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Technical Note

# Testing conditions and geomechanical properties influencing the CERCHAR abrasiveness index (CAI) value

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## 1. Introduction

In Western Europe the CERCHAR scratch test is one of the most common testing procedures used for laboratory assessment of hardrock abrasivity. It is conducted with reference to the original testing recommendation by the French CERCHAR institute [1], it features a steel needle of a specified shape and quality that is scratched over 10 mm of the specimen's broken surface. The CERCHAR abrasiveness index (CAI) is then calculated as a mean value of 2–5 individual tests from the needle wear flat diameter.

This technical note is intended to complete the note presented in the IJRMMS by West in 1989 [2] and presents some recent findings on geological factors and testing conditions influencing the CERCHAR scratch test and the CAI. It is based on a study at TU Munich and includes the records of 109 rock types [3–5]. This paper emphasizes the use of the original steel quality for the testing needles and recommends five individual tests for every rock sample. A detailed evaluation of the needle wear flat should be made by microscopic analysis. Sample preparation with diamond rock saws is recommended for inhomogeneous rock types to achieve even rock surfaces. These values can then be compared with standard CAI values achieved on rough surfaces by using the empirical equation.

## 2. Testing equipment

Two types of testing devices are in use today: The original layout of [1], here entitled "CERCHAR apparatus" and the testing device presented in [2], here entitled "West apparatus" (Fig. 1).

The original layout (Fig. 1, left) mainly features a vice holding the rock specimen and a testing lever that is directly connected to the steel pin. The steel pin is loaded with a static force of 70 N. In this testing setup, the steel pin is scratched over the rock surface by moving the lever at a velocity of 10 mm/s.

The "West apparatus" (Fig. 1, right) also features a vice and a steel pin loaded with 70 N. In contrast to the "CERCHAR apparatus", the testing velocity is slower, taking 10 s for the 10 mm scratching distance. This is due to the different movement control which here is done by a hand crank that moves the rock sample below the pin. Ignoring the effect of varying testing velocities, the CAI values derived from both types are estimated to be equal.

## 3. Testing needles—shape and material properties

The geometrical features of the testing pin used are clearly defined in the testing recommendations [1] and are therefore the same throughout Europe. Although the recommendations suggest the use of hardened steel with a Rockwell Hardness HRC of 54–56 and a tensile strength of about 2000 MPa, the steel qualities used in different testing sets have in the past been varied in a wider range for different reasons, as there are problems in material procurement [2] or "better" testing results while testing low abrasive rock types [6]. You should be

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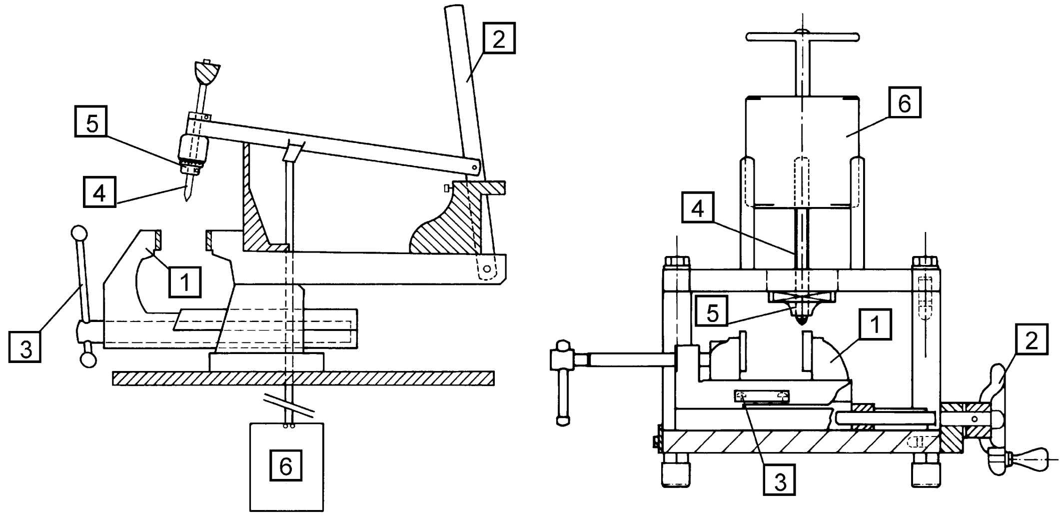


