LOUISIANA TRANSPORTATION RESEARCH CENTER

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Effect of Clay Content on Alkali-Carbonate Reactive (ACR) Dolomitic Limestone

In North America, alkali-carbonate reaction (ACR) was first documented by Swenson of the National Research Council of Canada. ACR is a deleterious reaction that results in the expansion and cracking of concrete in the presence of moisture, leading to premature deterioration and reduced service life. General indicators of ACR expansion include a map or pattern cracking, closed joints, blow-ups or crushed concrete, and relative offsets of adjacent slabs or substructures. Pavements containing alkali-carbonate reactive aggregates have been found in Louisiana on Interstate 20 between Ruston and Monroe and also near the Mississippi River bridge. Other paving and structural projects in Louisiana have also been identified as having ACR-susceptible aggregates. Because of these investigations, DOTD specifications were updated to reduce the risk of ACR deterioration in concrete using AASHTO PP65-11.

To this date, there is no consensus within the literature on what exactly triggers ACR in concrete. Rather, there are five theories that describe the mechanism behind ACR: (1) expansion through dedolomitization; (2) non-expansive dedolomitization in conjunction with the expansion caused by swelling of clay minerals from the uptake of water; (3) alkali-silica reaction (ASR) misdiagnosed as ACR; (4) expansion through a combination of ASR and clays; and (5) volumetric instability of dolomites caused by a substitution of iron for magnesium in its crystalline structure. Given the complex nature of ACR, it is unclear to what extent clay content contributes to deleterious expansion, particularly for aggregates that are suitable for concrete construction.

OBJECTIVE

This study aimed to evaluate whether an aggregate's clay content plays an overarching role in ACR expansion and deterioration within the limestone sources that have been approved for use in portland cement concrete in Louisiana.

SCOPE

The scope of this study was to evaluate the influence of a limestone's clay content on its alkali carbonate reactivity. This was achieved by screening all of the limestone sources that are included in DOTD's approved materials list for potential aggregate reactivity (per CSA A23.2-26A). If an aggregate was deemed to be potentially reactive, a standardized test method that measures the length change of concrete due to alkali-carbonate rock reaction (ASTM C1105) was used to characterize the aggregate's reactivity. The results of this study were limited to concrete mixtures that were designed similarly to the proportions described in ASTM C233.

METHODOLOGY

An inventory of limestone aggregates in DOTD's approved materials list (AML) was compiled for evaluation with the AASHTO PP 65 screening test, where 29 aggregates were screened. Specimens were prepared for analysis with X-ray fluorescence (XRF) equipment, where calcium oxide (CaO), magnesium oxide (MgO), and alumina (Al_2O_3) contents were determined in accordance with CSA-A23.2-26A.

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The clay content in aggregate can be estimated based on its alumina content.

The chemical analysis was also used to determine if the aggregates are considered potentially expansive based on a plot of CaO/MgO ratio versus Al_2O_3 contents as shown in Figure 1. If the composition of the aggregate did not fall in the "potentially expansive" range, the aggregate was considered to be unreactive and was not tested for the ASTM C1105 concrete prism test.

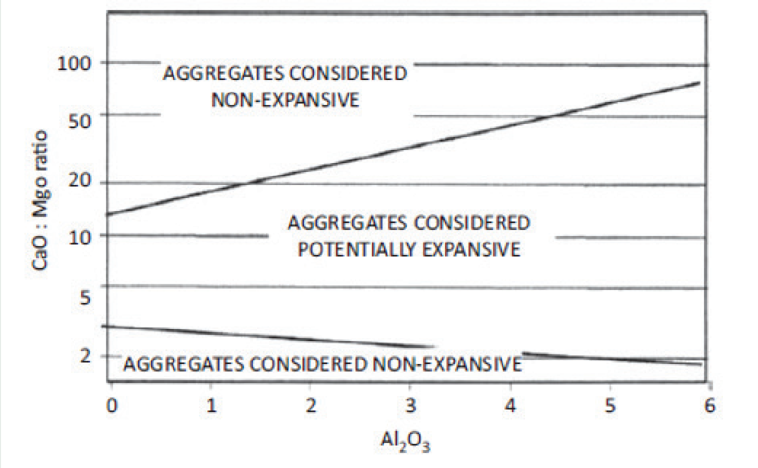

Figure 1. A sample plot of CaO/MgO ratio versus the Al_2O_3 content of quarried carbonate rocks.

Once the aggregates were screened by chemical analysis, those classified as potentially expansive were tested in concrete prisms for length change to evaluate their susceptibility to ACR per ASTM C1105. These specimens were monitored for 12 months and were classified based on the limits described in Table 1. Fresh concrete properties such as slump (ASTM C143), air content (ASTM C231), and unit weight were also measured for all concrete samples.

Table 1. Criteria for evaluating ACR expansion (ASTM C1105)

Testing Age	Expansion %
12 months	0.030
6 months	0.025
3 months	0.015

CONCLUSIONS

A total of 29 aggregate sources from DOTD's approved materials list were screened for chemical analysis to determine whether the aggregates were potentially expansive based on their calcium oxide, magnesium oxide, and alumina contents. Twelve out of 29 aggregates were found to be potentially reactive and therefore were selected for concrete prism tests per ASTM C1105 to verify their expansive potential.

The results showed that none of the aggregates tested exhibited deleterious expansion after 12 months, with only two aggregate sources near the 0.030% expansion threshold. In addition, the clay content (based on the aggregate's alumina composition) did not directly affect the selected group of aggregates' reactivity. However, given the complex nature of ACR expansion, and the inherent variability within carbonate rocks, more research is needed to conclusively determine whether an aggregate's clay content has an effect on ACR, specifically on carbonate rock sources that are compatible with portland cement concrete based on their soundness, strength potential, and durability index.