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RECORD No. 1964/165

MEASUREMENTS OF DYNAMIC ELASTIC CONSTANTS OF ROCK SAMPLES FROM RISDON BROOK DAM SITE,

TASMANIA

by

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SUMMARY

Dynamic elastic constants were measured on rock samples from the foundation site of a proposed dam at Risdon Brook, near Hobart, Tasmania. Results of the measurements and the inter-relations between various parameters are presented. Fracture planes in the samples had a strong disturbing effect on the measurements.

1. INTRODUCTION

On behalf of the Department of Mines, Tasmania, the Geophysical Branch of the Bureau of Mineral Resources, Geology and Geophysics, measured the dynamic elastic constants of six rock samples from the Risdon Brook dam site, near Hobart, Tasmania.

The samples were in the form of diamond-drill cores about 8 in long, five of about 2 in diameter and one of about 3 in diameter. They consisted of pebbly siltstone from the Ferntree Mudstone Formation of Permian age and were of a grey, grey-white, or grey-orange colour with a mottled appearance. There were no obvious bedding planes, but five of the six samples had fracture planes through them, generally with signs of weathering.

Measurements were made on the samples in their oven-dry state and also in their water-saturated, surface dry state. To facilitate the measurements, the end of the samples were cut perpendicular to their length.

2. METHOD

Measurements of the size and weight of a specimen in both its oven-dry state and its water-saturated state enables its density (ρ) and effective porosity (ϕ) to be calculated.

The velocity of propagation of longitudinal elastic waves in an extended medium - the bulk velocity (V_p) - is obtained by using an ultrasonic materials-tester, type UCT2. This equipment measures the transit time of a pulse of longitudinal waves of frequency 120 kc/s through a specimen of known length (L).

The velocity of propagation of longitudinal elastic waves in a slender, cylindrical-bar specimen - the bar velocity (V_b) - is obtained by using an electrodynamic materials-tester, type SCT4. This equipment measures the fundamental resonant frequency of a specimen (f_o) and the width of the response curve (Δf) at 70.7% of the amplitude at the resonant frequency. The bar velocity is given by

$$V_b = 2f_oL$$

The logarithmic decrement (δ) and qualtiy factor (Q) are given by

$$\delta = \pi \Delta f/f_o; \quad Q = f_o/\Delta f = \pi/\delta$$

Knowing V_p, V_b, and ρ, Young's modulus (E) is given by

$$E = cV_b^2 \rho g$$

where c is a constant to adjust for the various units used, and g is the gravitational acceleration.

Poisson's ratio (σ) is found from the expression

$$(V_p/V_b)^2 = (1-\sigma)/(1-2\sigma)(1+\sigma)$$

The bulk modulus (K) is given by

$$K = E/3(1-2\sigma)$$

and the rigidity modulus (G) by

$$G = E/2(1+\sigma)$$

A detailed discussion of the method, theory, and errors is given by Jesson (in preparation).

3. RESULTS

The results of the measurements are shown in Table 1 and the inter-relations of the parameters are shown in Plate 1.

The measurements of bar velocity were rather difficult to repeat because of secondary resonant peaks and because of the displacement of the fundamental resonant peak when a sample was rotated in the clamp. A series of four readings was taken in each case, the sample being rotated 90° in the clamp between each reading. Any extremely divergent values were discarded and an average value of f_0 was adopted. It is thought that the resultant values obtained are representative of the samples tested.

Sample 3, the only one not showing the narrow fracture planes, had good repeat measurements.

Sample 2 broke across one of the weak fracture planes as it was being clamped. The broken sample was too small for a complete set of measurements to be made on it, but the bulk velocity, after breakage, was appreciably higher than for the whole sample (Table 1).

These facts indicate that the weak, weathered, fracture planes are responsible for the difficulty of repeating observations and are probably responsible for some of the spurious secondary resonant peaks.

It is seen from Plate 1 that the correlations between the measured parameters are generally poor, which could possibly indicate low reliability. The correlation between Young's modulus and bar velocity is of little significance because an error in bar velocity will cause a corresponding error in Young's modulus and the value will still lie on the line through the other points. Similarly the correlations of Poisson's ratio with bar velocity and Young's modulus do not necessarily indicate good results; if the measurement of bar velocity is too low for instance, the calculated value of Poisson's ratio will be too high and Young's modulus will be too low, which will tend to keep the points in line. An error in bulk velocity will cause an error in Poisson's ratio for low values of Poisson's ratio (Table 2), but for higher values the error will be much less. Most values of Poisson's ratio are greater than 0.3 and in these cases errors in bulk velocity will probably not be significant.

Although the correlations are poor, some general trends are apparent; for example, the higher values of density correspond to the higher values of Poisson's ratio, and for samples in the saturated state, the higher values of quality factor correspond to the higher values of porosity and possibly to the lower values of Poisson's ratio.

