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ANALYSIS OF CALCITE, DOLOMITE AND TEXTURE, AND THEIR ROLES IN PREMATURE DETERIORATION OF PORTLAND CEMENT CONCRETE PAVEMENT IN KANSAS

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16 Abstract

Premature deterioration of concrete pavement produced with Class I limestone indicated a need to better predict limestone that would be deleterious in the future while passing Class I test criteria. Using the information contained in the database prepared for FHWA KS-97/4, a classification of Kansas limestone has been obtained using texture and iron content of the carbonate minerals. Iron content of both the calcite and dolomite is indicated by the colors obtained with staining. The iron content and texture information in this investigation indicate that the greater the iron content, the greater the chances that the tested limestone does not pass Class I criteria. Since the limestone in the prematurely deteriorated pavement was Class I, the high iron content may be playing an important role in the premature deterioration. Some textures seem to have less iron content as evidenced in the database. Finely textured limestones have less iron content as indicated by stained peels. Coarsely textured limestones have more iron content. A higher proportion of finely textured limestone passes criteria for Class I aggregate.

Using the presented findings, field geologists could be provided with a field manual that includes texture and color criteria, stain recipe and procedure, and interpretation of stain results. This field manual can be revised and redefined as results of current related research are available and as experience in the field is gained. The field geologists could use the manual in the quarry to determine quickly (1) which texture category and stain colors individual ledges produce, (2) the aggregate stain colors and textures in an available production stockpile, and (3) the textures and stain colors of adjacent nonproduction ledges. This information on stain colors and textures can be used by geologists while sampling ledges to signal possible quality problems or to verify quality of site stockpiled production. If this information is known then construction engineers using the information can use stain tests to verify project stockpiles.

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Analysis of Calcite, Dolomite and Texture, and Their Roles in Premature Deterioration of Portland Cement Concrete Pavement in Kansas

by

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Executive Summary

Premature deterioration of concrete pavement produced with Class I limestone indicated a need to better predict limestone that would be deleterious in the future while passing Class I test criteria. Using the information contained in the database prepared for FHWA KS-97/4, a classification of Kansas limestone has been obtained using texture and iron content of the carbonate minerals. Iron content of both the calcite and dolomite is indicated by the colors obtained with staining. The iron content and texture information in this investigation indicate that the greater the iron content, the greater the chances that the tested limestone does not pass Class I criteria. Since the limestone in the prematurely deteriorated pavement was Class I, the high iron content may be playing an important role in the premature deterioration. Some textures seem to have less iron content as evidenced in the database. Finely textured limestones have less iron content as indicated by stained peels. Coarsely textured limestones have more iron content. A higher proportion of finely textured limestone passes criteria for Class I aggregate.

Using the presented findings, field geologists could be provided with a field manual that includes texture and color criteria, stain recipe and procedure, and interpretation of stain results. This field manual can be revised and redefined as results of current related research are available and as experience in the field is gained. The field geologists could use the manual in the quarry to determine quickly (1) which texture category and stain colors individual ledges produce, (2) the aggregate stain colors and textures in an available production stockpile, and (3) the textures and stain colors of adjacent nonproduction ledges. This information on stain colors and textures can be used by geologists while sampling ledges to signal possible quality problems or to verify quality of site stockpiled production. If this information is known then construction engineers using the information can use stain tests to verify project stockpiles.

Introduction

When premature deterioration of concrete pavement in the Kansas City, Kansas area was found while attempting dowel bar retrofit construction on K-7 south of Bonner Springs, Kansas several questions were asked. Is the problem confined to this one project or all projects constructed with this aggregate source? Or is there a problem with this limestone from whatever source it is obtained? Do poor specs, poor adherence to the specs or inadequate testing enable this deterioration problem? Do we (the Kansas Department of Transportation, KDOT) need to change the specs or their administration? Do we need to change the tests, their criteria or add new tests? This investigation centers on limestone aggregate to find if there are additional indicators useful in determining good from poor quality aggregate. For this, the information obtained for the study FHWA KS-97/4, "Textural and Mineralogical Characterization of Kansas Limestone Aggregates in Relation to Physical Test Results" and contained in the database is used (1).

