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HIGHWAY RESEARCH REPORT

EVALUATION OF ROCK SLOPE PROTECTION MATERIAL

FINAL REPORT

69-27 DND

STATE OF CALIFORNIA
BUSINESS & TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT
RESEARCH REPORT
NO. M & R 632561

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads June, 1969

69-27
DND

STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

Research Project
P.W.O. 632561

June, 1969

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

EVALUATION

of

ROCK SLOPE PROTECTION MATERIAL

Travis Smith
Principal Investigator

Marvin L. McCauley
Ronald W. Mearns
Co-investigators

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

REFERENCE: Smith, Travis; McCauley, Marvin L.; and Mearns, Ronald W. "Investigation of Rock Slope Protection Material," State of California, Department of Public Works, Division of Highways, Materials and Research Department, June, 1969, Research Report Number 632561.

ABSTRACT: Samples of rock slope protection material were obtained and classified as "Good" or "Unsatisfactory" on the basis of visual examination and past performance on installations. Test data for the Durability and Rapid Abrasion tests and for the Durability Absorption Ratio were obtained and analyzed. Specifications for these quality determination methods were established. All of the new methods were more accurate in determining material quality than the 1969 Standard Specifications used by the California Division of Highways. Because the Durability Absorption Ratio is the most accurate and shows less tendency to discriminate against some rock types, it is recommended as the Standard Specification for quality control of rock slope protection material.

KEY WORDS: Abrasion, Absorption, Durability, Evaluation, Materials Testing, Materials Specifications, Quality Control Testing, Research, Riprap, Slope Protection, Specifications, Test Methods.

ACKNOWLEDGMENT

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The opinions, conclusions and recommendations expressed in this report are those of the authors and are not necessarily those of the Bureau of Public Roads.

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INTRODUCTION

One indication of the increasing need for satisfactory slope protection material is the fact that five times as many rock slope protection material samples were submitted to the Materials and Research Department of the California Division of Highways during 1968 as were submitted during 1958.

During this same period of time, various Districts of the California Division of Highways wrote special specifications for rock slope protection material on numerous contracts. Special specifications were necessary to permit the use of known satisfactory material which did not comply with requirements of the California Standard Specifications.

As a result of these conditions, the Materials and Research Department believed a thorough study of the properties of rock slope protection material was desirable. Development of specifications which correlate more closely with the field performance of the material would be a significant improvement. A research proposal was prepared and it was approved by the Bureau of Public Roads in 1963 and work was started in early 1964.

The original study had three major divisions: inspection and evaluation of material on installations; evaluation of the California Standard Specification tests; and evaluation of selected experimental tests. The results of this earlier study are contained in a report titled "Investigation of Rock Slope Protection Material" and dated April, 1967. In this report it was recommended that the Los Angeles Rattler test be eliminated and that the loss in the Sodium Sulfate Soundness test be increased to 10% maximum. A decrease in testing costs and closer correlation between test results and field performance were realized as the result of the adoption of these changes.

Three other recommendations made in the report referred to methods of determining rock quality that appeared better than the methods specified in the California Standard Specifications. A proposal to evaluate these recommendations was prepared by this Department and approved by the Bureau of Public Roads in 1967. The objectives of this second study were:

1. Develop a specification for Durability
2. Develop a test method and specification for Rapid Abrasion
3. Develop a formula and limits for the Durability Absorption Ratio

The results of the second study are presented in this report.

A total of 265 samples, gathered from throughout the state and representing all major rock types and environments, were used to fulfill the objectives of this research project.

SUMMARY

Test results from a total of 265 samples were used in meeting the objectives of this study. The samples were classified as either "Good" or "Unsatisfactory" on the basis of prior performance records, visual examination, and analysis of mineral composition but not on the basis of test results. After classifying the samples, results were obtained for each of the methods being studied and also for tests required in the 1969 California Standard Specifications. The test result which yielded the highest percentage of correct predictions of performance classification was then determined and used as the specification. Table 1 summarizes the results of this analysis.

Test Method	Specification	No. of Samples	Correct Predictions Number	Correct Predictions Percent
Durability Index	52 min.	264	249	94.3
Rapid Abrasion	24% max. loss	112	99	88.4
Durability Absorption Ratio	*	261	253	96.9
Standard Specifications	**	257	218	84.8

Table 1. Comparison of Correct Predictions by Various Test Methods

* Greater than 24 - pass
Less than 10 - fail
10 through 24 - if Durability Index 52 min. - pass

** California Standard Specifications - January 1969

It is readily apparent that all of these test methods offer significant advantages over the test methods required in the 1969 California Standard Specifications in terms of being able to predict field performance of the material. The Durability Absorption ratio is the most accurate of the three methods studied, is cheaper and faster to perform than the current required specification tests, can be done at the District level and does not appear to favor or discriminate against any of the major rock types. For these reasons, it is recommended that the Durability Absorption ratio be adopted as the quality control specification for rock slope protection material.

CONCLUSIONS

1. The specifications for quality control of rock slope protection material in the 1969 California Standard Specifications are correct only about 85% of the time. They are frequently responsible for the rejection of material which can perform satisfactorily. As a result the purchasing and hauling costs are frequently higher than necessary.

2. Material quality control with the present specifications is expensive and time consuming in comparison to use of the Durability Absorption ratio.

3. The Durability and Rapid Abrasion tests, although more accurate for quality control than the current Standard Specifications tests, tend to favor igneous extrusive rocks and discriminate against igneous intrusive rocks.

4. The Durability Absorption ratio provides the most accurate quality control of the methods studied, provides answers relatively quickly at the District level, and is relatively consistent with respect to the type of rock. Adoption of this method of quality control will provide satisfactory material at substantial savings in testing and shipping costs, and should result in a reduction in construction costs for rock slope protection material.

RECOMMENDATIONS

It is recommended that the following specification for material quality requirements be adopted in lieu of the requirements included in paragraphs 72-2.02 and 72-5.02 of the 1969 California Standard Specifications.

Test	Test Method No. Calif.
Absorption	206
Durability	229

Combine Durability and Absorption test results:

$$\frac{\text{Durability Index}}{\text{\% Absorption} + 1} = \text{Durability Absorption Ratio (DAR)}$$

1. DAR greater than 24 - acceptable material
2. DAR less than 10 - unacceptable material
3. DAR 10 through 24

   A. Durability 52 or greater - acceptable material
   B. Durability less than 52 - unacceptable material

TEST METHODS

Test results are a reflection of physical properties of the material in the sample tested. The application of these test results to large masses of rock is valid only when the sample is truly representative of the larger mass.

