POTENTIALLY REACTIVE CARBONATE ROCKS
(A Review of Virginia Reports)

Prepared by

W. Cullen Sherwood
Highway Materials Research Analyst
(April 1966)

Revised and Updated

by

Howard H. Newlon, Jr.
Assistant State Highway Research Engineer

Virginia Highway Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways and the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

September 1970
VHRC 70-R11

POTENTIALLY REACTIVE CARBONATE ROCKS

(A Review of Virginia Reports)

by
W. Cullen Sherwood
Highway Materials Research Analyst

Revised and Updated
by
Howard H. Newlon, Jr.
Assistant State Highway Research Engineer

An expansive reaction between portland cement and certain siliceous aggregates has been known since the work of T. E. Stanton in the early nineteen forties. It was not until Woods, Sweet and Shelburne (1945) had correlated pavement blowups in Indiana with a few carbonate aggregate sources that certain limestones and dolomites were suspected of causing expansion when used in concrete. Swenson (1957) correlated deleterious expansion of concrete with a single carbonate aggregate source at Kingston, Ontario, and further noted that the degree of expansion could be correlated with the level of cement alkali. Subsequent to this work expansive alkali-carbonate rocks have been found and reported in Indiana (Hadley - 1961), Virginia (Newlon and Sherwood - 1962), and Missouri (Axon and Lind - 1965).

The first indication that carbonate aggregates being quarried in Virginia were alkali reactive resulted from measurements obtained in 1957 from an instrumented bridge in Rockingham County. Abnormal expansions from both the bridge deck and a companion beam were indicated. Subsequent lab and field investigations led to the drafting of a working plan (Newlon - 1961) designed to locate and study potentially reactive carbonate rocks in Virginia. The following are brief resumes of the Progress Reports resulting from this study to date:

Progress Report No. 1 — "Initial Investigations"

This report includes the investigations which were made on the Rockingham County Bridge and the aggregate that went into the suspected concrete. It includes descriptions of expansion and cracking of the concrete bridge, laboratory study of alkali induced rock expansions, studies of laboratory concrete and characteristics of reactive rock. From these investigations it was concluded that a significant portion of the aggregate used in the bridge was alkali reactive, that the alkali reactive aggregate can cause expansion and cracking in concrete, and that reactivity can be detected in the laboratory by a simple prism test.

Progress Report No. 2 — "Statewide Survey for Reactive Carbonate Aggregates"

Two hundred and twenty-four rock samples were taken from 42 of the principal limestone and dolomite producing quarries throughout the state. These samples were tested for absorption and specific gravity and analyzed for mineral composition by thin section and X-ray methods. Also, prisms were made from each sample and tested for alkali reactivity in NaOH solution. Compositions of the samples were plotted in binary and ternary diagrams and expansive samples were shown on the same diagrams. Rocks with near equal amounts of calcite and dolomite and high insol contents were found to be most reactive. Rim formation in aggregates in concrete was briefly discussed.

Progress Report No. 3 — "Alkali Contents of Cements Used in Virginia Highway Construction"

A total of 317 cement samples representing 76 shipments from 12 mills were taken throughout the state. Seven mills were found to predominate as suppliers in Virginia. The predominant alkalies, with the exception of that in the cement produced at one plant, were found to be potassium compounds. Also, with the exception of this one plant, equivalent Na_2O averaged less than 0.70% in all cases with most plants being between 0.50% and 0.60%. It would appear then that if alkali contents of less than 0.40% were ever required, some adjustment in procedures would be required of all plants.

Progress Report No. 4 — "A Study of Remedial Methods for Reducing Alkali-Carbonate Reaction"

The purpose of this report was to describe the results of laboratory work investigating remedial measures which might be employed where alkali reactive aggregates must be used. The measures investigated were, 1) reduction of cement alkalies, and 2) dilution of reactive aggregate with non-reactive aggregate. It was concluded that both measures were effective in reducing concrete expansion, but that dilution of reactive aggregate with non-reactive aggregate appears to be a more practical and efficient remedial procedure. Freeze-thaw studies indicate that durability is also significantly affected by the combination of amount of reactive aggregate and cement alkali level.

