Positioning of reinforced concrete plate onto prepared ground surface.

A reinforced concrete plate of 1.5 m diameter was used to apply the load to the rock surface. Prior to installing the plate, the rock surface was thoroughly cleaned and a thin bed of levelling compound spread over it.

Immediately prior to lowering the plate onto the prepared bed, a fluid mix of cement grout was poured over the ground (see Figure 3).

Six single point extensometers were installed around the perimeter of the plate within individual boreholes, with anchors positioned at various depths each side of the plate.

A Linearly Variable Displacement Transducer (LVDT) was installed at the top of each extensometer. They were connected to a data logger, with readings recorded every 5 minutes for the two days prior to the test, and every 20 seconds during the test.

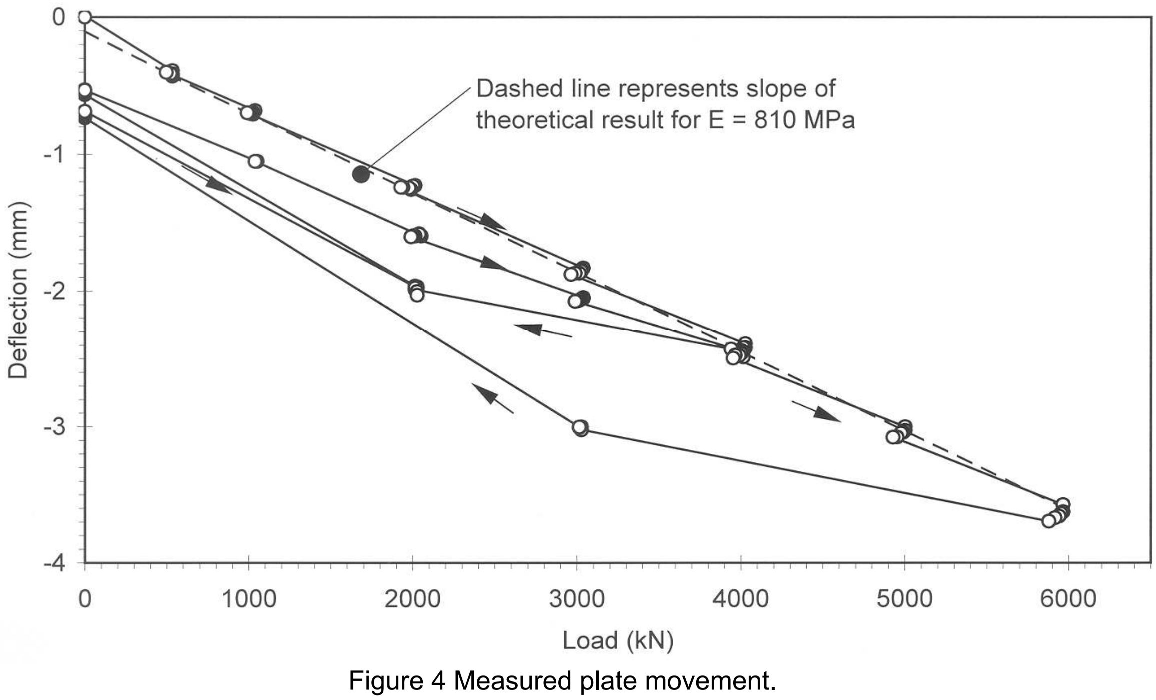

Figure 4 Measured plate movement.

Nine dial gauges were mounted on a steel reference beam as shown in Figure 1. Six of these were used to measure the movement of the extensometer heads.

The plate and reference beam had been enclosed in a 6 m by 6 m tent for a few days prior to the test to reduce temperature variations of the rock mass, steel beam, and extensometers.

The test commenced in the evening to avoid large temperature variations, and finished about 5 hours later.

Taking into account that both differential and absolute displacements could be used for back-figuring the modulus, the test provided some 20 largely independent measurements of the mass modulus.

Numerical modelling of the test configuration was used to back-figure the Young's Modulus of the sandstone bedrock for each measuring point by, in effect, calculating the influence factor for each measurement point.

An example of the vertical movements calculated using FLAC is presented below in Figure 5. This shows downwards movement near the surface, and upwards movement around the anchor bond zone and an effective loaded thickness of about 5 m.

It was concluded that the rock mass modulus at this location ranges from 800 MPa to 1000 MPa, with some indication of increasing stiffness with depth.

The test was located within a fault zone and it is likely that the results reflect poorer quality sandstone than elsewhere within the building footprint. Weathered seams were observed at several depths and it is most probable that these seams are of extremely low strength and are contributing significantly to the overall relatively low mass modulus.

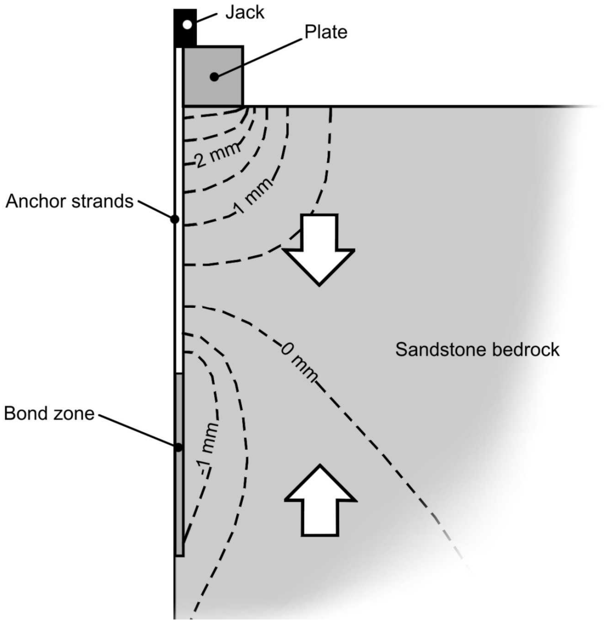

Figure 5 Axisymmetric FLAC model showing calculated vertical movement for a mass modulus of 900 MPa.

Ref. Clarke, S.J., and Pells, P.J.N., "A large scale cable jacking test for rock mass modulus measurement, Lucas Heights, Sydney", *Proceedings of the 9th Australia New Zealand Conference on Geomechanics*, Auckland, February 2004, pp 152 - 158