Background and Early Investigation

The first deteriorating pavement found was constructed using Argentine Limestone. It is an important source in the Kansas City area but problematic in that some sources pass testing and nearby sources fail. The reason for this is not understood. Information in the study database about Argentine ledges indicates that it often has high iron dolomite that stains a characteristic denim or indigo blue (PB). This blue color, as found in the entire database, is associated with failing tests in 67% of its occurrences. The remaining 33% pass Class I criteria and potentially are incorporated in Portland

Cement Concrete (PCC) pavement. This limited information concerning the Argentine and the incidence of the blue color led to a request to investigate the entire database. It was hoped the investigation would lead to a more inclusive understanding of how the limited information fits into the broader aspects of Class I aggregates.

The staining recipe used yields colors of red to red purple to purple for calcite with no to increasing amounts of iron in the structure (1). No iron in dolomite is indicated by lack of stain color, and small amounts by light blue and turquoise hues. High iron content is indicated by indigo blue, the characteristic blue mentioned with the Argentine Limestone. The colors resulting from the limestone staining were used as gradations on calcite and dolomite axes joined at the no iron content indicators. Examples of the color combinations for the calcite-dolomite color (or mineral color) grid are in Appendix A. Iron in these minerals is in the reduced or unoxidized state. Weathering causes the iron to form the rusty yellow or orange color found in some limestone.

Procedure for Investigation

Throughout this discussion, reference to passing or failing to meet Class I test criteria is given. The testing was done on individual ledges. The counts are derived from data on individual peels, which may vary from one to six obtained for each ledge. Each peel description recorded for a given ledge is different by texture, color combination, and area of stain or intensity of color. No attempt has been made to determine what portion of a ledge is represented by each peel. Thus a peel, representing a given set of limestone characteristics, but possibly present as a very minor portion of the ledge and contrary in description to the majority of the ledge, is given equal weight by count to a peel representing the major portion of the tested ledge.

Using the information contained in the database for the study FHWA KS-97/4, each peel was coded by dominant stain color and associated stain colors. The peels were sorted by the mix of calcite and dolomite staining and by texture. The tallies of peels falling into each category were placed in the calcite-dolomite stain color grid for each texture. Since there were few occurrences of Textures 4 through 8, these textures, which are related, were gathered into a combined mineral color grid. The complete texture grids are found in appendix A. Note that other factors have been found to be related to passing Class I testing. This study is limited to peel colors as they fall into the Munsell colors described and to textures. Other factors have not been investigated in this study. Neither the stain color intensity nor saturation was studied. Both of these indicators provide information on iron content. Increasing intensity or saturation indicates increasing iron in the carbonate minerals according to several studies. Other investigations found that clay content and type were important in passing Class I testing. This has not been checked with the reference ledges, but is currently part of the research on recent ledges. Many ledges have multiple peels, each different. The mix of colors and textures obtained when peels of one quarry ledge are combined is not addressed in this study. Research is ongoinginto the relationship of peel colors from ledge samples and stain colors from crushed aggregate from the tested ledge.

Figures 1 through 5 present the tallies for each texture and peel color combination in the grid. The columns and rows having no members in the mineral stain grid have been eliminated for producing contingency tables. Where necessary for mathematical reasons, some columns and rows have been combined, but only with closely related columns or rows. Once the contingency tables were satisfactory, each table or portion of table was used in χ 2 and Cramer's V tests as explained in the Smith and Pollock report (1).

Cramer's V calculations yield values from 0 to 1 with 0 having complete independence (no relationship) and 1 having complete dependence (variables completely explain the relationship). The Cramer's V values put all of the χ^2 scores on an equivalent basis so they can be compared. Low χ^2 scores usually mean low V values, but the population and dimension size of the table influences the computation also. The closer to 1 the better the examined variable explains the relationship being considered.

Discussion of Analysis Results

The figures 1 through 5 present the counts of peels passing or failing by mineral stain color combinations for each texture or consolidation of textures. Note that the patterns of occurrences vary by mineral color combination from texture to texture. This variance can be expected to lessen the significance of the texture consolidation tables based on the grid in Appendix A and Figure 1. The Cramer's V value for the table of those passing in Figure 1 is .33 and for those failing is .40. For Texture 1 the Cramer's V values improve, with a value for the table of passing counts of .49, and for that of failing of .63. Texture 2 values are .53 for the table of passing counts and .36 for failing. Texture 3, which had the least significance in the earlier study, has Cramer's V values of .64 and .49 for the tables based on passing and failing counts respectively. For Textures 4 through 8, the Cramer's V values are .38 and .33 for passing and failing count tables. The lower V values of Texture 1 and combined Textures 4 through 8 are probably explained by their smaller population numbers.

