



# Standard Test Method for Laboratory Determination of Abrasiveness of Rock Using the CERCHAR Method<sup>1</sup>

This standard is issued under the fixed designation D7625; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the abrasiveness of rock by the CERCHAR Abrasiveness Index (CAI) method. The test method consists of measuring the wear on the tip of steel stylus with a cone shape and known Rockwell Hardness, caused by scratching against a freshly broken or saw cut rock surface for a prescribed 10 mm distance using one of the two test apparatus.

1.2 This test method is intended for freshly broken rock surfaces; however, saw cut surfaces are covered for when a satisfactory rock surface cannot be obtained.

1.3 Stylus Rockwell Hardness (HRC) can have a profound effect on the results and the focus of this test method is an HRC value of 55 for every test (1,2).<sup>2</sup> However, there are situations where stylus with different Rockwell Hardness can be used. Therefore, this test method includes discussions on stylus with different Rockwell Hardness.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics. Current edition approved May 15, 2010. Published July 2010. DOI: 10.1520/D7625-10.

<sup>2</sup> The bold numbers in parenthesis refer to a list of references at the end of this standard.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- D653 Terminology Relating to Soil, Rock, and Contained Fluids
- D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
- D5079 Practices for Preserving and Transporting Rock Core Samples
- D6026 Practice for Using Significant Digits in Geotechnical Data
- E18 Test Methods for Rockwell Hardness of Metallic Materials

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology D653.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *abrasiveness, n*—the wear or loss of material which the rock produces on contact with another material such as TBM cutter or drill bit.

3.2.2 *Rockwell Hardness Scale (HRC), n*—a hardness scale based on the indentation hardness of a material, which correlates linearly with its tensile strength. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. The results, as a dimensionless number, are noted by HR followed by the designation letter from A-F based upon used scale. For current standard, letter C is used as the scale letter for hard steel.

## 4. Summary of Test Method

4.1 A steel stylus having a 90E conical tip with its axis perpendicular, and in contact with a rock surface, under a total constant force of 70 N, is scratched in a direction parallel to the rock surface over a distance of 10 mm.

4.2 Basically, the CERCHAR test is a measurement of the relative different hardness of stylus tip and rock specimen surface. The stylus tip is made of steel having a known Rockwell Hardness. Experiments have shown that CAI varies inversely with stylus hardness. Test results with the same steel

type stylus but with different hardness need to be normalized to standard stylus hardness (3).

4.3 After the test, width of the wear flatness is measured on stylus tip surface in units of 0.1 mm and number of units reported as the CERCHAR Abrasiveness Index, 0.1mm (= 1CAI).

4.4 The scratch distance shall be limited to 10 mm. A CAI of 85 % is achieved after the first 2 mm of the scratch's length, and 15 % of the change in CAI is achieved on the last 8 mm of the testing length. Deviations in CAI due to variations of scratch length shall not be significant when the variation in testing length is kept between  $\pm 0.5$  mm in length (1).

4.5 Five individual CAI tests shall be conducted for each rock specimen to achieve a defined average value (1). If there is not any obvious preference, for example, different colors, beddings, foliations on specimen, a set of three parallel tests in one direction, and two more perpendicular to first set shall be done.

### 5. Significance and Use

5.1 The CERCHAR test and associated CAI were developed at a time of more demand for application of mechanical excavation machines at the Laboratoire du Center d' Études et Recherches des Charbonnages de France (CERCHAR) (4). CAI is used to assess the abrasiveness of rock for mechanical excavation. Rock abrasiveness governs the performance of disc cutters, the rate of its replacement and therefore subsequent tunnel costs. Advances in methods of underground excavation, in particular the use of the tunnel boring machine (TBM), necessitates knowledge of rock abrasiveness. Abrasiveness expresses a behavioral characteristic of rock rather than a fundamental physical or mechanical property.

5.2 CAI tests were originally carried out on natural broken surfaces. In heterogeneous rock types such as conglomerates, coarse grained granite or schistose rock, suitable fresh test surfaces are not achieved by mechanical breakage using a hammer. In these cases CAI values for "smooth" surfaces cut

with a diamond saw are acceptable for use but shall be normalized by Eq 2 before they can be used (1).

5.3 The test velocity for the Original Cerchar apparatus is approximately 10 mm/s and 1 mm/s for the West Cerchar apparatus. The CAI values obtained for both testing velocities (1) are estimated to be equal.