Progress Report No. 5 — "An Evaluation of Several Methods for Detecting Alkali-Carbonate Reaction"

The data collection and analyses is essentially complete and this report should be completed during the coming year.

Progress Report No. 6 — "Field Manifestation of Alkali-Carbonate Reaction Based on a Survey of Structures"

Material is essentially complete and a report should be issued in the coming year.

Progress Report No. 7 — "Studies on the Mechanisms of Alkali-Carbonate Reactions, Part 1, Chemical Reactions"

An understanding of the mechanisms of alkali-carbonate rock reaction which result in expansion of concrete is of primary importance in dealing with the resultant problems on a practical level. Each of the three major constituents of carbonate rocks — silica, clay minerals and the carbonate minerals — were exposed to alkali solutions. The silica and clays gave no apparent expansive reaction. The carbonates, particularly dolomite, reacted and increased in volume in the presence of alkali solutions. The reaction products developed in alkali solutions of different concentrations were identified. Evidences of some of these produces were found in aggregate from distressed field concrete.

Additional data on some of the p ysical mechanisms of alkali-carbonate reactions have been developed through measurement of expansions of reactive rocks under varying degrees of external restraint.

Progress Report No. 8 — "Recommendations Relating to the Control and Use of Potentially Reactive Carbonate Aggregates"

Much of this portion of the project has already been completed with the enlistment of the cooperation of those quarry owners in the state who have reactive material in their quarries. A report on this phase is in progress and should be completed in 1971.

REFERENCES

1. Axon, E. O. and Junior Lind, "Alkali-Carbonate Reactivity — An Academic or a Practical Problem", HRB Record No. 45 (1965)

2. Hadley, D. W., "Alkali Reactivity of Carbonate Rocks, Expansion and Dedolomitization" HRB Proceedings 40 (1961)

3. Newlon, H. H. and W. C. Sherwood, "An Occurrence of Alkali Reactive Carbonate Rock in Virginia", HRB Bulletin 355 (1962)

4. Swenson, E. G., "A Reactive Aggregate Undetected by ASTM Tests", ASTM Bulletin 226 (1957)

5. Woods, K. B., H. S. Sweet, and T. E. Shelburne, "Pavement Blow-Ups Correlated with Source of Coarse Aggregate", HRB Proceedings 25 (1945).

BIBLIOGRAPHY OF REPORTS RELATING TO VIRGINIA STUDIES OF ALKALI REACTIVE CARBONATE ROCKS

A. Reports of Virginia Highway Research Council

1. Newlon, Howard H. Jr. "Proposal — A Study of Potentially Reactive Carbonate Rocks," (February 1961)

2. Newlon, Howard H. Jr. "Working Plan – A Study of Potentially Reactive Carbonate Rocks" (April 1961)

3. Newlon, Howard H. Jr. and W. Cullen Sherwood. "Potentially Reactive Carbonate Rocks". A paper presented to the Materials and Test Committee of the Southeastern Association of State Highway Officials. Louisville, Kentucky (October 1962)

4. Newlon, Howard H. Jr., and W. Cullen Sherwood. "Progress Report #1 — Potential Reactive Carbonate Rocks — Initial Investigation" (May 1962)

5. Sherwood, W. Cullen and Howard H. Newlon, Jr. "Progress Report #2 — Potentially Reactive Carbonate Rocks — A Statewide Survey for Reactive Carbonate Aggregates" (February 1964)

6. Newlon, Howard H. Jr., and W. Cullen Sherwood. "Progress Report #3 — Potentially Reactive Carbonate Rocks — Alkali Contents of Cements Used in Virginia Highway Construction" (May 1964)

7. Newlon, H. Jr., and W. Cullen Sherwood. "Progress Report #4 — Potentially Reactive Carbonate Rocks — A Study of Remedial Methods in Reducing Alkali Carbonate Reaction" (May 1963)