Fig. 1. Testing devices to determine the CERCHAR abrasiveness index according to [1,2]. (Left) CERCHAR apparatus: 1 + 3—sample vice; 2—hand lever; 4—testing pin; 5—pin chuck; and 6—weight. (Right) West apparatus: 1—sample vice; 2—hand crank; 3—vice sled; 4—testing pin; 5—pin guide; and 6—weight.

aware of the fact that any change in the mechanical properties of the testing pin may have a significant impact on the CAI values obtained. Currently, there are no investigations available on the comparison of CAI values derived from tests with different steel qualities so that such testing results cannot be compared with standard tests. The authors suggest the use of a 115CrV4 tool steel which is hardened to 55 HRC. Special care should also be taken when resharpening used testing pins. High temperatures arising from sharpening too quickly can influence the hardness of the pin tip and may therefore have a negative impact on CAI values obtained using such pins.

## 4. Surface conditions of rock specimen

With reference to the CERCHAR testing recommendations, the tests should be carried out on even, ‘‘broken’’ surfaces. Experience has shown that in many inhomogeneous rock types (such as conglomerates, coarse grained granite or schistous rock types) no suitable rock surfaces can be gained by breaking the rock samples with a hammer or any other splitting device. As a result of this problem, the influence of different surface conditions has been investigated by comparing samples of the same rock type that had been formatted using different methods: (a) samples with ‘‘rough’’ surfaces, produced by splitting using a hammer; (b) samples with ‘‘smooth’’ surfaces, after cutting using a water-cooled diamond saw and (c) samples with ‘‘polished’’ surfaces that had been polished using corundum powder of 100–140 μm grain size.

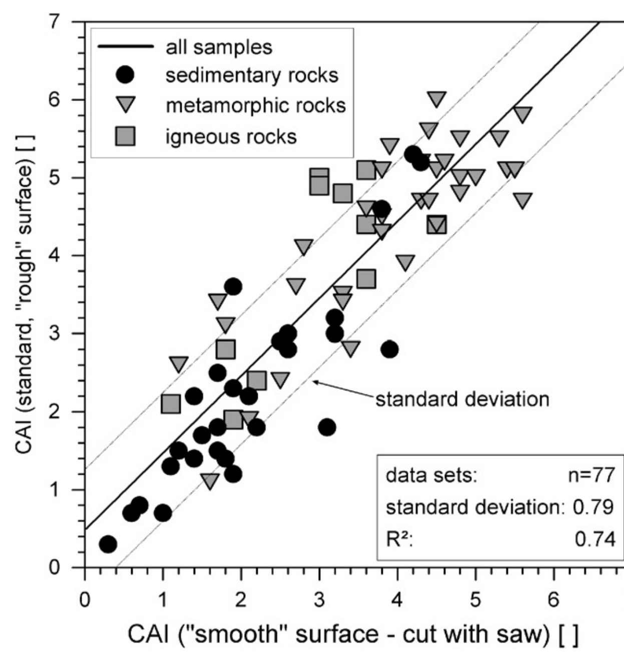


Fig. 2. Plot of CAI values gained on the same rock samples after different surface formatting.

The results show that the CAI values on rock samples with ‘‘rough’’ surfaces have a CAI of about 0.5 higher than the samples with ‘‘smooth’’ surfaces (Eq. (1), Fig. 2). This trend shows good to moderate fit and even data distribution which does not depend on the rock sample’s lithological characteristics. For inhomogeneous and anisotropic rock samples that have unsuitable sample surfaces after breaking the authors therefore suggest the use of a diamond saw for surface formatting and correction of the test result by using Eq. (1).

Correction equation for CERCHAR Abrasiveness Indices gained on saw cut rock samples:

$$CAI = 0.99 CAI_S + 0.48 \quad (1)$$

with $CAI$, CERCHAR abrasiveness index (standard, “rough” surfaces) [], $CAI_S$, CERCHAR abrasiveness index (“smooth” surfaces, cut with diamond saw) [].

