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THE APPLICATION OF UNDULATORY EXTINCTION ANGLES (UEA) AS AN INDICATOR OF ALKALI–SILICA REACTIVITY OF CONCRETE AGGREGATES

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1. ABSTRACT

This paper presents the results of a round-robin test where the Undulatory Extinction Angles (UEA) of quartz were measured in thin sections representing three different rock types. The measurements were performed by six petrographers from four independent laboratories in Denmark and comprised the measurement of 50 extinction angles in each of the three thin sections.

The aim of the round-robin test was primarily to assess the reproducibility of the UEA method.

The results obtained, comprising 900 UEA measurements, show that large variations occur between results obtained by the individual petrographers. Considering the magnitude of these variations, the applicability and reproducibility of the method in its present form are questioned.

The majority of the measured UEA values indicate that the tested rocks should be considered potentially alkali reactive. This contradicts available field and laboratory experience.

In view of the non-reactivity of the rock types analyzed, the paper also discusses the suggested threshold limit which states that an aggregate containing an amount of 20% of quartz grains with an UEA larger than 15^o should be considered as potentially reactive.

2. INTRODUCTION

Alkali-silica reactions in concrete caused by the use of metamorphic rocks as aggregate has become of increasing interest. Brown (1955) and Mielenz (1958) expressed the opinion that quartz in rocks that have been exposed to severe deformation could be potentially alkali-reactive when used in concrete and that such quartz might be identified by showing signs of strain.

Later work by Gogte (1973) on metamorphic granites and quartzites from India brought new interest into the discussion of quartz with undulatory extinction as an indicator of alkali-silica reactivity. Subsequent work by Dolar-Mantuani (1975, 1981, and 1983), Buck (1983) and Buck and Mather (1984) and Buck (1987) have elaborated on the issue and provided guidelines for a quantitative determination of the Undulatory Extinction Angle (UEA) and, based upon the measured angle, a criterion for distinguishing between reactive and non-reactive rocks. The criteria outlined by Dolar-Mantuani (1981) are somewhat uncertain as it is only specified that average UE angles below 15^o indicate non-reactive rocks. However, in the report by Buck and Mather (1984) it is stated (on page 13): "The criteria for recognition of reactive strained quartz are the presence of more than 20% of such quartz in an aggregate and an average undulatory extinction angle greater than 15 degrees". According to this definition, it is additionally required that the aggregate examined must contain at least 20% of strained quartz in order to be evaluated according to the UEA method. Later experiments by Grattan-Bellew (1987) indicate, however, that other factors than large UEA may contribute to an enhanced reactivity of deformed rocks.

The present paper focuses on the practical results obtained by comparative measurements of the UEA of quartz by six skilled petrographers. A detailed review of the principles and field experience which serve as a basis for the use of undulatory extinction angles of quartz as an indicator of alkali silica reactivity, by the authors, is due to be published shortly.

3. COMPARATIVE STUDY OF UEA MEASUREMENTS

A comparative study of UEA measurements was carried out between six skilled Danish petrographers from: The Technological Institute (IB), AEC (TSH & JBJ), Danish Concrete Technology (PL) and G.M. Idorn Consult A/S (KTA & NT).

Each of the six petrographers were provided with the directives for measurement of the UEA of quartz as outlined by Ludmilla Dolar-Mantuani in her textbook: "Handbook of Concrete Aggregates", pages 98-99 (1983). The individual petrographer was asked to measure 50 quartz grains in each of three thin sections according to his/her personal interpretation of the guidelines. The intention was to get an assessment of the reproducibility of the method when used by independent laboratories. The amount of quartz in each thin section was more than 20%.

4. RESULTS

The results from the round-robin test are shown in Table 1. For each thin section the mean value, the standard deviation and the variance of the measurements of the individual petrographer are calculated. The average UEA values measured in each thin section by the individual petrographers are presented in Figures 1 - 3 together with thin section micrographs of the aggregates.