The effects of saturating the samples with water appear to be an increase in bulk velocity and Poisson's ratio and a decrease in bar velocity, Young's modulus, and quality factor.

Table 2, listing maximum errors and factors affecting the observations, has been reproduced with slight modification from a detailed consideration of the subject (Jesson, in preparation). Fracture planes, as found in the Risdon Brook samples, were not considered when the table was prepared; they have a highly variable influence which is virtually impossible to estimate.

4. REFERENCE

JESSON, E.E. — Measurement of dynamic elastic constants of rock samples from Broome, WA. Bur. Min. Resour. Aust. Rec. (in preparation).

TABLE 1 Results

LAB. NO. (SAMPLE NO.)	BORE NO. AND (DEPTH in ft and in)	DENSITY (ρ) g/cm^3	POROSITY (ϕ) %	BULK VELOCITY (V_p) ft/s	BAR VELOCITY (V_b) ft/s	POISSON'S RATIO (σ)	YOUNG'S MODULUS (E) 10^6 lb/in^2	BULK MODULUS (K) 10^6 lb/in^2	RIGIDITY MODULUS (G) 10^6 lb/in^2	LOG DECREMENT (δ)	QUALITY FACTOR (Q)	SAMPLE CONDITION	BEDDING.
1472	4	2.26	15+	12,100	10,300	0.31	3.2	2.8	1.2	0.39	8	DRY	No bedding planes visible. A few fracture planes at about 90° to core axis.
(1)	(1')	2.37	11	12,450	9,300	0.37	2.8	3.7	1.0	0.22	14	SATURATED	
1473	4	2.34	12+	12,300°	9,100	0.37	2.6	3.4	0.9	0.18	17	DRY	As above.
(2)	(71' 3")	2.44	10.5	13,200°	11,000*	0.32*	4.0*	3.8*	1.5*	-	-	SATURATED	
1474	3	2.20	17+	12,070	11,330	0.22	3.8	2.2	1.6	0.12	27	DRY	No bedding or facture planes visible.
(3)	(14' 5")	2.35	15	12,100	10,450	0.30	3.5	2.9	1.3	0.15	21	SATURATED	
1475	3	2.29	13.5+	13,300	12,750	0.19	5.0	2.7	2.1	0.10	33	DRY	As sample 1.
(4)	(80' 3")	2.41	12.5	13,400	10,820	0.34	3.8	4.0	1.4	0.18	17	SATURATED	
1476	2	2.38	10.5+	13,550	9,290	0.40	2.8	4.6	1.0	0.15	21	DRY	No bedding planes visible. A few fracture planes between 15° and 85° to core axis.
(5)	(11' 10")	2.47	9	14,100	8,860	0.42	2.6	5.4	0.9	0.18	17	SATURATED	
1477	2	2.44	8+	12,750	10,670	0.32	3.7	3.4	1.4	0.10	33	DRY	As sample 1.
(6)	(54' 2")	2.52	8	13,200	9,700	0.38	3.2	4.5	1.2	0.26	12	SATURATED	

REMARKS

+ porosity calculated from dry weight assuming a matrix density of 2.65 g/cm^3; other porosity values from wet and dry weights.

o V_p (dry & sat.) = 13,900 ft/s after sample broken; sample too small for complete set of measurements.

* values taken from incomplete set of measurements; less reliable than for other samples.

TABLE 2 Maximum errors and factors affecting the observations

PARAMETER	MAXIMUM ERROR %	CONDITIONS FOR MAXIMUM ERROR	REMARKS
Length (L)	± 0.2	short sample	The sample should have been carefully cut and should be undamaged. If not, all the measured and derived parameters may be affected.
Radius (a)	± 0.8	small diameter	
Density (ρ)	± 2.8	small, high-porosity sample in its saturated state.	If the pores are not fully interconnected, the dry and saturated states may not be fully reached. The actual density and effective porosity will be measured rather than the true values.
Porosity (ϕ)	± 7.0	small, high-porosity sample	
Longitudinal bulk velocity (V_p)	± 2.2 for samples with V_p = 20,000 ft/s	short, high-velocity sample	Sample must be large enough to ensure V_p is being measured. Grease couplant should be used.
Longitudinal bar velocity (V_b)	+ 3.7	short sample	A non-isotropic sample may have velocities dependent on the direction of propogation. Orientation of any bedding in the sample should be noted. This will also affect the parameters derived from V_p and V_b.
Logarithmic decrement (δ)	+ 50	Influence of outside effects. These parameters seem to be very uncertain.	Grease couplant should not be used when making these measurements. Better values will be obtained for small samples if they are supported on rubberised horse-hair. The pressure of the transducers on the samples should be as small as possible consistent with obtaining readings.
Quality factor (Q)	- 50		
Young's modulus (E)	+ 10.2	as for ρ and V_b	The factors affecting ρ and V_b also apply here.
Poisson's ratio (σ)	very large for small σ -45% for σ = 0.2 -14% for σ = 0.3 - 3% for σ = 0.4	as for V_p and V_b, particularly for low values of σ when V_b is very close to V_p.	The general range of values for Risdon Brook is 0.3 to 0.4.
Bulk modulus (K)	-32% for σ = 0.1 -17% for σ = 0.2 - 9% for σ = 0.3 - 3% for σ = 0.4	These values are influenced by σ and have large errors for low values of σ. Also dependent on E.	
Rigidity modulus (G)	+52% for σ = 0.1 +19% for σ = 0.2 +12% for σ = 0.3 +11% for σ = 0.4		