## 5. Testing length

According to the testing recommendations [1], the scratching distance on the rock sample is defined with a length of 10 mm. At the beginning of the research work at TU Munich, a longer testing length was taken into consideration for a greater wear flat and therefore better evaluation of the CAI value. A series of tests were carried out on identical rock samples with differing testing lengths (Fig. 3) which confirmed the observations of Al-Ameen and Waller [6]: About 70% of the pin wear occurs during the first millimeter of the testing length, about 85% of the CAI is achieved after 2 mm, and only 15% of the change in CAI are achieved on the last 8 mm of the testing path. According to these findings, the testing length would have to be extended to some 5–10 cm to achieve noticeable greater wear flat on the testing pin. Based on these results, lengthening the scratch distance was considered to be useless. A positive impact of this effect is that deviations in the CAI coming from the variation of scratch length will not be very significant when the variation in testing length is kept between ±0.5 mm in length.

## 6. Evaluation of test results

The original paper [1] recommends a “microscopic reading method” of the pin wear flat diameter which is not described in detail. From their testing experience, the authors suggest the use of a reflected light microscope and evaluation of the wear flat with 50× magnification and a measuring ocular. The error of this method is at about 0.02 mm (=0.2 CAI). Though magnifications higher than 50× do not appear useful, the use of pocket lenses with magnifications of about 10× is also not recommended because of reading errors on the scale of 0.1 mm (=1 CAI).

During the research program the wear form of the pin was documented. This has proven to be valuable when testing inhomogeneous, coarse to very coarse grained rock types where the wear flat is too asymmetrical for simple and proper reading of the wear flat diameter. In such cases, two measurements should be carried out at a 90° angle to each other and a mean value should be used for further interpretation.

## 7. Number of tests

CERCHAR [1] considers 2–3 single tests as sufficient for fine-grained, homogeneous rock samples and suggests five or more tests only for samples with grain sizes

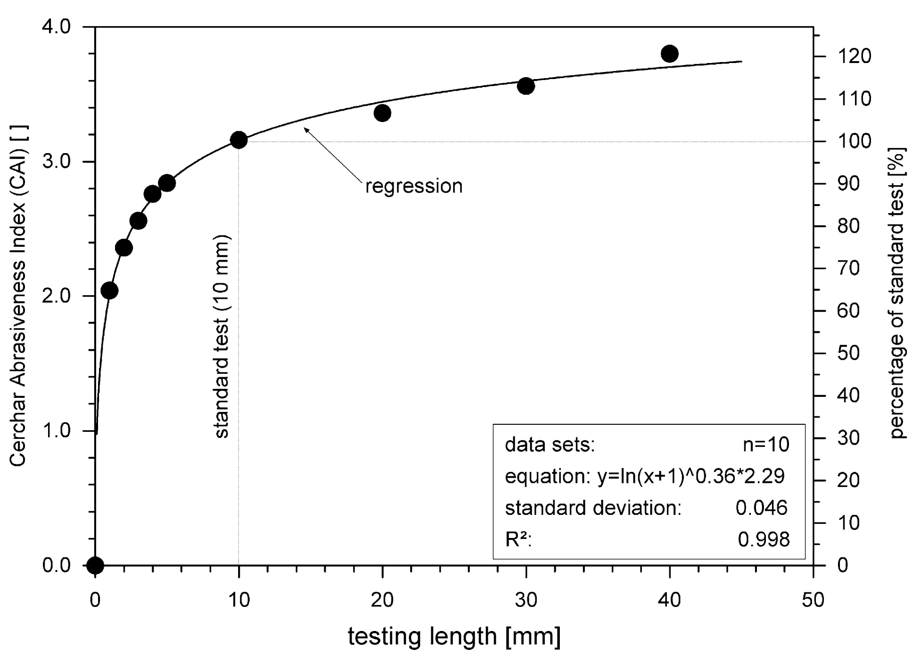


Fig. 3. Plot of CAI versus testing length.

of more than 1 mm. Based on testing experience, we suggest five individual tests for every rock sample to achieve a better defined mean value.