If rock is homogeneous, unweathered and massive, sampling is a relatively simple task but it becomes increasingly difficult as differing degrees and depths of weathering, complex geologic structures, and varying rock types are encountered. It should be obvious that judgment and experience are required to obtain representative samples. It should be equally obvious that test results and specifications are meaningless unless the sample is representative of the rock being tested. Proper sampling is the key to good quality control of rock slope protection material.

Visual evaluation of a material by an experienced engineer or geologist is an extremely accurate method of determining rock quality. In the original study of rock slope protection material, samples with known performance were shown to an experienced engineering geologist and he correctly evaluated 93% of these samples without prior knowledge of their performance. It is believed that qualified observers will evaluate samples substantially the same as each other, although no tests were performed to verify this.

In this report the methods of measuring quality in rock slope protection material are compared by using the percentage of correct performance predictions. The quality scale of the material is determined by previous performance and visual evaluation but not test results. The value of test results which has the highest percentage of agreement with the quality evaluation is determined and used for the purpose of comparison with other test methods. The percentages of correct predictions reported are in relation to this base. The absolute percentage of correct performance predictions will probably not vary greatly from the reported percentage due to the high accuracy of the quality evaluations.

Originally, all samples used in this study were classified either "Good," "Marginal" or "Unsatisfactory" on the basis of visual examination in the laboratory. The "Marginal" category was used for those rocks which were borderline quality or which might work in certain mild environments. It was anticipated that this "Marginal" category would complicate the analysis of test results so all "Marginal" samples were reclassified as "Good" or "Unsatisfactory." This reclassification was accomplished in most cases by obtaining performance records but in some cases judgment with a lower confidence level was used. Test results were not used in any way to determine rock quality classification.

Data obtained during this study are tabulated in Appendix 1. The distributions of results for the quality determination methods being studied are shown on the histograms in Appendix 2. The value for each test method, which when used as a specification, gave the highest percentage of correct predictions of rock quality was determined and used as the specification for the tests being evaluated.

The test methods with which this study is concerned are discussed in this section of the report and described in detail in Appendix 3.

Durability Index

The Durability Index for coarse aggregate is determined by Test Method No. California 229. It is a measure, to some extent, of the quality and quantity of fine material washed and/or abraded from the surface of the material being tested. There is a good correlation between results of this test and rock quality but no effort was made to determine the reasons for this correlation.

The peculiar data gaps evident in the Durability histogram in Appendix 2 are the result of the complex mathematical computations used in obtaining the Durability Index.

Durability indices were obtained for 264 samples. Of this total, 221 (83.7%) were classified "Good" and 43 (16.3%) were classified "Unsatisfactory." The highest percentage of correct predictions was 94.3 and occurred when a minimum Durability Index of 52 was used to determine "Good" rock.

Although this test was a significant improvement over the tests required by the 1969 California Standard Specifications it was decided not to recommend a Durability Index specification because of a tendency to discriminate against igneous intrusive rocks and to favor igneous extrusive rocks. Only 9% of the rocks classified as "Unsatisfactory" were igneous intrusive rocks but 15% of the rocks that failed the Durability Index 52 minimum requirement were igneous intrusive. Igneous extrusive rocks comprised 30% of all rocks classified as "Unsatisfactory" but only 18% of all rocks that failed the Durability Index 52 minimum requirement.

Rapid Abrasion

The Rapid Abrasion test used in this study was developed by the Materials and Research Department. The concept is based on the assumption that there is some correlation between the resistance to waterborne abrasives and the ability to provide adequate protection on a rock slope protection installation.

The test method, which is described in Appendix 3, was adapted from the tumbling technique used by "rockhounds" for polishing small rocks. It consists of rolling rock, water and abrasives together for a given time and then measuring the weight loss of the rock.

A standard laboratory jar mill, number 784V and Roalox grinding jars Size 0 manufactured by U.S. Stoneware were selected for use in this study. The jar rolling rate was arbitrarily set at 66 rpm which is a typical rock tumbling rate.

The amount of water to be used, also set arbitrarily, is the amount necessary to just cover the sample and abrasive.

A thorough study of the quantity of abrasives and sample to use in the jars which were selected was not made because of a shortage of samples, time and funds, and because it was believed that any standardized test method would provide results useful for comparative analysis. Some testing was performed and the results confirm what professional rock polishers suggested for optimum quantities. The sample should fill up about 50 to 60 percent of the tumbler as it was found that too much sample inhibited the tumbling action and too little does not permit it to start. The amount of abrasive was not as critical and the tests indicate that 3.5% by weight of abrasives will give the maximum abrasive effect. Increasing the quantity of abrasive above 3.5% results in a reduction of the abrasive effect as the abrasive particles begin to act on each other instead of on the sample.

The length of time that samples should be tumbled was thoroughly investigated because of a possible relationship to reproducibility. The findings are included in Table 2 and are plotted in Figures 1 and 2. No evidence of a relationship to reproducibility was found and in all cases our eight-hour rolling time was found to be well into the most linear portion of the loss curve.

Time in Hours	PERCENT LOSS BY WEIGHT									
	64-5175	65-2716	65-2717	65-3190	65-3192	67-3490	68-1190	68-1571	68-2497	68-2498
0.5	2.1	-	1.5	1.8	3.2	7.9	1.7	3.9	2.3	3.0
1	3.4	2.6	3.2	2.5	4.4	9.8	2.7	7.8	4.4	4.6
2	5.1	-	4.6	4.5	7.8	12.8	4.8	9.3	6.7	7.2
3	7.2	5.9	5.5	6.0	10.0	15.5	5.5	13.0	8.6	9.4
4	8.2	-	-	-	11.7	23.3	7.5	-	10.6	11.9
5	-	8.3	6.8	9.1	-	26.1	8.8	17.0	12.4	-
6	-	-	9.2	10.0	15.7	25.3	9.5	-	-	-
7	10.6	9.5	8.8	11.1	-	30.5	9.8	21.2	13.9	15.7
8	13.1	-	9.6	10.8	19.5	32.1	11.2	22.6	16.4	19.2
9	-	10.8	9.7	12.2	20.2	36.5	12.3	23.7	-	-
10	-	-	-	12.0	21.6	38.6	13.1	25.2	-	-
11	-	11.7	-	13.5	23.4	39.2	13.2	26.9	-	-

Table 2. Loss in the Rapid Abrasion Test versus time.