NOTE 1—The quality of the result produced by these practices is dependent upon the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing and sampling. Users of these practices are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

### 6. Apparatus

6.1 CERCHAR Apparatus—Two types of Cerchar apparatus (1) are in use today (See Fig. 1). Both devices employ a vice to clamp the specimen and a constant force of 70 N acting axially on a stylus tip when placed against the test surface. The original apparatus employs a manually operated hand lever to displace the stylus tip on the stationary rock surface held fixed in place by a vice. The West apparatus displaces the vice holding the rock by use of a hand crank and driving screw under a stationary stylus.

6.2 Stylus—As mentioned in the Scope, CERCHAR test is a measurement of the relative different hardness between the stylus tip and rock specimen surface. The stylus tip shall be made of steel having a known Rockwell Hardness. Experiments have shown that CAI varies inversely with steel hardness. Test results with the same steel type stylus but with different hardness should be normalized to standard stylus hardness (3). The use of stylus hardened to 55 HRC (1,2), and conforming to Test Methods E18 is advised. The length and diameter of stylus shall be greater than 15 mm and 10 mm respectively, and have a sharpened profile at one end to a conical angle of 90°, and 1 mm in length.

6.3 Mass—The static mass for either test apparatus shall be appropriately sized and configured so that the total force of 70

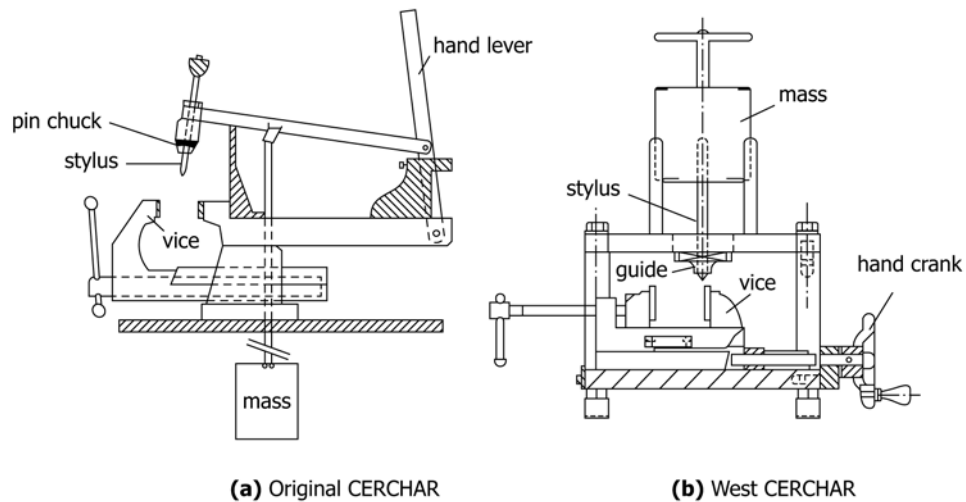


FIG. 1 Illustrations of Two Types of CERCHAR Testing Apparatuses

N, including any other components which would contribute any force to the stylus tip during testing. This force shall act axially on the stylus tip in contact with the specimen surface all the time during the test.

6.4 *Vice*—The vice in Fig. 1a shall be of sufficient rigidity, such that the clamped specimen is immobilized during the test. The vice in Fig. 1b holds the specimen and moves under the stylus by using the hand crank that advances the driving screw. Small wooden wedges may be used to ensure tightness of fit. Also, the vice shall have precise control of movement in two horizontal planes, with accurate positioning and change of position of the specimen with a secure hold.

6.5 *Resting Support*—a mechanism or configuration to hold the mass and stylus in a stationary position above the test surface location while setting up and removing the test specimen. The original Cerchar uses a resting support to place the lever arm on and the West Cerchar apparatus has a set of lock screws to grip onto the static mass.

6.6 *Hand Lever*—The articulated hand lever arm shall be of sufficient stiffness to displace the stylus over the rock surface allowing unrestrained vertical displacement of the stylus under the total force of 70 N (Fig. 1a).

6.7 *Hand Crank*—The hand crank screw-feed attached to the vice and powered manually with a crank displaces the vice holding a specimen under the stationary stylus. The screw-feed thread shall be machined such that displacement of the rock surface occurs at a constant displacement per revolution under the stationary stylus while allowing unrestrained vertical displacement of the stylus under the total force of 70 N (Fig. 1b).

6.8 *Microscope*—A toolmaker’s microscope equipped with digital micrometer heads, XY stage and LCD readout are recommended. The microscope shall have a minimum magnification of 30X. The XY stage micrometer heads shall have a minimum range of 50 mm graduated to 0.01 mm and readable to 0.001 mm (4). Fig. 2 shows one example of this microscope with a stylus tip positioned under it, during flatness measurements.

