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By Fred H. Dorheim

This investigation (Dorheim, 1950) was made in an effort to identify mineralogic or textural characteristics of limestones that might effect the durability of concrete. The Iowa State Highway Commission has found that when certain limestones were used as coarse aggregate in concrete, that concrete gave excellent service in paving. Other limestones that responded to standard testing procedures in a similar manner, gave very poor results when used in concrete paving.

For the present investigation samples were taken to represent limestones that were known to have given good service in paving, some that were known to give very bad service and some that are still in question. The identification of samples, their geologic occurrance and their service classification are listed in table 1.

The State (Iowa State Highway Commission, unpublished) and Federal testing laboratories both use growth and sonic modulus as a means of determining the soundness of aggregates used in concrete. Although this method appears to be rather dependable, it is too slow for use as a basis of acceptance or rejection of new material to be used for a specific project. In order to relate any new test to an accepted procedure, both growth and sonic tests were run on all samples studied in this investigation (Dorheim, 1950). The results of these tests are shown in Fig. 1 and Fig. 2. It should be pointed out that those samples coming from sources that are classified as good show little expansion and small changes in resonant frequency

Table 1

Sample	Geologic Occurrance	Classification
E1-E6	Bethany Falls	Bad
A1 & A2	Alden	Very good
LG1,LG2, LG3 & LGO	Kinderhook	Questionable
B1 & B2	Cedar Valley	Bad
P1-P4	Cedar Valley	Questionable
D-CV	Cedar Valley	Bad
DD1 -DD3	Davenport	Good

and those coming from sources classified as bad show considerable expansion and large changes in resonant frequencies. The kinderhook samples are an exception.

Grim, Lamar and Bradley (1937), in studying the clay minerals contained as an integral part of some of the limestones of Illinois, found various types of clay in varying amounts in the several limestones studied. They state that limestones containing kaolenite will be more resistant to weathering than will one containing montmor-

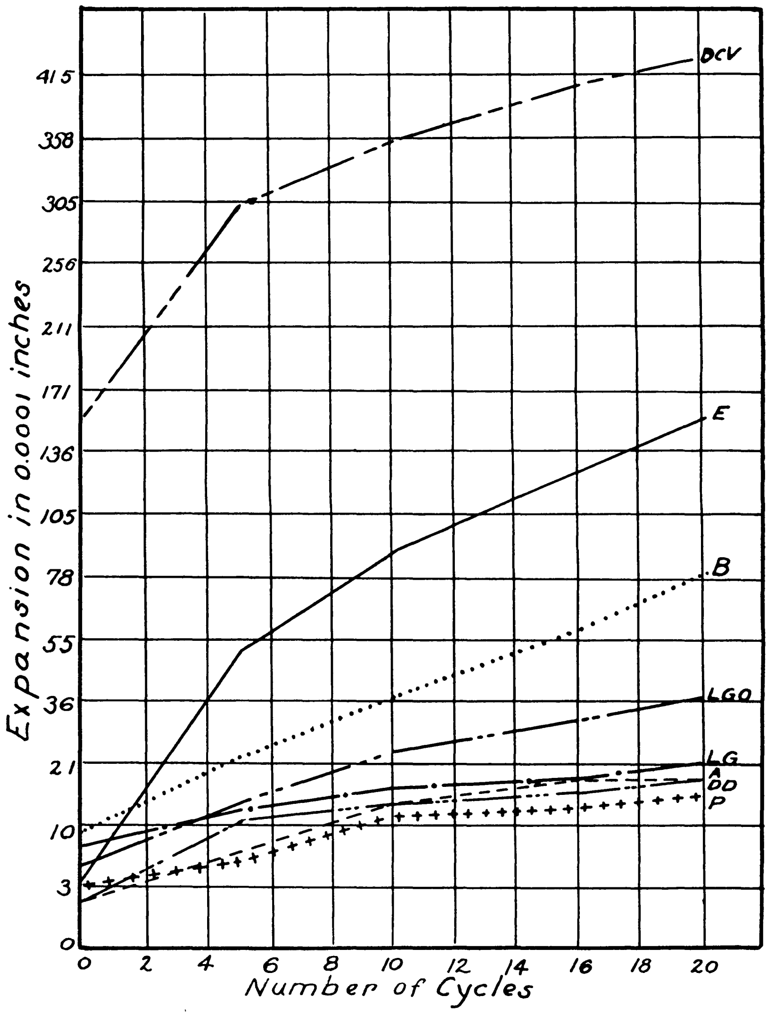

Fig. 1. Expansion of Concrete During Freezing & Thawing.