## 8. Geological influencing factors

Another research focus was put on quantifying geological factors that influence the test result. Therefore, 109 different rock types with a broad range of abrasivenesses ($CAI = 0.3-5.6$) were investigated using the CERCHAR Scratch Test and some additional "standard" hardrock testing procedures, such as testing UCS, Young's modulus and Brazilian tensile strength as well as petrographical thin section analysis, grain size analysis and measurements of rock dry density. Compared with West [2] who identified the Quartz Content to mainly influence the CAI, the records presented in Fig. 4 show that the Equivalent Quartz Content alone is not suited to interpret the abrasion values of the CERCHAR Scratch Test. Similar correlations presented for the CAI and the Abrasive Mineral Content by Al-Ameen and Waller [6] could also not be confirmed.

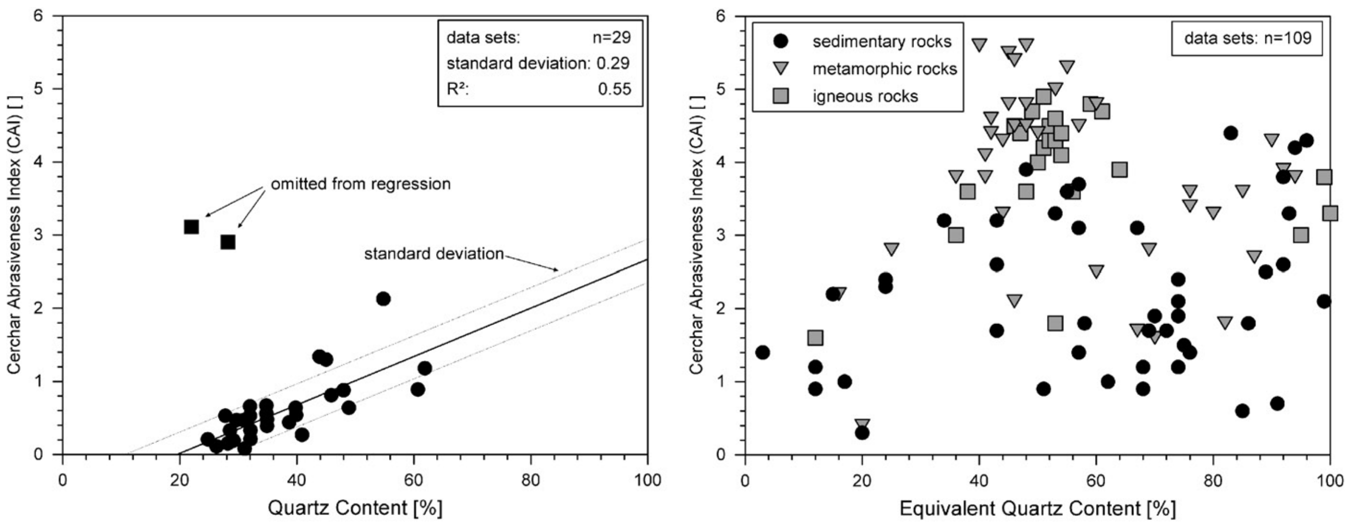


Fig. 4. CERCHAR abrasiveness index (CAI) plotted against the Equivalent Quartz Content. To the left the results by West [2], to the right the results of the TUM research program.