As can be seen in the figures 1 through5, several separate areas of the tables may have high counts or low counts. This bunching of counts into separate opposing areas is good for purposes of interpreting the results. The mathematical results can be lower Cramer's V scores. Nevertheless, these Cramer's V values indicate that there is dependence upon color and texture as described here but it is not complete dependence nor is it uniformly seen in all the color combinations and textures. This can be expected since the counts are based on peels not on ledges. The following discussion will be by textures, using divisions of each table to find the areas of higher significance.

While the consolidated texture table (Figure 1) does not have the highest Cramer's V values, discussion of it by color combination divisions will prove fruitful in the later discussions of the individual textures. By examination of the data from the table and for the practical reasons of using the information in the field for prospecting or for quality assurance, the table has been divided into the calcite stain color combinations of dominant red (R), dominant red purple (RP) and dominant purple (P). The dolomite exhibiting no iron (no stain or clear) is combined with the counts of light blue, indicating a small amount of iron, whether or not either of these is dominant. Iron oxide indicated by yellow red stain color (YR), is neither calcite nor dolomite, but is included in the division having little or no iron on the dolomite stain color axis. Indigo blue (PB) indicates high amounts of iron in the dolomite structure. The combinations of stains exhibiting only calcite stains, with no dolomite stain colors, is depicted as NONE and is included in the division of the dolomite axis having little or no iron. For the calcite stain color axis, the absence of dolomite colors is also shown as NONE, but is grouped with the high iron, or P, colors. These placements were made by inspection of the data and grouping it to make the most useful, practical calculations concerning relationships among stain colors and textures.

It is useful to study the tables as divided into nine segments. A schematic of these divisions is shown in figure 6a. These segments are described by columns A, B, and C with A representing red stain and its combination when dominant, B for red purple stain combinations and C for purple stain color combinations on the calcite axis. The rows are 1, 2, and 3 with NONE, no stain color (clear), light blue and yellow red in row 1, the combination yellow red with purple blue (PB) in row 2 and purple blue in other combinations in row 3. Row 2 is very minor in counts, but since yellow red usually is indicated in passing counts and purple blue more likely in failing counts this combination is separated from rows 1 and 3 which contain one or the other color. These segments in order indicate a rough approximation of stains having little iron content to those having high iron content in the carbonate minerals.

The passing and failing counts for the combination of all the textures, as divided into the nine segments, are presented in figure 6b. The percent passing Class I test criteria are shown for each segment in figure 7. The portion of the entire count that falls into each segment is seen in figure 8 and expressed as percent. Note that as iron content increases in calcite (reading in order A, B, C) the percent passing Class I criteria decreases. This same observation can be made for dolomite. The exception is shown by row 2 having very few counts. This shows the general pattern to be seen in each of the texture divisions, noting that row 2 can be contradictory as mentioned but having very low counts. The details for the separated texture tables differ as can be seen in the following discussions. The Cramer's V calculation for the data in this schematic is .53, increased from .33 and .40 for Figure 1.

Texture 1, seen in Figure 2, is over 17% of the counts in Figure 1, totaling 78. Figure 9 presents the counts for each segment by passing/failing categories. Note that very few fall into the segments in row 2, A3 or B3, the higher iron content areas. Also, note that over half of the overall total is in segments in row 1. The percent passing in each segment is presented in Figure 10. The portion of the total occurring in each segment is shown in Figure 11. For this texture, there are few descriptions that include high iron content stain color especially in the dolomite mineralogy. Because of this distribution, nearly 67% of the descriptions with Texture 1 pass Class I test criteria. Half of those failing are in segment C3, the highest in iron content. Cramer's V calculation is .32 for Texture 1, probably lower because of the small number.

Texture 2, as seen in Figure 3, has nearly twice the population as Texture 1. The counts and percent passing per segment are shown in Figures 12 and 13. Observing Figure 14, one can note that the population is spreading differently. Only 51 of the total 140 occur in segments in row 1 for about 36% of the total. The percent passing in each segment follows a different pattern than Texture 1 in that 91% pass in the column A; segments B1 and B2 have 38% of the counts; and about 53% pass in the segments of column 3 and B3, representing 62% of the counts. Despite these differences from the pattern of Texture 1, the general pattern of decreased percentages passing as iron content increases is still demonstrated in Texture 2, except in low count segments. Cramer's V value for Texture 2 is .64.