5. DISCUSSION

5.1 Thin section no. 2298-2. Danish tertiary quartz sand from Voervadsbro

The average UEA values show considerable variation between the individual petrographers ranging from approximately 9^o to 43^o. Using the criteria by Buck and Mather (1984) which states that an average UEA above 15^o indicates potential reactivity shows, in 5 out of 6 incidents, that this aggregate should be considered potentially reactive.

Voervadsbro Sand is, however, used as reference sand in Denmark due to its well known non-reactivity towards alkalies in concrete. Neither extensive field experience nor 5 - 6 years of continuous testing according to the accelerated Danish TI-B 51 Mortar Bar Method have shown any indication of reactivity of this sand.

5.2 Thin sections nos. 2534-5 and 2534-10. Granitic gneiss from Kenya

The two rock types represented in thin section nos. 2534-5 and 2534-10 have been extracted from the same bulk aggregate material and are treated together. The average UEA values measured in thin section no. 2534-5 vary between 9^o and 31^o and can roughly be subdivided into a group within the interval of 9-13^o and a group lying between 27^o and 31^o. The standard deviations for measurements on thin section no. 2534-5 are between 5 to 8 degrees which are generally lower than for thin section 2298-2. Only one average value lies below the 15^o threshold which separates non-reactive rocks from potentially reactive rocks. This means that this rock, according to the applied method, would be deemed potentially reactive by 5 out of 6 petrographers.

The UEA measurements on thin section no. 2534-10 show roughly the same tendencies as for thin section no. 2534-5. This rock is also to be considered potentially reactive by 5 out of 6 petrographers according to the criteria outlined by Buck and Mather (1984) and Buck (1987).

Thin sections nos. 2534-5 and 2534-10 represent a granitic gneiss and a hornblende-biotite gneiss, respectively. These two rock types constitute the major fraction of crushed aggregate material which has been tested according to ASTM C-289 Rapid Chemical Test, ASTM C-227 Mortar Bar Method and the Danish TI-B 51 Mortar Bar Method. None of these tests have shown any signs of deleterious alkali-reactivity even after continuation of the ASTM C-227 and the TI-B 51 test for a prolonged period of 180 weeks instead of the normally prescribed 26 and 20 weeks, respectively.

6. CONCLUSION

The round-robin test concerning the reproducibility of UEA measurements of quartz in various aggregates have shown significant variations between the 6 individual petrographers. This scattering of results suggests that the UEA measurement method, in its present form, may be too uncertain to produce reliable results.

The aggregates which should be classified as potentially alkali-reactive by 5 out of 6 petrographers according to the UEA method have not shown any signs of reactivity, neither as inferred from field performance nor from prolonged accelerated testing. These observations suggest that the present UEA method and the rejection criterion, the 15^o threshold, should be critically re-evaluated and/or further documented by systematic studies.