8. Hilton, Marvin. "Progress Report #5 — Potentially Reactive Carbonate Rocks — An Evaluation of Several Methods for Detecting Alkali-Carbonate Reaction (Mortar Bar Studies) — Partial Rough Draft" (May 1964)

9. Sherwood, W. Cullen, and Howard H. Newlon, Jr. "Progress Report #7 — Potentially Reactive Carbonate Rocks — Studies on the Mechanisms of Alkali Carbonate Reaction — Part 1: Chemical Reactions (February 1964)

10. Hilton, Marvin H., "Progress Report #7b Potentially Reactive Carbonate Rocks — The Effects of Textural and External Restraints on the Expansion of Reactive Carbonat Aggregates", (September 1968)

11. Walker, Hollis N., "Alkali Carbonate Reaction Products Found in Mortar Bars and Prisms", (December 1967)

B. Published Papers (In Some Cases Containing Duplications of Above Reports)

12. Newlon, Howard H. Jr., and W. Cullen Sherwood. "An Occurrence of Alkali-Reactive Carbonate Rock in Virginia", HRB Bulletin 355, pp. 27-44 (1962) VHRC Reprint #51

13. Newlon, Howard H. Jr., and W. Cullen Sherwood. "Discussion of Durability of Concrete in Service", Journal of American Concrete Institute, Part 2, pp. 2071 - 2075 (June 1963)

14. Newlon, Howard H. Jr., and W. Cullen Sherwood. "A Study of Remedial Methods for Reducing Alkali-Carbonate Reactivity", HRB Research Record 45, pp. 134-150 (1964) VHRC Reprint #61

15. Sherwood, W. Cullen, and Howard H. Newlon, Jr. "Studies on the Mechanisms of Alkali-Carbonate Reaction — Part I: Chemical Reactions", HRB Research Record 45, pp. 41-56 (1964)

16. Sherwood, W. Cullen, and Howard H. Newlon, Jr. "A Survey for Reactive Carbonate Aggregates in Virginia", HRB Research Record 45, pp. 222-233 (1964) VHRC Reprint #59

17. Newlon, Howard H., Jr. "Alkali-Carbonate Rock Reactions in Concrete", prepared for presentation at U.S.-Japan Joint Seminar on Research on Basic Properties of Various Concretes, Tokyo, Japan, January 1968. Published in Concrete Journal, Vol 6, No. 8, August 1968, JANACC No. 35 (Published in Japanese)

Above paper published in "Abstracts of papers from U.S.-Japan Seminar on Research on Basic Properties of Concrete, January 1968", published by the American Concrete Institute and Japan National Council on Concrete. (Published in English)

C. Miscellaneous Related Papers and Publications

18. Liu, Yan-Ning. "Reactivity of Carbonate Aggregates — Expansive Effects of Different Kinds of Solutions", Unpublished report (June 1962)

19. Huang, J. H. and W. C. Sherwood. "Effective Diffusivity with Chemical Reaction in Porous Rocks", Materials Research and Standards, Vol. 5, No. 7, pp. 362-366 (1965) VHRC Reprint #56

20. Newlon, Howard H. Jr., "Summary of Cooperative Testing of Carbonate Aggregates for ASTM C-9 Subcommittee II-b", distributed November 14, 1967.

D. Presentations given or Scheduled (Publication in Progress)

1. Ozol, Michael A. and Howard H. Newlon, Jr., "An Example of Bridge Deck Deterioration Influenced by Alkali-Carbonate Reaction", Presented at Highway Research Board Annual Meeting, Washington, D. C. January 1969.

2. Ozol, Michael A. and Howard H. Newlon, Jr. "Bridge Deck Deterioration Promoted by Reaction of a Dolomitic Limestone Coarse Aggregate with Cement Alkalies", Sched uled to be presented at the Annual Meeting of the Geological Society of America, Milwaukee, Wisconsin November 1970.