Figure 4, presenting Texture 3, has the largest population of the texture divisions at 358. Figures 15, 16 and 17 present the information by segments concerning the distribution for Texture 3. This distribution is also different in pattern compared to Textures 1 and 2. This texture has very few counts in the segments contained in column A, and B accounts for 33% of the total counts, and column C accounts for 61% of the total counts. Note that 58% pass in B1 and 58% pass in B3 with no decrease in passing with iron content. This could be something that on further accumulation of data can be explained as a current non-random collection of samples in this texture and color combination, or it may reflect higher amounts of iron in the calcite structure. While the percent passing does not change in these two segments, the portion of the table is increasing in B3, which is a clear difference from Textures 1 and 2. Inspection of the figures confirms that the general pattern of decreased occurrence of passing is exhibited with the increase in iron content of the carbonate minerals dolomite and calcite with the exception noted. Cramer's V value is .52 for Texture 3.

With the Textures 1 and 2 similar in the pattern, more so than with Texture 3, combining the two divisions would be helpful in eliminating unneeded clutter. Both are dominated by micrite giving a fine texture. The new information by segments is given in figures 18, 19, and 20. The proportions of each segment reflect the combining of the two groups. The general pattern of percent passing decreasing as iron content increases is maintained as would be expected. The calculation of Cramer's V yields .67, an increase for both textures.

For the remaining Textures, 4 through 8, the counts are seen in Figure 5. These textures are related by being dominated by courser grains in the rock structure and individually would not present much information, but combined they present useful meaning for the group. The information by segments is found in Figures 21, 22, and 23. The most important aspect coming from inspection of Texture 4 through 8 information is that only 37% and 33% pass in the segments C1 and C3, and B3 has only 41% passing. These segments have much lower passing rates than the other textures in these high iron areas. Cramer's V value is .37 for Textures 4 through 8. The lower values for both Texture 1 and this grouping may be a reflection of their small populations.

Examining the figures for Textures 1 and 2 together, Texture 3, and Textures 4 through 8 together, one can note that Textures 1 and 2 have a larger percent of counts in columns A and B, those with less iron content on the calcite axis. There are also many more passing, 76% compared to 63% for Texture 3 and 48% for Textures 4 through 8 in row 1. Texture 3, while having very similar proportions to Textures 4 through 8 by row or column totals, is intermediate between the other texture groups. Note the changing proportions in each texture group in row 1 reading from no iron to high iron. The changing percent passing has already been discussed for row 1. Examining row 3, note the trends among texture groups. The general pattern discussed for the combined textures for Figures 6 through 8 remains true; as iron content increases, percent passing decreases. There are also differences that have some pattern relating to texture and stain color. Textures 1 and 2 have higher counts dominated by low iron dolomite. Textures 4 through 8 have higher counts and fewer passing in the portion dominated by high iron dolomite and calcite. The coarser the texture and the higher the iron content, especially in the dolomite minerals, the more failure is encountered.

With these findings it is now possible to investigate Argentine Limestone variability and also the role of the characteristic blue (PB) stain color. In the database 24 ledges yield 13 Class I designations and 11 fail criteria. Of these 24 ledges there are 45 peels of which 20 are from the Class I ledges and 25 from failed ledges. Of the 13 passing ledges only four have no blue color in the stain description. The remaining nine have purple blue included. Of the 11 failing ledges, two have no purple blue stain color described. The counts of pass/fail for all the Argentine ledges in the database are presented in Figure 24.

The information presented can now allow for much better prediction of a ledge passing or failing, if peels are made. Since the study was made with data from peels with many ledges exhibiting much variability and therefore many peels, a study to find ways to better predict using multiple peels as are exhibited by many ledges may be more helpful for prediction. We have been exploring various means including pie charts or other graphics for usefulness in prediction. The current implementation of carbonate staining tests by comparing peel colors to crushed aggregate stain colors may help simplify the task. This is a current research activity.

Several factors known to be influential in passing or failing have not been considered in this study; clay content, and clay type (2), and stain color by saturation and intensity. An earlier limited study indicated that natural color can predict clay content or high iron minerals and failing to some extent. The use of natural color and acid insoluble residue for X-Ray Diffraction (XRD) analysis of clay type may allow better discrimination of poorer performers from better aggregates. This is currently under investigation. Because of the many steps involved, this analysis will require a large portion of time.