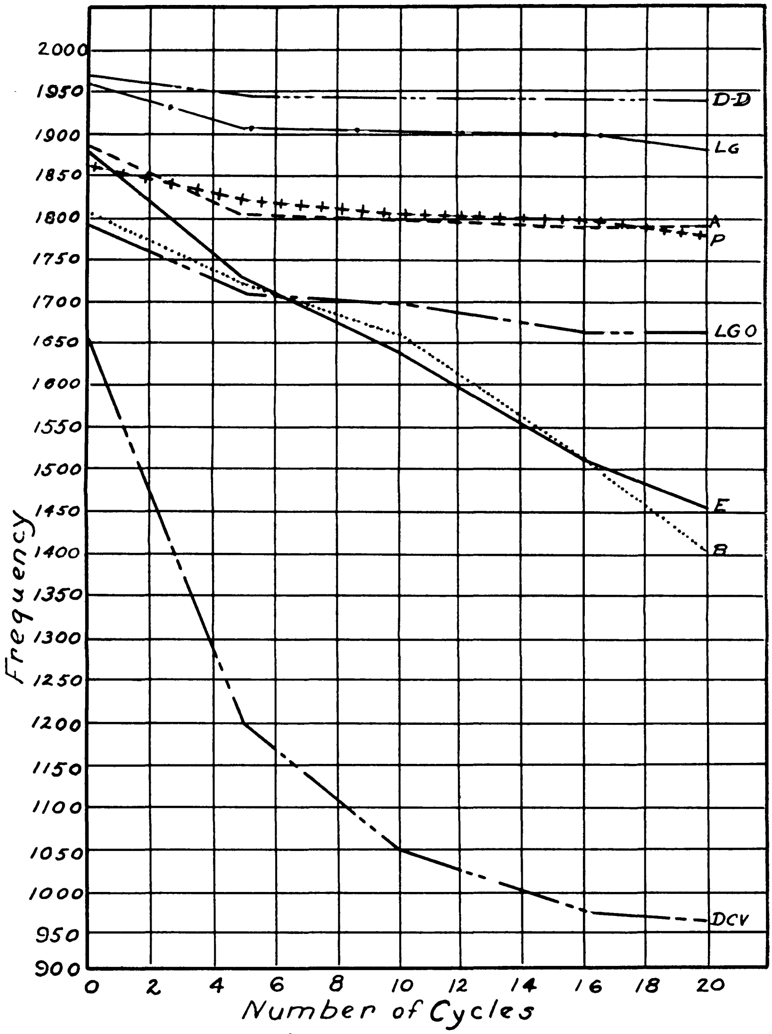

Fig. 2. Frequency Changes During Freezing & Thawing

illonite. Rhoades and Mielenz (1948) in discussing concrete aggregate say,

"Where expansion results from hydration of montmorillonitic type clays, the volumetric change is accompanied by pressures greatly in excess of the tensile strength of concrete."

M. E. King* suggested to the writer the method of organic dyes as a means of distinguishing the montmorillonitic clays from the kaolinitic clays. This method has been discussed by both Faust

*Clay pertrographer, U. S. Bureau of Reclamation Laboratories, Denver, Colorado.

(1940) and by Hendricks and Alexander, and was adopted for use in this investigation.

The samples were prepared for clay study by crushing the limestone until it all passed a one-eighth inch screen. The sample was then divided by quartering until about fifty grams were retained. This was then digested in HCl until all the carbonates were dissolved. The clay fraction of the residue was then separated from the sand fraction by sedimentation. The separation was made at the 1/256 mm. size. For identification, about one-half gram of clay was placed in a 20cc. beaker. About five times this volume of HCl (concentrated) was added and the mixture was heated on top of a 100° F oven for about two hours. The mixture was then filtered and washed with about 400 cc. of distilled water. The residue was dried in a 100° F oven and divided into three parts for treatment with the organic dyes. The identifying reactions are as follows:

Dye	Reaction with keolin	Reaction with montmorillonite
Safranine "y"	Red	Purple
Malachite green	Green	Amber
Benzadine	No color	Blue

The amounts of clay occurring in the samples and the identification of the clays are shown in tables 2 and 3.