7. ACKNOWLEDGEMENTS

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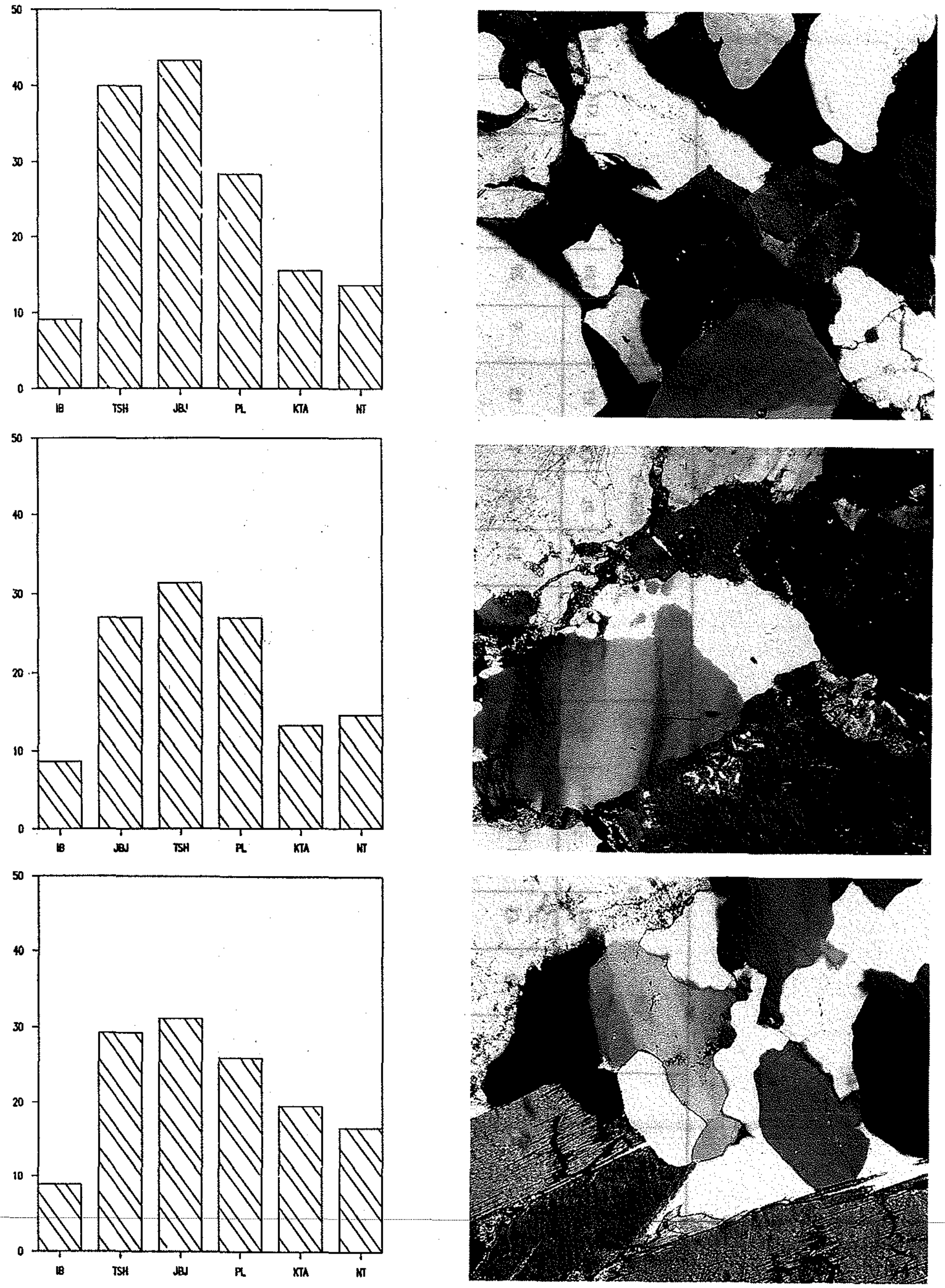
	T.S No 2298-2						T.S No 2534-5						T.S No 2534-10					
	IB	TSH	JBJ	PL	KTA	NT	IB	TSH	JBJ	PL	KTA	NT	IB	TSH	JBJ	PL	KTA	NT
MEAN	9	40	43	28	16	14	9	27	31	27	13	15	9	29	31	26	20	17
STD.DEV	6	27	18	5	9	12	6	8	8	5	5	6	5	10	9	3	8	5
VARIANCE	41	712	326	21	76	134	38	71	59	25	29	37	28	94	85	9	72	24

Table 1. Table showing the mean, standard deviation and variance for UEA measurements performed on thin section nos. 2298-2, 2534-5 and 2534-10 by the operators: IB, TSH, JBJ, PL, KTA, and NT.



Figures 1 - 3. Average UEA values for Voervadsbro sand (top), granitic gneiss (middle) and hornblende-biotite gneiss (bottom) as determined by six different petrographers on the same thin sections. Thin section micrographs of the aggregates in 63x magnification are presented to the right.