Conclusions

From the inspection of data in this study, two main items are much clearer than in the previous study. As iron content increases in both calcite and dolomite in the limestone, the probability of passing Class I criteria decreases. The coarser the texture the more pronounced is the tendency to fail with increasing iron content. There may be ledges that pass Class I criteria, but have iron in the crystal structure of either or both calcite and dolomite. The iron ion in the crystal structure possibly makes it unstable enough to react after several years in a concrete pavement. When the iron oxidizes, the concrete may fail. The coarser textures may be more vulnerable to iron being incorporated into the structure and/or for the iron present to be exposed to further destabilization once in a pavement. Certainly, the amount of iron would be a greater factor in the elapsed time between placing the pavement and its failure.

Implementation

The information presented here can form the basis for collecting information using a field manual. A field manual can provide the following:

a) stain recipe suitable for use on ledge samples or crushed aggregate
b) procedures to stain selected samples in the field
c) color code for interpreting stain results
d) texture classification
e) mineral grid for Textures 1 and 2
f) mineral grid for Texture 3
g) mineral grid for Textures 4 through 8

During inspection of quarries or stockpiles, selected samples can be classified by textures and stain color. When the stain colors and textures for production and adjacent non-production ledges are known, similar classification of stockpiled aggregates can be a useful tool for assessing the quality of the stockpile. Stockpile information can be collected and used by construction engineers for assessing project stockpiles. Comparison of stockpile information with information from the ledge sources can be useful for quality management.

The calcite/dolomite mineral grid provides more organization and information to the data from limestone ledges. The iron content of the carbonate minerals along with the textures reveals relationships to passing or failing Class I test criteria. This schematic will be used with current research as data becomes available. Ongoing current research includes x-ray diffraction identification of clay types, natural color, stain colors of crushed aggregate compared to colors of peels in the same ledge. As new information proves useful for field assessment, it can be added to the field manual.

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(2) Goldstein, R.H., J. McKirahan, and E. K. Franseen, "Sequence Stratigraphy of the Lane – Island Creek Shale and the Farley Limestone in Northeastern Kansas and Geologic Factors Affecting the Quality of Limestone Aggregates" (in process) K-TRAN: KU-97-1.

	(R)+(R /RP)	(R/RP/P)	RP/R	(RP)	RP/R/P+ (R/P)	RP/P	P/R+RP/P	P/RP/R	P	P/RP
None	18/2	4/0	10/0	12/13	8/1	2/0	9/10	2/1	-	7/11
(CL)	4/0	4/0	10/3	22/4	3/1	6/3	11/7	1/2	3/0	2/6
(YR)	-	-	-	3/0	1/0	-	1/0	1/0	-	-
(B)+CL/YR	-	-	-	3/2	-	-	-	-	1/1	-
(PB/YR)	1/2	-	-	1/2	-	-	-	-	2/1	-
(PB/CL)	8/0	-	7/0	10/9	4/4	7/5	7/4	2/2	3/5	9/12
(PB/CL)	1/1	-	-	0/6	1/1	1/1	-	-	6/17	0/1
PB	0/2	1/0	-	15/9	7/1	2/1	4/2	5/0	3/0	9/17
PB	2/0	-	-	-	3/4	5/4	-	-	6/7	1/1

Figure 1. Pass/Fail data for all textures totaled together as prepared for calculation of Chi-sq and Cramer's V values.

Figure 2. Pass/ Fail data for Texture 1 as prepared for calculation of χ^2 and Cramer's V values.

	R+RP+	RP	R/RP/P	R/P RP/P RP/P	RP/R/P P/RP/R	None	P/R P/RP P
None	5/2	4/4	0/0	2/0	3/0	0/0	5/2
(Cl)	4/0	4/2	1/0	1/0	3/0	2/0	0/1
PB/CL	2/0	1/0	0/0	1/1	0/0	0/1	0/1
YR + YR+	0/0	0/0	0/0	0/0	0/0	0/0	1/0
CL/YR	0/0	0/0	0/0	0/0	0/0	0/0	1/0
PB/YR+ YR	1/0	0/0	0/0	0/0	0/0	3/0	0/0
PB/CL	0/0	0/0	0/0	0/0	0/0	0/0	1/4
PB	0/1	0/0	0/0	2/0	0/0	0/0	5/3
PB	0/0	0/0	0/0	0/0	0/0	3/3	0/0

Figure 3. Pass/Fail data for Texture 2 as prepared for calculation of χ^2 and Cramer's V values.