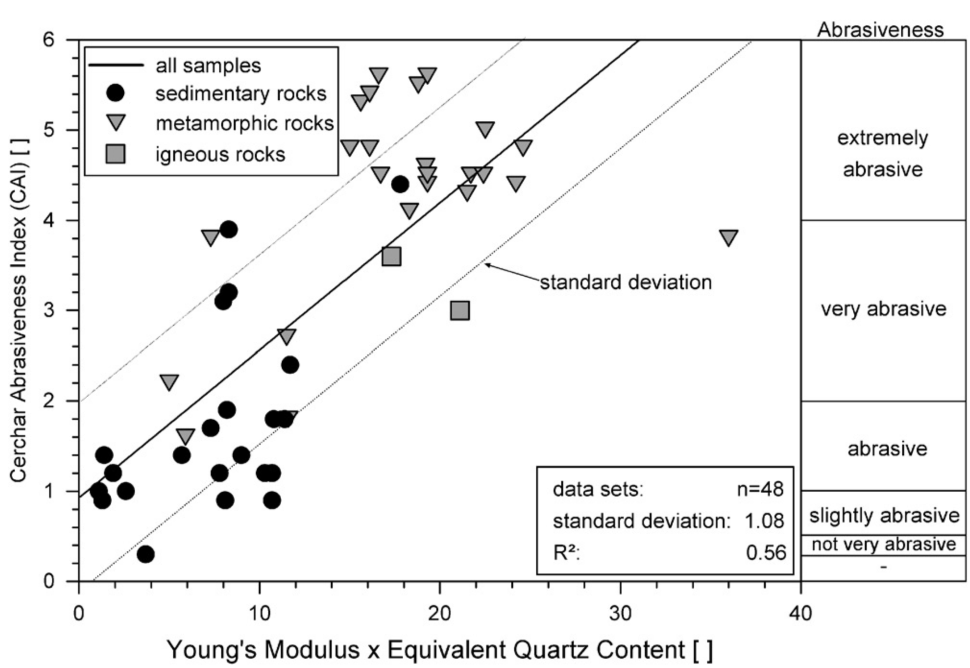


Fig. 5. CERCHAR abrasiveness index (CAI) plotted against a product of Young's modulus and Equivalent Quartz Content.

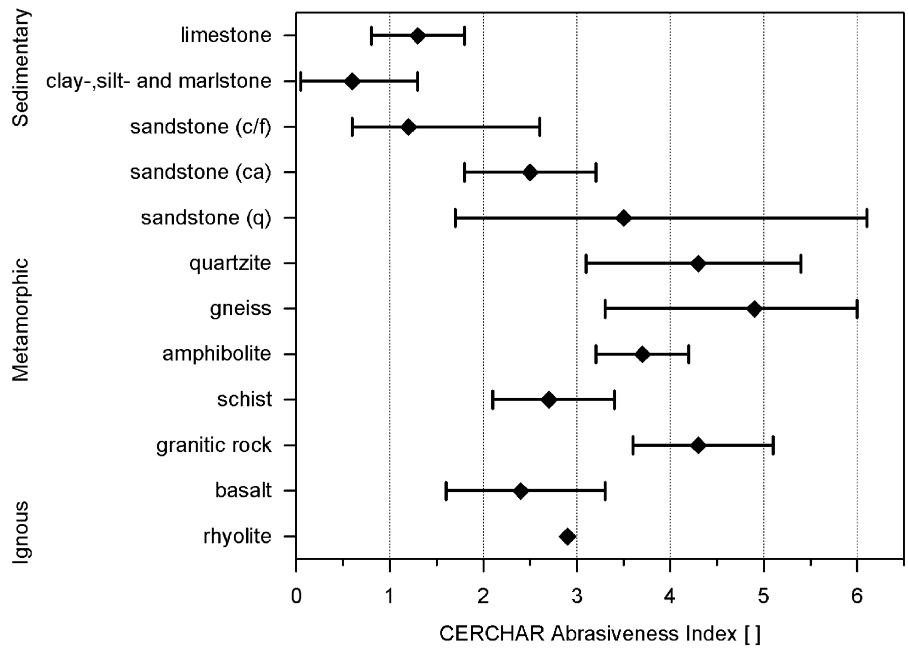


Fig. 6. Compilation of typical CAI values for some rock types according to [3,4,7]. Legend: c/f—clay/ferric binder, ca—calcareous binder, and s—siliceous binder.

Combination of all rock parameters lead to the finding that a product of Young's Modulus and the Equivalent Quartz Content of a rock sample was best suited to interpret the CAI by means of "classical" rock mechanical parameters. The fair correlation presented in Fig. 5 gives rise to the supposition that the rock's abrasiveness determined using the CERCHAR Scratch Test is mainly influenced by its deformability and content of abrasive minerals. Fig. 6 gives a compilation of typical CAI values for some main rock types derived from the research program and additional data presented by Büchi et al. [7].

## 9. Conclusions

The testing program carried out has proven that some technical factors have a reasonable impact on the test result of the CERCHAR Scratch Test. The use of testing pins with the recommended material properties and careful microscopic evaluation of the pin wear flat diameter are of crucial importance for obtaining good and comparable testing results. The use of diamond saw cut surfaces is recommended to investigate very inhomogeneous rock types, where broken sample surfaces may not be suited for a direct test. Test results on such surfaces can be compared with standard CAI values determined on broken surfaces by using an empirical correction equation. The comparison with "standard" rock parameters gives rise to the supposition that the CAI is mainly influenced by the rock's deformability and its content of abrasive minerals.

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