Figure 1

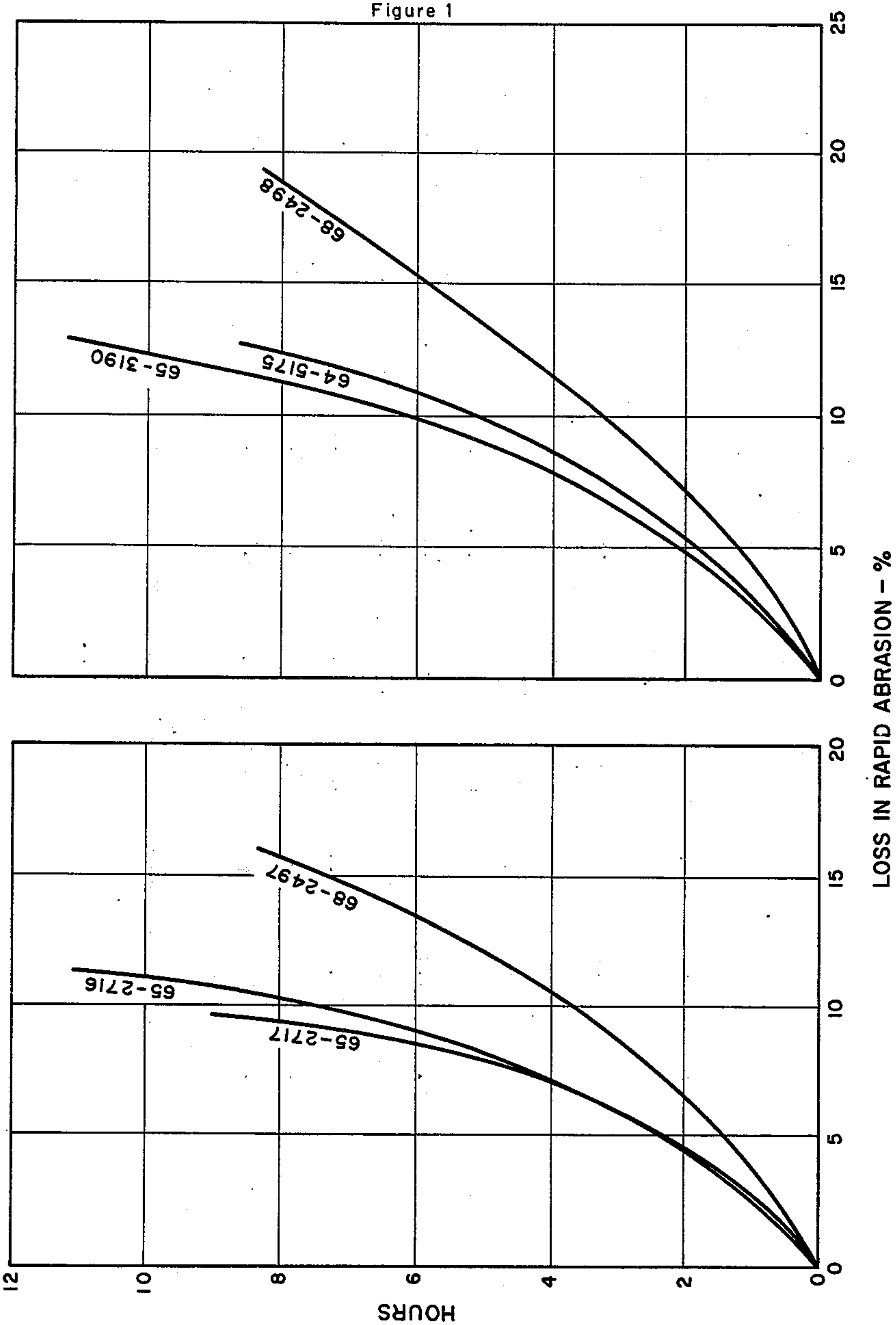
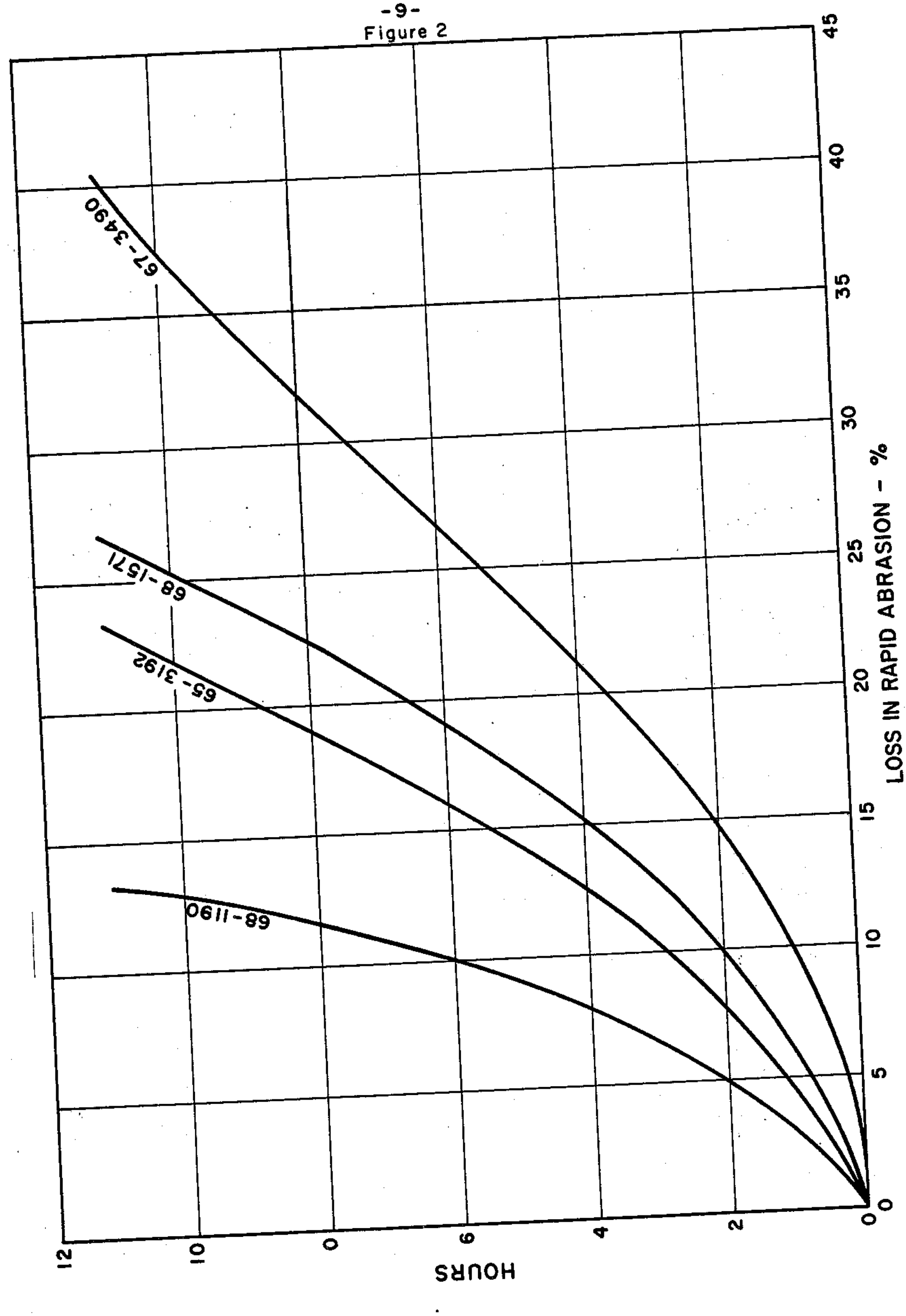