	(R)	R + RP	R + RP With P	NONE P/R P/R/RP	P/RP	P
None	1/0	17/0	5/4	2/0	1/2	0/0
(Cl)	0/0	2/0	11/1	2/1	0/1	2/3
(B)+YR	0/0	2/0	2/1	2/1	0/0	1/1
PB/CL+ PB/YR	0/1	7/1	6/9	0/1	0/2	6/1
PB/CL	0/0	3/0	1/3	1/2	2/1	6/10
PB	1/0	0/1	1/3	3/2	0/0	0/0

Figure 4. Pass/Fail data for Texture 3 as prepared for calculation of χ^2 and Cramer's V values.

	(R) (R/RP)	(RP),RP/R (R/RP/P)	(R/P) (RP/P)	R/P P/RP/P NONE	P	P/RP	P
NONE	7/0	7/6	8/9	0/1	0/0	4/4	5/4
(CL)+(B)	6/0	16/5	7/7	2/2	0/0	2/3	1/6
YR PB/YR CL/YR	0/0	1/1	0/0	0/1	1/0	0/0	2/0
PB/YR CL/PB PB/YR	1/0	0/0	0/0	1/0	1/1	0/0	4/1
PB/CL	2/0	9/4	9/8	4/3	2/3	7/8	18/4
PB/CL	1/1	1/5	1/1	0/3	5/15	0/0	0/0
PB	0/1	11/3	8/2	0/0	1/0	5/13	18/24
PB	1/1	0/1	8/4	2/7	3/2	0/0	1/0

Figure 5. Pass/Fail data for Textures 4, 5, 6, 7, and 8 as prepared for calculation of χ^2 and Cramer's V values.

All R +	All RP R with PorRP	P/R except w/P	P + + P	NONE
None	3/0	0/1	0/0	1/7
(Cl)	0/0	4/0	3/2	1/3
(B)+YR + CL/PB	0/0	0/2	0 /0	2/0
PB/CL+ PB/CL	1/0	4/1	1/2	4/6
PB	3/0	1/4	2/3	5/10

Figure 6a. Schematic of partitioning data into stain color segments.

	(R)	(RP)	(P)
None, CL, (YR), (B)	A1	B1	C1
(YR/PB)	A2	B2	C2
PB alone and with CL	A3	B3	C3

Figure 6b. Pass/Fail counts for each segment of all textures together.

	A	**B**	**C**
Row 1	32/2	62/32	55/57
Row 2	1/2	1/3	6/2
Row 3	12/5	56/45	114/146

Figure 7. Percent passing of entire segment for all textures together.

	A	**B**	**C**
Row 1	94	66	50
Row 2	33	25	75
Row 3	71	55	43

Figure 8. Portions of the total of all textures together shown by percent passing in each segment.

	A	**B**	**C**
Row 1	5	13	18
Row 2	>1	>1	1.5
Row 3	2.5	16	41

Figure 9. Pass/Fail counts for each segment of Texture 1 data.

	A	B	C
Row 1	9/2	20/6	8/4
Row 2	0/0	1/0	1/0
Row 3	0/1	4/0	9/13

Figure 10. Percent passing of each segment of Texture 1data.

	A	B	C
Row 1	82	77	67
Row 2	0	100	100
Row 3	0	100	49

Figure 11. Portion of the total of Texture 1 data shown by percent passing in each segment.

	A	B	C
Row 1	14	33	15
Row 2	0	>1	>1
Row 3	>1	5	28

Figure 12 Pass/Fail counts for each segment of Texture 2 data.

	A	B	C
Row 1	7/0	34/5	10/10
Row 2	0/2	0/3	1/0
Row 3	2/1	14/11	22/21

Figure 13. Percent passing of each segment for Texture 2 data.

	A	B	C
Row 1	100	87	50
Row 2	0	0	100
Row 3	33	56	51

Figure 14. Portion of the total of Texture 2 data shown by percent passing in each segment.

	A	B	C
Row 1	5	28	14
Row 2	1	2	>1
Row 3	2	18	31

Figure 15. Pass/Fail counts for each segment of Texture 3 data.