I think the significance of the clay-aggregate relationship can best be summarized in the form of a table.

Sample	Classification	Growth	Sonic Modulus	Percent Clay	Type Clay
E	Bad	High	High	6.57	M
A	Good	Low	Low	0.10	K
LG	Questionable	Low	Low	1.86	K
B	Bad	High	High	14.78	M
P	Questionable	Low	Low	8.46	K
DCV	Bad	High	High	22.23	M
DD	Good	Low	Low	2.83	K

It is recognized that, since only twenty-two samples were studied, this investigation cannot be considered to be conclusion. The writer believes, however, that it strongly indicates the part played by montmorillonitic clays in the breakdown of certain aggregates used in concrete.

Table 2

Percent of Insoluble Residue, Coarse Fraction, Clay Fraction

Sample No.	Percentages[1]			Classification Based on Service Record
	Total Residue	Coarse Fraction	Clay Residue	
E-1	2.37	0.52	1.85	Bad
E-2	10.25	0.12	10.13	Bad
E-3	9.26	0.10	9.16	Bad
E-4	9.87	0.04	9.83	Bad
E-5	7.36	0.19	7.17	Bad
E-6	1.41	0.11	1.30	Bad
A-1	0.21	0.02	0.19	Good
A-2	0.10	0.09	0.01	Good
LG-1	1.24	0.51	0.73	Questionable
LG-2	2.81	0.21	2.60	Questionable
LG-3	3.62	0.34	3.28	Questionable
LGO	2.84	1.99	0.85	Questionable
B-1	10.90	2.47	8.43	Bad
B-2	21.42	0.29	21.13	Bad
P-1	0.97	0.57	0.40	Questionable
P-2	1.88	0.02	1.86	Questionable
P-3	1.61	0.09	1.52	Questionable
P-4	14.06	1.89	12.17	Questionable
D-CV	22.28	0.05	22.23	Bad
D-D1	4.24	0.30	3.94	Good
D-D2	2.93	0.35	2.58	Good
D-D3	1.93	0.14	1.79	Good

[1]All percentages are based on the dry weight of the original sample. Weights were taken to the fourth decimal place and corrected to the third.

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Table 3

Clay Identification

Sample No.	Colors produced by			Identification
	Safranine "y"	Malachite Green	Benzidine	
E-1	Purple	Amber	Blue	Montmorillonite
E-2	Purple	Amber	Blue	Montmorillonite
E-3	Purple	Amber	Blue	Montmorillonite
E-4	Purple	Green	Blue	Montmorillonite
E-5	Purple	Amber	Blue	Montmorillonite
E-6	Red	Green	No Color	Kaolinite
A-1	Red	Green	No Color	Kaolinite
A-2	----	----	----	Quartz
LG-1	Red	Green	No Color	Kaolinite
LG-2	Red	Green	No Color	Kaolinite
LG-3	Red	Green	No Color	Kaolinite
LGO	----	----	No Color	Kaolinite
B-1	Purple	Yellow	Blue	Montmorillonite
B-2	Purple	Amber	Blue	Montmorillonite
P-1	Red	Green	No Color	Kaolinite
P-2	Red	Green	No Color	Kaolinite
P-3	No Color	Green	No Color	Kaolinite
P-4	Violet	Green	Blue	Montmorillonite
D-CV	Purple	Yellow	Blue	Montmorillonite
D-D1	Purple	Yellow	Blue	Montmorillonite
D-D2	Red	Green	No Color	Kaolinite
D-D3	Red	Green	No Color	Kaolinite

Rhoades, R. and Mielenz, R. C. 1948. Petrographic and mineralogic characteristics of aggregates. Symposium on mineral aggregates. American Society for Testing Materials. Special Technical Puplication No 83 p. 20-48.

CEDAR RAPIDS, IOWA.