LOSS IN RAPID ABRASION – %
HOURS
68-2498
64-5175
65-3190
68-2497
65-2716
65-2717
0
5
10
15
20
25
0
2
4
6
8
10
12

Figure 2


LOSS IN RAPID ABRASION - %
0
5
10
15
20
25
30
35
40
45
HOURS
0
2
4
6
8
10
12
67-3490
68-1571
65-3192
68-1190

The Rapid Abrasion Test was made on 112 samples and the results were analyzed. There were 32 igneous intrusive, 20 igneous extrusive, 20 metamorphic, and 40 sedimentary rocks from throughout the state. Most of the samples were collected especially for this study and their quality was known from past field performance. There were 91 (81.3%) rocks classified as "Good" and 21 (18.7%) classified as "Unsatisfactory." The highest percentage of correct predictions was 88.4% and was obtained by using a specification of 24% maximum loss.

This Rapid Brasion Test is somewhat better than the 1969 California Standard Specifications tests for determining the quality of rock slope protection material. It is, however, not recommended as a specification test at this time because the property of abrasion resistance is not necessarily the most significant property on a given installation. It should also be noted that equipment and materials would have to be purchased, and personnel trained before anyone could perform the test.

The test method discriminates significantly against igneous intrusive and metamorphic rock and favors igneous extrusive rock. Igneous intrusive rocks comprised only 9% of the rocks classified as "Unsatisfactory" but 19% of the rocks failing the 24% maximum Rapid Abrasion Loss were igneous intrusive. Metamorphic rocks comprised only 2% of the rocks classified as "Unsatisfactory" but 10% of the rocks failing the Rapid Abrasion requirement were metamorphic. Although igneous extrusive rocks comprised 30% of the rocks classified as "Unsatisfactory," only 5% of the rocks that failed the Rapid Abrasion requirement were igneous extrusive. No study of possible causes for these conditions was attempted.

Durability Absorption Ratio

The combining of test results in a formula was considered desirable as a specification for rock slope protection material because it would allow the use of material which is weak in some property but which is strong enough in some other property to compensate for the weakness.

A desirable formula should combine the results of easily performed and inexpensive tests which are relatively accurate in predicting performance.

The 1969 California Standard Specifications tests require about four weeks between the time of taking the sample and the time of receiving complete test results. This time lag is too long for an effective construction material quality control test. For this reason, it was decided to work with tests which can be performed at the District level or in some cases on the job. Test results would be available within three days of sampling. It was also decided that a simple formula was desirable and so only two tests, Durability and Absorption, which seemed to be complimentary were selected. The results of this study were so encouraging that no other formulas were tried.

Some attempts were made to control the range of values obtainable, to assure linearity of results, and to balance the effect on the results of changes in the individual test results. The complications introduced by the various correction factors did not increase the percentage of correct predictions significantly so the simple formula shown below was used.

$$\frac{\text{Durability Index}}{\text{\% Absorption} + 1} = \text{Durability Absorption Ratio (DAR)}$$

The +1 term in the denominator was necessary to avoid complications on those samples with zero percent Absorption.

Included in this study were 219 (84%) rocks classified as "Good" and 42 (16%) rocks classified as "Unsatisfactory" for a total of 261 samples. Analysis of the data indicate that correct predictions are made on 96.9 percent of the samples and the results of this method are less strongly influenced by rock type than the other methods. To achieve the above percentage of correct predictions, the following specifications were used:

If DAR is greater than 24 - Material passes
If DAR is less than 10 - Material fails
If DAR is 10 through 24 - Check Durability Index
  If Durability Index is 52 or greater - Material passes
  If Durability Index is 51 or less - Material fails

These specification limits were obtained by trying various limits until the one with the highest percentage of accurate predictions was determined.

Using these specifications, 21 of the 261 samples in this study were rejected outright, only one of which had been classified as "Good." Of the 46 samples which would require evaluation by the Durability Index test result, 24 are "Good" and 22 are "Unsatisfactory." The remaining 194 samples are all classified "Good" and are accepted by the 24 Minimum Durability Absorption Ratio specification.

Forty of the 46 samples requiring additional evaluation are sedimentary or igneous extrusive rocks. Since these rock types are most frequently "Unsatisfactory" and also most commonly rejected by the 1969 California Standard Specifications requirements, it seems appropriate that additional effort be made in their evaluation.

It is recommended that the Durability Absorption Ratio requirement be adopted by the California Division of Highways as the Standard Specifications test requirement for the quality control of rock slope protection material. Adoption of this test requirement will reduce the amount and cost of shipping and testing samples, will reduce from weeks to days the time required to evaluate a material, and will increase substantially the number of correct performance predictions in comparison to the present Standard Specifications test requirements. Of additional benefit to the State is the fact that the DAR is a more lenient specification which should result in lower material costs and shorter hauls. It is estimated that a minimum of $8000 will be saved each year in shipping and testing costs alone.