	A	B	C
Row 1	12/0	30/22	25/27
Row 2	1/0	0/0	4/2
Row 3	4/3	39/28	70/91

Figure 16. Percent passing of each segment for Texture 3 data.

	A	B	C
Row 1	100	58	49
Row 2	100	0	67
Row 3	57	58	43

Figure 17. Portion of the total of Texture 3 data shown by percent passing in each segment.

	A	B	C
Row 1	3	14	14
Row 2	1	0	1
Row 3	2	17	48

Figure 18. Pass/Fail counts for each segment when Texture 1 and Texture 2 data are combined.

	A	B	C
Row 1	16/2	54/11	18/14
Row 2	0/2	1/3	2/0
Row 3	2/2	18/11	31/24

Figure 19. Percent passing of each segment for combined Texture 1 and Texture 2 data.

	A	B	C
Row 1	89	83	56
Row 2	0	25	100
Row 3	50	62	48

Figure 20. Portion of the total of combined texture 1 and 2 data shown by percent passing in each segment.

	A	B	C
Row 1	8	30	15
Row 2	>1	2	>1
Row 3	2	13	30

Figure 21. Pass/Fail counts for each segment of Textures 4, 5, 6, 7, 8 combined.

	A	B	C
Row 1	1/0	5/3	6/12
Row 2	0/0	0/0	1/0
Row 3	4/0	7/10	13/22

Figure 22. Percent passing of each segment for combined Textures 4 through 8.

	A	B	C
Row 1	100	63	33
Row 2	0	0	100
Row 3	100	41	37

Figure 23. Portion of the total of combined Textures 4 through 8 data shown by percent passing in each segment.

	A	B	C
Row 1	1	12	21
Row 2	0	0	1
Row 3	5	20	39

Figure 24. Pass/Fail counts for Argentine ledges reported from the FHWA-KS-97/4 database. All textures are combined.

	A	B	C
Row 1	0/0	6/3	3/4
Row 2	0/0	0/0	1/0
Row 3	0/0	4/3	7/15

Appendix A

Table 1....Texture ALL

Calcite / Dolomite Color Tallies by Texture November 1999

Texture ALL

Note: ( ) includes dominant and non dominant color entries; dominant; Pass/Fail notation

	R		R		R/RP		R/RP		R / RP / P		R / RP / P		RP		RP		RP/R		RP / R / P	
None	1	0			5	1	12	1	1	0	3	0			12	13	10	0	6	1
(CL)					3	0	4	0	2	0	2	0			21	3	10	2	3	1
(B)													1	0	2	1				
(YR)															2	0			1	0
CL/YR															0	1				
YR/PB			0	1	1	1									1	2				
PB/YR																				
PB/CL													0	1						
PB/CL					8	0							1	0	8	9	7	0	1	0
PB/CL	1	1											0	5	1	0				
PB					0	2			1	0			2	1	13	8			1	0
PB			2	0	0	1	0	1												

	R/P		R/P		RP/P		P/R		RP/P		P / RP / R		P		P/RP		P		NONE	
None	2	0	2	0			8	6	1	4	2	1			7	11	8	8		
(CL)			5	3			9	7	1	0	1	2	3	0	2	6	4	11	0	1
(B)													0	1			0	1	3	1
(YR)									1	0			1	0			4	0	1	0
CL/YR																	2	0	0	1
YR/PB													0	1			5	1		
PB/YR													1	0						
PB/CL																				
PB/CL	0	1	3	3	7	5	7	4	2	2			3	5	9	12	25	19	1	0
PB/CL					1	1	1	1			0	1	6	17	0	1	1	3	0	4
PB	2	1	4	0	2	1	4	2	5	0			3	0	9	17	31	42		
PB			1	4	5	4	2	0					6	7	1	0	1	0	3	10

Table 2....Texture 1

Calcite / Dolomite Color Tallies by Texture November 1999

Texture 1

Note: ( ) includes dominant and non dominant color entries; dominant; Pass/Fail notation Pass/Fail values of 0/0 are not shown

	R		R		R/RP		R/RP		R / RP / P		R / RP / P		RP		RP		RP/R		RP / R / P	
None					5	1	0	1							4	4	2	0	3	0
(CL)					2	1			1	0	1	0			4	2	2	0	2	0
(B)																				
(YR)																				
CL/YR																				
YR/PB													1	0						
PB/YR																				
PB/CL																				
PB/CL															1	0	1	0		
PB/CL																				
PB					0	1														
PB																				