6.9 *Grinder*—An apparatus that uses an abrasive stone wheel that is rotated and when place in contact with softer material removes material from that surface without appreciable wear to the stone wheel, or other suitable metal work apparatus, capable of shaping metal pen stock or sharpening the end of the stylus according to desired geometry. Cooling of the surface being ground by some type of fluid may be required in order not to heat up the metal excessively and change the original Rockwell hardness of the metal being used for the stylus.

6.10 *Miscellaneous*—Machinist’s blue dye, wood shims, timer.

## 7. Sampling and Test Specimens

7.1 The specimen shall be selected from the core sample or pieces of in situ rock to represent a true average of the type of rocks to be drilled or bored. This can be achieved on a large scale by viewing rock types encountered at the project and on a smaller scale by visual observations of mineral constituents,



FIG. 2 Toolmaker’s Microscope

grain sizes and shape, partings, and defects such as pores and fissures. Core or irregular shape specimens with a typical diameter or length of approximately 50 mm are recommended.

7.2 The moisture conditions of the specimen at the time of test can have a significant effect upon the indicated strength of the rock. The field moisture condition for the specimen shall be preserved until the time of test in accordance with Practices D5079. This may be problematic when saw cut or drilled rock surfaces that need a water coolant are used instead of natural rock surfaces.

7.3 Specimens displaying apparent anisotropic features such as bedding or schistosity shall be prepared so that the orientation of the CAI test surface relative to anisotropic features can be determined precisely.

7.4 Specimen test surface shall be either fresh flat natural surface or saw cut one. For saw cut surface, specimen surfaces shall be prepared by cutting the rock sample with a water cooled diamond saw blade to expose fresh specimen surfaces provided the resulting surfaces are reasonably planar.

7.5 The specimen test surface should be of sufficient length such that edge chipping within the 10 mm test path does not occur as the stylus approaches the specimen outer dimension.

7.6 Specimens with either natural or saw cut test surfaces shall be trimmed to fit in the CERCHAR test machine by cutting the rock sample with a water cooled diamond saw blade.

7.7 Before and after photographs shall be taken of tested surfaces.

## 8. Preparation of Apparatus

8.1 The stylus shall be in good condition and verified under a microscope before use.

8.2 If stylus is not in good condition or previously used, then prior to testing, stylus tip shall be sharpened to the prescribed shape and condition described in 6.2. Special care shall be taken when re-sharpening used styli. High temperatures induced from sharpening too quickly can influence the styli hardness. Therefore application of a water coolant during re-sharpening process is recommended.

8.3 Regularly re-examining of stylus hardness is advised; Rockwell Hardness of stylus shall be 55.

8.4 Rockwell Hardness of stylus shall be verified in accordance with Test Methods E18.

8.5 Prior to testing, coating of each stylus tip with machinist's blue dye makes the wear flat area of the tip more visible under the microscope, and also helps to differentiate ready for test styli from used ones.

## 9. Procedure

9.1 Orient and securely clamp the test specimen in the vice such that the test surface is horizontal and parallel to the direction of displacement with the stylus. If necessary, use wood or other suitable materials between the vice and specimen surface to assist clamping and orienting the specimen.

9.2 The stylus and associated components are lowered with care to bear on the specimen test surface so that the stylus tip is not damaged before testing.

9.3 The static mass and any associated components are positioned and checked for functionality ensuring there are no frictional impediments to the specified 70 N total force.

9.4 Two scratching velocities are used depending on which device is available. A scratching distance of 10 mm is used for both devices.

9.4.1 The articulated hand lever is pulled over the test surface with a stylus scratching speed (1) of approximately 10 mm/s (Fig. 1a).

9.4.2 The hand crank is turned at a rate consistent with the number of threads on the screw-feed for moving the specimen surface under the stylus with a scratching speed of approximately 1 mm/s (Fig. 1b) (1).

9.5 Carefully lift the stylus, with it associated components, off the test surface and secure in the at rest position.

9.6 The tested stylus is taken off the apparatus and two perpendicular diameters of the abraded flat area of the stylus are measured under a microscope in 0.1 mm increments and recorded based on the observations and suggested action noted in Fig. 3.

9.7 The test is repeated 5 times, each time with a new/refurbished stylus on a new scratch location of the rock surface (see 4.4 and 4.5).

9.8 Where the results are sensitive to water content, it may be necessary to determine the actual water content of the specimen at the time of testing. Water content may be determined in accordance with Test Methods D2216.