BRASS TAGS

In Appendix A of our report "Investigation of Rock Slope Protection Material" dated April 1967 we described an experimental technique for measuring the amount and rate of decrease in the size of rocks on an installation.

Thirty-five brass tags were installed on various rock types throughout the state between March 1965 and September 1966. Between May and September 1968 all of these locations were revisited. Five tags had been destroyed by vandals, two were buried by maintenance work, two were buried by sand deposits from streams, two were apparently destroyed by wave action at the beach, one adhesive bond failed, one was lost apparently due to shifting of material due to high water and one was made inaccessible by the river cutting a new channel.

Of the tags on which measurements could be made only two showed any discernible difference. Both were granitic rocks subject to erosion forces and the losses after 3 years were only .03 inch, an amount which is insignificant when the original size of the rock and the design life of the installation are considered. Little information concerning weathering rates of rock was gained from this relatively short term study.

At one location it was noted that excessive heat caused by burning brush and debris on an installation caused the rock (a glassy basalt) to fracture and spall at a significant rate. A substantial amount of the material in the area that was burned has already failed or will fail in the very near future. This suggests that clean up work on installations should be done without fire especially for this type of rock.

APPENDIX 1

The tabulation on the following pages includes all samples on which sufficient data could be obtained to permit analysis.

Letters in the column headed "Std. Specs." stand for "pass" (P) or "fail" (F) and refer to the 1969 California Standard Specifications which specify a minimum apparent specific gravity of 2.50, a maximum absorption of 2% (both determined using Test Method No. Calif. 206) and a maximum loss of 10% in the Sodium Sulfate Soundness Test (as determined using Test Method No. Calif. 214).

The letters in the column headed "Rock-Type" stand for "Intrusive" (I), "Extrusive" (E), "Metamorphic" (M) and "Sedimentary" (S). This gross classification of material is related to the mode of origin of the rocks and was used to determine whether specific tests are more or less harsh in their effect on various types of rock.

The letters in the column headed "Rock-Quality" stand for "Unsatisfactory" (U) and "Good" (G). These categories were assigned independently of test results and are based on visual inspection of the material and/or performance of the material on an installation.

SAMPLE NO.	STD. SPECS.	ROCK TYPE	ROCK QUALITY	RAPID ABRAS.	ABS.	D_c	D_c/ABS RATIO
63-2261	F	E	U	-	7.0	74	9
2262	F	E	U	-	7.0	57	7
64-3233	F	E	U	-	6.5	43	5
3484	F	E	U	-	3.4	80	18
3487	P	E	G	-	1.9	80	27
3488	P	E	G	-	1.9	90	31
4379	P	E	G	-	1.8	85	30
4380	P	I	G	-	0.9	67	35
4381	P	I	G	-	1.2	68	30
4382	P	I	G	-	1.0	73	36
4383	P	S	G	-	1.4	80	33
4384	P	S	G	-	1.3	65	28
4385	F	S	U	-	9.7	4	.04
4664	F	I	G	-	1.8	67	23
4665	F	S	G	-	2.0	76	25
4666	F	E	U	-	6.5	34	4
4667	P	S	G	-	1.3	63	27
4668	P	I	G	-	0.9	66	34
5175	P	E	G	13.1	2.0	85	28
65-1434	F	E	G	-	2.7	87	23
1435	F	E	G	-	2.3	85	25
1567	F	S	U	-	4.1	44	8
1568	F	S	U	-	3.8	50	10
1617	P	I	G	-	0.3	82	63
1618	P	M	G	-	0.4	82	58
1619	P	I	G	-	0.6	71	44
1620	P	M	G	-	0.5	67	44
1622	P	I	G	-	0.9	68	35
1773	P	S	G	-	1.2	68	30
1870	P	S	G	-	0.5	73	48
1871	P	S	G	-	0.6	73	45
1872	P	S	G	-	0.4	90	64
1873	F	S	U	-	2.2	37	11
1874	P	M	G	-	0.5	67	44
1875	P	S	G	-	0.7	74	43
1876	P	S	G	-	1.6	76	29
1920	P	S	G	-	0.7	82	48
1922	P	I	G	-	0.3	73	56
1923	P	M	G	-	0.6	71	44
1924	P	I	G	-	0.4	78	55
1925	P	I	G	-	0.4	67	47
1926	P	M	G	-	0.6	53	33
1927	P	I	G	-	0.3	51	39
1928	P	M	G	-	0.6	66	41
1929	P	I	G	-	0.7	71	41
1930	P	M	G	-	0.5	73	48
1931	P	I	G	-	0.6	80	50
1935	F	E	U	-	3.1	51	12
1946	P	I	G	-	0.3	68	52
1971	P	S	G	-	0.6	73	45