	R/P		R/P		RP/P		P/R		RP/P		P / RP / R		P		P/RP		P		NONE	
None					2	0					1	0			2	1	2	1		
(CL)							0	1	1	0			2	0	0	1				
(B)																				
(YR)																				
CL/YR																	1	0		
YR/PB																				
PB/YR																				
PB/CL																				
PB/CL									1	0			0	1	0	1				
PB/CL							0	1							0	1	1	2		
PB									1	0					2	1	3	3		
PB													2	0					1	3

Table 3....Texture 2

Calcite / Dolomite Color Tallies by Texture   November 1999

Texture 2

Note: ( ) includes dominant and non dominant color entries; dominant; Pass/Fail notation   Pass /Fail values of 0/0 are not shown.

	R		R		R/RP		R/RP		R / RP / P		R / RP / P		RP		RP		RP/R		RP / R / P		R/P		R/P		RP/P		P/R		RP/P		P / RP / R		P		P/RP		P		NONE	
None	1	0					5	0			2	0			5	4	8	0			2	0					1	0			1	0			1	2				
(CL)															7	0	2	0	1	0					3	1	2	0	1	0	0	1			0	1	2	3		
(B)													1	0																			0	1			0	1	2	1
(YR)													1	0	1	0			1	0									1	0							1	0		
CL/YR																																								
YR/PB			0	1	0	1									0	2							0	1											1	0				
PB/YR																																								
PB/CL																																								
PB/CL															3	5	1	0	1	0							3	0	1	2			0	1	0	2	5	1		
PB/CL																																					0	1	0	1
PB									1	0			1	0	4	2			1	0			1	0	0	1	1	1	1	0			1	0	2	1	6	9		
PB			1	0			0	1															0	1			2	0					1	2					1	2

Table 4....Texture 3

Calcite / Dolomite Color Tallies by Texture   November 1999

Texture 3

Note: ( ) includes dominant and non dominant color entries; dominant; Pass/Fail notation   Pass/Fail values of 0/0 are not shown.

	R		R		R/RP		R/RP		R / RP / P		R / RP / P		RP		RP		RP/R		RP / R / P		R/P		R/P		RP/P		P/R		RP/P		P / RP / R		P		P/RP		P		NONE	
None							7	0			1	0			3	5	2	10	1	1							7	6	1	3	0	1			4	4	5	4		
(CL)							4	0							7	2	6	2	0	1					2	3			5	4	1	1			2	3	1	6		
(B)															2	0																								
(YR)															1	0																	1	0			1	0		
CL/YR															0	1																					1	0		
YR/PB					1	0																											0	1			3	1		
PB/YR																															1	0								
PB/CL																																					1	0		
PB/CL					2	0							1	0	3	4	4	10					3	3	5	4	4	4					2	3	7	8	18	14		
PB/CL	1	1											0	5	1	0									1	1							5	15						
PB													1	0	9	3					1	1	1	0	1	0	3	1	2	0			1	0	5	13	18	24		
PB			1	0	0	1																	1	3	5	4							3	2			1	0	1	4

Calcite / Dolomite Color Tallies by Texture November 1999

Texture 4-8

Note: ( ) includes dominant and non dominant color entries; dominant; Pass/Fail notation Pass/Fail values of 0/0 are not shown.

	R		R		R/RP		R/RP		R / RP / P		R / RP / P		RP		RP		RP/R	
None											2	0					0	1
(CL)									1	0					3	0	0	1
(B)															0	1		
(YR)																		
CL/YR																		
YR/PB																		
PB/YR																		
PB/CL													0	1				
PB/CL					1	0									1	0	1	0
PB/CL																		
PB													0	1	0	3		
PB																		

	RP / R / P		R/P		R/P		RP/P		P/R		RP/P		P / RP / R		P		P/RP		P		NONE	
None																	0	4	1	3		
(CL)									2	2							0	1	2	2		
(B)																						
(YR)																			1	0		
CL/YR																						
YR/PB																			1	0		
PB/YR																						
PB/CL																						
PB/CL							2	1							1	0	2	1	2	4		
PB/CL									1	0			1	0	1	2						
PB	1	0	2	0							1	0			1	0	0	2	4	6		
PB															0	3	1	1			0	1