Chapter 8
Lesson 12
Laboratory Testing of Intact Rocks

FHWA NHI Subsurface Investigations
Why Test Rock?
Objectives: Lab Testing of Rock

- Recognize why and when to test intact rock
- Locate & review standard lab testing procedures for indexing parameters of strength, stiffness, and durability.
- Select representative specimens for testing
- Recognize importance of QA/QC for mitigating common errors during lab testing of intact rock.
Laboratory Testing of Rocks

- Index testing of intact rock materials for identification & classification.
- Strength and stiffness characteristics
- Degradation potential; Durability
- Used in assessing the overall Rock Mass
- Purposes of Construction: rockfill, cuts, slopes, foundations, tunnels
Rock Core Specimens

FIG.8-0

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Index Testing of Intact Rocks

- **Unit weight**, \( \gamma_R = \text{Weight/Volume} \)
- **Ultrasonics Velocities**
- **Strength**
  - Point Load Index
  - Swiss Hammer (Schmidt Hammer)
  - Uniaxial Compressive Strength
Ultrasonics Testing

- Determine compression (P-wave) and shear (S-wave) velocities of rock core
- Nondestructive measurements
- Fast and inexpensive
- Evaluation of small-strain elastic stiffness (strains < $10^{-6}$ mm/mm)
- May be used to evaluate anisotropy

FIG.8-7
Lab Ultrasonics Testing of Rocks

FIG. 8-7

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Uniaxial Compression Test

GCTS Device

ARA Setup at Tyndall AFB, Florida
Uniaxial Compression Test

State of stress in the middle part of the sample:
\[ \sigma_1 = \sigma, \quad \sigma_2 = \sigma_3 = 0 \]

Specimen strains:
\[ \varepsilon_{\text{axial}} = \frac{\Delta H}{H}, \quad \varepsilon_{\text{radial}} = \frac{\Delta D}{D} \]

Fig. 8-2

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Uniaxial Compressive Strength

- Standard index property \( q_u = \sigma_u = \sigma_c \)
- Analogous tests in concrete and soil (unconfined compression test).
- ASTM 4543 procedures.
- Planar ends on NQ size core (\( d = 47.6 \text{ mm} \))
- Length-to-width ratio: \( 2 < H/d < 2.5 \)
- Axial loading of cylindrical core specimen
- \( \sigma_u = \text{Max. Force}/(\pi d^2/4) \)
Swiss Hammer (Schmidt Hammer)
Point Load Index

- Quick evaluation for uniaxial strength (field or lab setup)
- ASTM D 5731 procedures
- Little sample preparation (cores, pieces)
- Measure force (P) to crunch intact rock specimen
- Point Load Index: \( I_s = \frac{P}{d_e^2} \) where \( d_e \) = equivalent core diameter

Fig.8-1
Point Load Index

GCTS Device

Roctest Equipment

Fig. 8-1

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Triaxial Compression (ASTM D 2664)

Computerized Compression Frame

Rock Triaxial Cell

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Deformation Parameters of Intact Rocks

(a) Tangent Modulus Measured at a Fixed Percentage of Ultimate Strength

(b) Average Modulus of Linear Portion of Axial Stress-Strain Curve

Elastic Modulus from Uniaxial and/or Triaxial Compression

Fig. 8-6
Tensile Strength \((T_0)\) of Rocks

- Direct tensile strength (ASTM D 2936) is difficult because of end effects.
- Generally replaced by indirect (Brazilian) split-tension test (ASTM D 3967).
- Length-to-diameter ratios: \(2 < H/d < 2.5\)
- Diametrical compression of rock core specimens across
Brazilian Split-Tension Test on Rock

\[ \sigma_T = \frac{2P}{\pi LD} \]

Fig. 8-3
Direct Shear Testing of Rock Specimens (ASTM D 5607)

Fig. 8-4
Direct Shear Testing of Rock Specimens (ASTM D 5607)

Roctest Equipment, Montreal

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Durability of Rock Materials

- Longevity of the materials for use in construction (fill, backfill, rockfill)
- Will the rock deterioriate when exposed to the elements, time, freeze-thaw, wet-dry cycles, temperatures, chemicals.
- Tests used to accelerate exposure (slake durability, LA abrasion, freeze-thaw).