SAMPLE NO.	STD. SPECS.	ROCK TYPE	ROCK QUALITY	RAPID ABRAS.	ABS.	Dc	Dc/ABS RATIO
65-2001	P	I	G	-	0.3	82	63
2111	P	M	G	-	0.8	56	31
2183	P	I	G	-	0.6	85	53
2184	P	I	G	-	0.8	78	43
2185	P	M	G	-	0.6	76	47
2186	F	E	G	-	2.3	87	26
2187	F	E	G	-	2.3	87	26
2188	P	I	G	-	0.6	52	32
2189	F	E	U	-	5.0	67	11
2190	F	E	G	-	3.4	74	16
2191	P	E	G	-	1.6	80	30
2204	P	I	G	-	0.5	74	49
2205	P	I	G	-	0.6	80	50
2219	P	I	G	8.5	0.4	82	58
2220	F	S	G	-	1.3	32	13
2221	P	I	G	-	0.4	78	55
2293	P	M	G	-	0.5	82	54
2303	P	I	G	-	1.2	59	26
2385	P	M	G	-	0.4	71	50
2386	P	S	G	-	0.6	70	43
2387	P	M	G	-	0.6	76	47
2388	P	M	G	-	0.5	80	53
2498	P	S	G	-	0.9	56	29
2499	P	S	G	-	0.8	71	39
2500	F	I	G	-	1.6	67	25
2501	F	S	U	-	1.7	48	17
2502	P	I	G	-	0.4	78	55
2561	F	E	G	-	2.4	90	26
2562	P	E	G	-	1.6	93	35
2563	F	E	G	-	3.2	87	20
2574	P	M	G	-	0.8	85	47
2575	P	M	G	-	0.8	59	32
2576	P	I	G	-	0.2	78	64
2577	P	M	G	-	0.6	82	51
2618	P	I	G	-	0.4	80	57
2699	P	I	G	-	0.4	55	39
2712	P	I	G	10.4	0.2	82	68
2713	F	E	G	3.3	1.4	96	39
2714	F	E	U	-	4.1	38	7
2715	P	M	G	17.8	0.4	73	52
2716	P	I	G	9.7	0.4	78	55
2717	P	M	G	10.2	0.9	80	42
2718	P	M	G	13.0	0.5	71	47
2719	P	I	G	10.9	0.4	87	62
2942	P	M	G	-	0.6	85	53
2943	P	M	G	-	0.6	87	54
3187	F	S	U	21.7	2.1	47	15
3188	P	S	G	14.4	1.7	78	28
3189	P	S	G	16.1	1.7	73	27
3190	P	M	G	11.9	0.4	85	60
3191	P	E	G	10.4	1.1	90	42
3192	P	S	G	18.5	2.0	70	23
3193	F	S	G	24.0	2.5	61	17
3226	P	M	G	-	0.7	78	45

SAMPLE NO.	STD. SPECS.	ROCK TYPE	ROCK QUALITY	RAPID ABRAS.	ABS.	D_c	D_c/ABS RATIO
65-3227	P	M	U	-	1.6	34	13
3257	P	S	G	-	1.0	61	30
3305	P	I	G	-	0.5	85	56
3400	P	M	G	-	0.5	78	52
3505	P	I	G	-	0.8	67	37
3612	-	S	G	-	1.5	70	28
3705	P	M	G	-	0.5	85	56
3706	P	M	G	-	0.3	90	69
3757	F	S	G	-	2.4	67	19
3812	F	I	G	-	3.3	66	15
3813	-	M	G	-	1.5	74	29
3892	P	E	G	-	1.3	87	37
4008	P	I	G	-	0.3	87	66
4065	F	E	G	-	2.3	80	24
4068	P	E	G	-	1.0	93	46
4080	F	S	G	-	2.9	66	16
4244	F	E	G	-	2.6	80	22
4382	P	I	G	-	0.6	85	53
4383	P	M	G	-	0.6	77	48
4486	P	I	G	-	0.7	71	41
4487	P	I	G	-	0.5	66	44
4488	P	M	G	-	0.6	68	42
4651	F	E	G	-	2.9	82	21
66-1288	P	I	G	-	0.5	82	54
1289	P	I	G	-	0.5	73	48
1357	P	E	G	-	2.0	85	28
1371	P	I	G	-	0.4	75	53
1427	P	E	G	-	1.5	82	32
1570	P	I	G	-	0.8	85	47
1571	P	I	G	12.2	0.5	73	48
1572	P	M	G	4.2	0.4	87	62
1573	P	M	G	-	0.8	66	36
1574	P	E	G	10.6	1.3	66	28
1601	F	S	G	-	1.0	52	26
1602	F	E	G	15.3	5.3	66	10
1603	P	M	G	-	0.9	61	32
1604	P	I	G	4.2	0.6	90	56
1605	P	I	G	-	0.6	73	45
1606	F	E	U	-	6.0	50	7
1607	P	E	G	6.0	1.0	68	34
1608	P	I	G	8.3	0.7	87	51
1650	F	S	U	-	2.2	45	14
1651	P	S	G	-	1.4	65	27
1652	F	S	U	-	2.2	52	16
1653	F	S	U	-	2.2	48	15
1877	P	I	G	-	0.8	67	37
1878	P	I	G	-	0.9	78	41
2459	P	S	G	22.3	0.4	73	52
2460	F	I	G	-	1.3	78	33
2461	F	E	G	16.4	5.4	65	10
2462	P	I	G	10.2	0.7	76	44
2463	P	M	G	12.7	0.9	70	36

SAMPLE NO.	STD. SPECS.	ROCK TYPE	ROCK QUALITY	RAPID ABRAS.	ABS.	D_c	D_c/ABS RATIO
66-2464	P	I	G	8.3	0.4	80	57
2465	P	I	G	7.0	0.4	80	57
2581	F	S	U	-	4.6	45	8
2640	P	I	G	-	1.3	65	28
2738	P	I	G	-	0.5	67	44
2877	P	I	G	-	0.4	76	54
3101	P	E	G	19.2	2.0	85	28
3102	P	E	G	16.4	1.5	87	34
3103	P	I	G	-	0.3	80	61
3104	P	M	G	7.6	0.4	82	58
3346	P	I	G	-	0.5	85	56
3367	F	E	U	11.5	3.4	80	18
3368	P	E	G	17.8	1.9	80	27
3369	P	E	G	11.3	1.9	90	31
3391	P	I	G	-	0.5	66	44
3463	P	M	G	-	0.9	73	38
3736	P	M	G	-	1.6	73	28
3854	P	M	G	-	0.3	73	56
67-1984	P	I	G	-	0.8	80	44
1985	P	M	G	-	0.6	85	53
2126	F	S	U	-	3.8	39	8
2127	F	S	U	-	3.8	58	12
2139	-	I	G	-	0.9	51	26
2192	F	S	U	-	3.6	56	12
2317	F	S	G	-	3.3	70	16
3035	P	S	G	-	1.6	73	28
3088	P	S	G	14.2	1.5	80	32
3120	P	I	G	12.4	0.6	82	51
3121	P	I	G	13.7	0.5	82	54
3198	P	M	G	7.1	0.3	90	69
3264	P	I	G	-	1.3	66	28
3329	P	S	G	-	0.5	76	50
3330	P	S	G	-	1.2	78	35
3331	F	S	U	-	1.2	37	16
3332	P	S	G	15.7	1.0	61	30
3333	P	S	G	13.2	1.3	74	32
3490	F	E	U	35.7	6.5	37	4
3507	P	M	G	16.6	0.9	82	43
3508	P	M	G	14.8	0.5	80	53
3580	P	I	U	30.6	0.6	38	23
3644	P	I	G	11.0	0.8	55	30
3769	P	E	G	4.4	1.6	93	35
3823	P	M	G	15.3	1.7	52	19
68-1004	F	S	G	45.4	3.9	33	6
1007	P	I	G	11.9	0.7	78	45
1009	F	S	U	46.5	4.3	38	7
1010	F	S	U	72.9	5.9	17	2
1011	F	S	U	43.7	2.6	32	8
1056	P	I	G	13.9	0.4	85	60
1068	P	I	G	9.4	0.7	80	47
1078	P	M	G	9.1	0.0	87	87

