

Determination of the moduli of elasticity of rocks. Comparison of the ultrasonic velocity and mechanical resonance frequency methods with direct static methods

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In the present investigation, dynamic methods for the determination of moduli of elasticity were compared with direct static methods. The dynamic moduli of rocks, such as Young's modulus (E) and Poisson's ratio (ν) were determined, using both mechanical resonance frequency and classic P and S wave ultrasonic velocity techniques. For this purpose rock samples from different areas of France, covering a wide range of velocity values, were used. The mechanical resonance frequencies were investigated using a Grindo-Sonic machine while the P and S wave ultrasonic velocities were measured using a Pundit ultrasonic machine, connected to an oscilloscope. The static moduli were determined using deformation gauges. Statistical interpretation of the test results indicated significant correlation between these dynamic and static methods. Accordingly, the above non-destructive dynamic methods are suitable for the determination of static moduli of elasticity.

1. INTRODUCTION

Moduli of elasticity, used to express the deformability of rocks, may be obtained by dynamic methods in addition to static compression or shear tests. Dynamic moduli of elasticity are obtained by the rapid application of stress to the sample. In the present investigation, two different dynamic methods were used to provide data comparable with those obtained using ordinary static methods. The first dynamic method uses P and S wave ultrasonic velocity measurements, along core specimens, while the second uses the excitation and detection of mechanical resonance frequencies in small cylindrical or prismatic specimens. The same rocks were also tested to determine their static moduli of elasticity. A direct compressional technique is used for this purpose. Small deformation gauges, attached both horizontally and vertically to the specimen axis, provide the deformation data. The test results were compared statistically with each other, using regression methods to verify the static moduli using dynamic, non-destructive techniques. These dynamic methods (instead of the direct static ones) are simple and preserve the specimens.

2. STATIC ELASTIC MODULI

Deformation data may be obtained for specimens undergoing strength tests and used to calculate the static moduli of elasticity of intact rock. The modulus of elasticity (E , or Young's modulus) and Poisson's ratio (ν) are the most commonly used. The modulus of

elasticity, which is derived from a form of Hooke's law, is obtained from the applied axial compressive stresses and the resulting axial strains. Poisson's ratio is calculated from the axial and diametral strains resulting from applied axial compressive stresses.

They are both useful in estimating the elastic response of intact rock to compression from *in situ* construction and post-construction stresses. Abutment stresses in a dam or those exerted against the rock by water-pressure tunnels are examples of post-construction stresses. The values for the modulus E may be obtained from stress-strain diagrams. Between the average modulus, tangent modulus and secant modulus, referred to in the literature, the last mentioned is the most common, predicting the maximum elastic deformation that would occur at 50% of ultimate strength [1].

3. DYNAMIC MODULI OF ELASTICITY

3.1 Ultrasonic velocity tests

The modulus of elasticity E_d , and Poisson's ratio ν_d may be obtained by dynamic methods, as well as by static compression tests. One common dynamic method for determining moduli is to subject the rock sample to compression and shear wave pulses. Compression and shear wave transducers are attached to the ends of the core specimen for this purpose. Wave velocity is calculated from the travel time of the pulse through the specimen. Samples may be loaded to approximately field conditions because both P and S wave responses increase