Section 8.2.2.
Slake Durability Test of Rocks

- Evaluate shales and weak rocks that may degrade in service environment.
- Rock fragments of known weight placed in rotating drum apparatus (ASTM D 4644).
- Materials are circulated through wet & dry cycles.
- Reweigh rock fragments to determine the Slake Durability Index (SDI).

Fig. 8-5.
Slake Durability Test

- Select representative rock sample consisting of 10 lumps each of 40-60g, roughly spherical in shape with corners rounded during preparation. The sample is placed in the test drum of 2 mm standard mesh cylinder of 100 mm long and 140 mm in diameter with solid removable lid and fixed base, and is dried to a constant mass at 105°C. The mass of drum and sample is recorded (Mass A). The sample and drum is placed in trough which is filled with slaking fluid, usually tap water at 20°C, to a level 20 mm below the drum axis, and the drum is rotated at 20 rpm for 10 minutes. The drum and sample are removed from trough and oven dried to a constant mass at 105°C without the lid. The mass of the drum and sample is recorded after cooling (Mass B). The slaking and drying process is repeated and the mass of the drum and sample is recorded (Mass C). The drum is brushed clean and its mass is recorded (Mass D).

- The slake-durability index is taken as the percentage ratio of final to initial dry sample masses after to cycles,

- Slake-durability index, \( I_{d2} = \frac{(C-D)}{(A-D)} \times 100\% \)

- The first cycle slake-durability index should be calculated when \( I_{d2} \) is 0-10%,

- Slake-durability index, \( I_{d1} = \frac{(B-D)}{(A-D)} \times 100\% \)

<table>
<thead>
<tr>
<th>Slake Durability Index</th>
<th>( I_{d2} ) (%)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 25</td>
<td></td>
<td>Very low</td>
</tr>
<tr>
<td>25 – 50</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>50 – 75</td>
<td></td>
<td>Medium</td>
</tr>
<tr>
<td>75 – 90</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>90 – 95</td>
<td></td>
<td>Very high</td>
</tr>
<tr>
<td>95 – 100</td>
<td></td>
<td>Extremely high</td>
</tr>
</tbody>
</table>
Abrasion resistance test:

Sample weight 5 kg, specific size gradation specific number of steel spheres, interior projecting shelf, 500 revolutions, then use #12 sieve with \( d = 0.141 \) mm.

Percent loss = \( \frac{\text{material finer than #12 sieve}}{\text{original weight}} \)

For highway construction, we need percent loss less than 35 – 50 \%. 
Common Sense Lab Testing of Rocks

- Clear identification of samples & specimens
- Avoid moisture loss
- Prevent physical damage to samples
- Consult field records during specimen selection
- Maintain equipment in good working order
- Photo documentation of test specimens
- Careful alignment of axes for measurement by dial gages, load cells, and displacement transducers
- Save remnant pieces of rock after testing.

Table 8-2
Objectives: Lab Testing of Rock

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5.5 Uniaxial Compressive Strength (UCS)

**UCS Strength** $\sigma = \frac{P_{\text{max}}}{A_o}$
5.4 Brazilian (Indirect Tensile Strength) Test

Apparatus for Brazilian test

Brazilian Compressive Strength $\sigma_c = \frac{P}{D \times t}$

Indirect Tensile Strength $\sigma_t = 0.636\frac{P}{D \times t}$
5.3 Point Load Test

- **Point Load Tester**

**Diametral Test**
- Sample Size and Equivalent Core Diameter \((D_e)\)
  - \(L > 0.5D\)
  - \(D_e = D\)

**Axial Test**
- Sample Size and Equivalent Core Diameter \((D_e)\)
  - \(0.3L < D < L\)
  - \(D_e = (4DL/\pi)^{1/2}\)

**Point Load Index;** \(I_s = P/D^2\)

**Point Load Index Strength;** \(I_{s(50)} = I_s \times (D_e/50)^{0.45}\)

Value is given in MPa