SAMPLE NO.	STD. SPECS.	ROCK TYPE	ROCK QUALITY	RAPID ABRAS.	ABS.	D_c	D_c/ABS RATIO
68-1118	P	E	G	12.6	1.9	68	23
1119	F	I	G	24.3	-	47	-
1120	F	S	G	33.3	-	33	-
1123	F	E	G	20.8	2.1	85	27
1172	P	I	G	-	0.4	85	60
1183	F	S	G	14.3	1.3	63	27
1184	P	S	G	15.5	2.0	76	25
1185	P	I	G	7.6	0.9	66	34
1186	F	I	G	15.3	1.2	74	33
1187	P	S	G	20.1	0.2	93	77
1189	P	M	G	14.8	1.2	85	38
1190	P	M	G	9.8	0.3	82	63
1229	P	M	G	7.5	0.3	85	65
1230	P	E	G	11.4	0.4	82	58
1251	P	M	G	9.7	0.6	82	51
1252	-	I	G	12.4	0.6	82	51
1254	-	E	G	8.6	0.5	90	60
1293	P	I	G	6.7	0.3	93	71
1317	F	S	G	25.7	2.9	66	16
1344	F	S	U	21.8	1.8	50	17
1393	F	S	G	20.8	3.8	54	11
1396	F	S	G	-	1.9	73	25
1450	P	I	G	18.3	0.8	73	40
1451	P	S	G	13.5	1.3	65	28
1452	F	S	U	20.4	1.9	50	17
1454	P	S	G	15.1	1.4	80	33
1455	P	S	G	16.2	1.4	65	27
1456	F	S	U	66.9	9.7	4	0.4
1488	-	S	U	36.7	1.7	35	12
1489	F	S	G	28.0	1.3	55	23
1490	P	S	G	18.2	2.0	67	22
1491	P	M	G	19.2	1.2	76	34
1492	P	S	G	22.2	1.7	70	25
1493	F	E	U	21.4	5.6	59	8
1494	F	S	U	25.6	2.4	34	10
1495	P	S	G	15.3	0.6	66	41
1496	F	S	U	51.3	19.6	5	0.2
1571	F	S	G	22.5	3.1	62	15
1611	P	M	G	31.0	1.1	58	27
1612	F	I	U	79.3	6.9	19	2
1613	P	I	G	15.3	0.5	74	49
1614	P	I	G	17.1	0.9	76	39
1721	F	I	U	73.2	-	47	-
1723	F	I	U	58.4	-	-	-
1730	P	M	G	11.0	0.8	71	39
1731	F	E	U	23.6	6.0	44	6
1732	P	I	G	11.8	0.8	85	47
1733	-	I	G	22.5	1.1	66	31
1734	P	M	G	27.3	0.9	71	37
1735	-	I	U	36.7	1.6	39	15
1736	P	I	G	13.0	1.3	85	36

SAMPLE NO.	STD. SPECS.	ROCK TYPE	ROCK QUALITY	RAPID ABRAS.	ABS.	D_c	D_c/ABS RATIO
68-1737	P	I	G	12.3	0.6	76	47
1827	F	S	G	21.8	3.2	63	15
1828	P	S	G	10.3	1.2	80	36
1829	F	S	G	19.6	3.1	74	18
1894	P	S	G	19.0	1.7	76	28
1897	F	S	U	34.9	3.8	43	8
1900	F	S	U	23.9	1.9	43.	14