## 10. Calculation or Interpretation of Results

10.1 The arithmetic average width of the wear flat of the stylus tip  $d_i$  (two perpendicular diameters of the abraded flat area for each of five used stylus), measured in units of 0.1 mm is reported as the CAI or  $CAI_s$  value, using Eq 1 (1):

$$CAI \text{ or } CAI_s = \frac{1}{10} \sum_{i=1}^{10} d_i \quad (1)$$

where:

$CAI$  or  $CAI_s$  = CERCHAR index for natural or saw cut surface respectively and  $d_i$  is diameter of the abraded flat area measured in units of 0.1 mm.

10.2 If saw cut specimen is tested, then calculated  $CAI_s$  of Eq 1, it is advised to be normalized using Eq 2 (1):

$$CAI = 0.99CAI_s + 0.48 \quad (2)$$

where:

$CAI$  = CERCHAR index for natural surface, and  
 $CAI_s$  = CERCHAR index for smooth (saw cut) surface from Eq 1.

10.3 The arithmetic average of CAI for each specimen shall be calculated and reported.

10.4 The CAI classification shall be determined from Table 1 based on the stylus tip Rockwell Hardness.

## 11. Report

11.1 Report the following information:

11.1.1 Sources of the specimen including project name and location, and if known, storage environment. The location is frequently specified in terms of the borehole number and depth of specimen from collar of hole. Specimens are frequently logged by chainage referenced to a benchmark.

11.1.2 Physical description of the specimen including fresh broken or saw cut rock surface, rock type, location and orientation of apparent weakness planes, bedding planes, and schistosity; large inclusions or in homogeneities, if any.

11.1.3 Sampling and testing dates, and name(s) of testing personnel.

11.1.4 As a minimum, a general indication of the moisture condition of test specimens at the time of testing, such as saturated, as received, laboratory air dry, or oven dry.

11.1.5 Direction of stylus displacement (parallel to or normal to plane of weakness or anisotropy directions, if any).

11.1.6 The number of specimens tested.

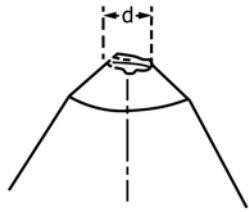
11.1.7 The stylus Rockwell Hardness, tip shape.

11.1.8 The calculated uncorrected, average, and corrected CAI values.

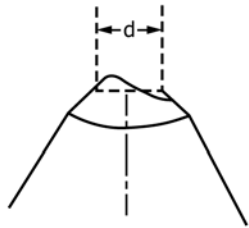
11.1.9 The CERCHAR apparatus type shall be recorded.

11.1.10 The specimen classification of abrasiveness based on Table 1.





(a) Normal wear:  
 $d = 0.1 \text{ mm}$   
 C.A.I. = 1



(b) Non-symmetrical wear:  
 measurements still possible as an  
 average of the values in two sides.



(c) Very rough surface of the test sample.  
 Measurement of such a pin should be in-  
 correct. A remake of the test is suitable.

FIG. 3 Sketch of Abraded Shape of Extremity of Stylus After Testing Under a Microscope (5)

TABLE 1 Criteria for the CERCHAR Abrasiveness Index

| Classification        | Average CAI (3) (HRC=55) | Average CAI (2) (HRC=40) |
|-----------------------|--------------------------|--------------------------|
| Very low abrasiveness | 0.30–0.50                | 0.32–0.66                |
| Low abrasiveness      | 0.50–1.00                | 0.66–1.51                |
| Medium abrasiveness   | 1.00–2.00                | 1.51–3.22                |
| High abrasiveness     | 2.00–4.00                | 3.22–6.62                |
| Extreme abrasiveness  | 4.00–6.00                | 6.62–10.03               |
| Quartzitic            | 6.0–7.0                  | N/A                      |

## 12. Precision and Bias

12.1 *Precision*—Test data on precision is not presented as it is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program.

12.2 The Subcommittee D18.12 is seeking any data from the users of this test method that might be used to make a limited statement on precision. Extensive preliminary data presented by others can be found in Ref. (2).

12.3 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

## 13. Keywords

13.1 abrasiveness; abrasivity; CERCHAR; disk cutter; mechanical excavation; Rockwell Hardness; TBM

## REFERENCES

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- (3) Sanford, Julian and Hagan, Paul. “An Assessment of the impact of stylus metallurgy on the CERCHAR Abrasiveness Index value,” Coal operators’ conference, University of Wollongong, 12-13 Feb. 2009, pp. 347-355.
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- (5) ROCTEST Limited. “The CERCHAR ABRASIVENESS INDEX,” Geotechnical and Structural Instrumentation and Techniques, Montreal, Canada, 13 October 1986, 12p.

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