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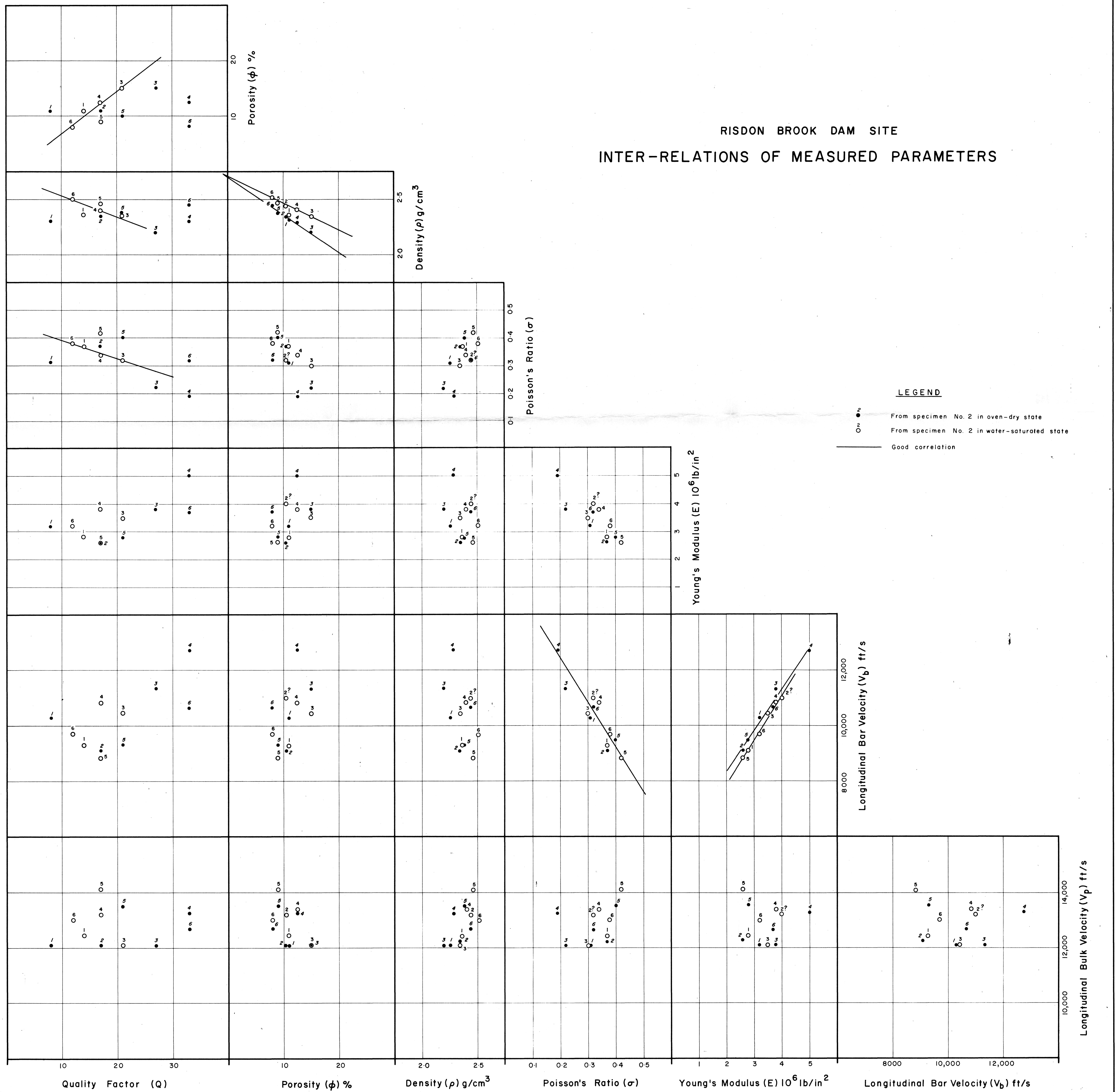
RISDON BROOK DAM SITE

INTER-RELATIONS OF MEASURED PARAMETERS



(BASED ON G16-33)

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics K55/B5-69

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