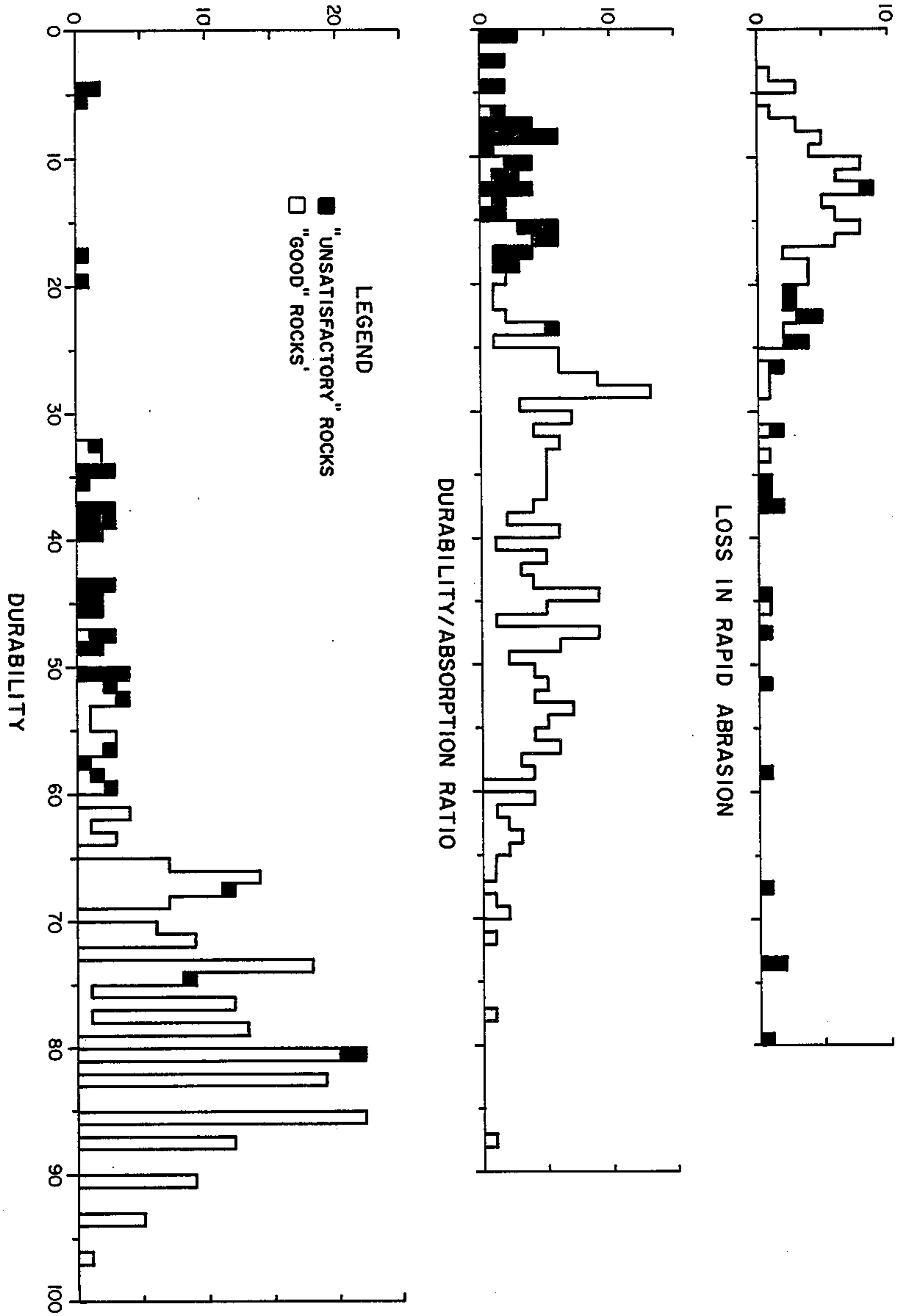
APPENDIX 2

This histogram shows the distribution of test results for each of the three tests evaluated during this study.

The solid portion represents samples which were considered "Unsatisfactory" by visual examination and/or previous performance. The uncolored portions represent "Good" materials.

The peculiar intermittent nature of the Durability Histogram is the result of the method of computation of the Durability and not related directly to the samples.

DISTRIBUTION OF TEST RESULTS



APPENDIX 3

METHOD OF DETERMINING QUALITY BY RAPID ABRASION

Scope

This test is intended to determine the resistance to abrasion of rock slope protection material.

Equipment

1. A U.S. Stoneware 784V jar mill and 3 U.S. Stoneware Roalox jars size 0.
2. An oven capable of maintaining a heat of 230° ± 10°F for 16 hours.
3. A balance having a capacity of at least 1000 grams and a sensitivity of 1 gram or less.
4. A 12-inch diameter No. 4 woven wire sieve having square openings and conforming to AASHO Designation: M 92.

Materials

1. Closely graded size 30 silicon carbide abrasive.

Sample Preparation

1. Crush and sieve the sample as described in Test Method No. Calif. 201.
2. Dry the 1" x 3/4" fraction at 230° ± 10°F for 16 ± 1 hours.
3. Weigh out 3 each 1000 ± 5 gram samples.

Test Procedure

1. After cooling the samples, place one in each of the Roalox jars.
2. Add 35 ± 1 grams of No. 30 silicon carbide abrasive and enough water to just cover the sample and abrasive.
3. Seal the jars and place them on the jar mill.
4. Roll the jars for 8 ± ¼ hours at 66 RPM.
5. Empty the contents of the jar onto the No. 4 sieve and wash away all abrasives and waste products and any particles that have been reduced to minus No. 4 size.
6. Dry the retained No. 4 material in the 230° ± 10°F oven for 16 ± 1 hour and weigh.

Calculations

Calculate the percentage weight loss to the nearest full percentage point using the following formula:

$$\text{Percent Loss} = \frac{\text{Original weight} - \text{Final weight}}{\text{Original Weight}} \times 100$$

METHOD OF TEST FOR SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE

Scope

This test method, which is a modification of AASHO Designation: T 85, specifies procedures for the determination of the bulk and apparent specific gravities, and absorption of coarse aggregates.

Procedure

A. Apparatus

1. A balance having a capacity of at least 5,500 g. and sensitive to 1 g. or less.
2. A wire mesh basket made of No. 4 mesh, and dimensions such that the basket will have sufficient capacity for samples up to 5,500 g. maximum. A generally satisfactory size is 8 in. x 8 in. by 4½ in. deep.
3. A container of sufficient size to allow the wire mesh basket to be completely immersed. A copper tank, 11½ in. wide, 14 in. long and 8 in. deep, is satisfactory for the 8-in. sq. basket described above.
4. Suitable apparatus for suspending the immersed basket from the balance so that the weight of the aggregate in water can be obtained.
5. Vessels, each of approximately 2-gallon capacity, that are deep enough to permit immersing entire sample during soaking period.

B. Test Record Form

Record the test data on work sheet Form No. T-2025.

C. Preparation of Sample

1. Rock Slope Protection: Crush the submitted sample to pass the 1½ inch sieve. Then sieve the crushed material over the 1½ inch, 1 inch and ¾ inch sieves. Prepare a test specimen weighing 5000 ± 500g. by combining equal weights of the 1½″ x 1″ and 1″ x ¾″ sieve size fractions of material.
2. All Other Materials: Prepare a representative 5,000 ± 500g. portion of the retained No. 4 sieve size material for testing.

D. Test Procedure

1. Place sample in vessel, cover with water at a temperature of 59 to 77 F., and allow to soak for a minimum period of *15* hours.
2. Pour sample into wire basket, rinse clean, suspend the wire basket from the center of the balance scale pan, immerse basket completely, use suitable tare weight, and weigh to nearest gram. Record weight as "Weight of Sample in water."
3. Remove basket, drain off free water for a few seconds, then pour sample out of basket on to a large absorbent cloth, and roll sample in the cloth until all visible films of water are removed, although the surfaces of the particles may still appear to be damp. Large aggregate particles may be individually wiped in lieu of rolling in cloth. In order to avoid evaporation of absorbed water, perform this surface drying operation as rapidly as possible and then immediately weigh to nearest gram. Record weight as "Weight of saturated surface-dry sample in air."
4. Pour sample into suitable drying pan, dry sample to constant weight in oven at a temperature of 230 ± 9F (110 ± 5C), cool to room temperature, pour sample into balance pan, use suitable tare weight, and weigh to nearest gram. Record weight as "Oven-dry weight."

E. Calculations

1. For Bituminous Mix aggregates, calculate the bulk specific gravity, oven-dry basis, from the following formula:

$$\text{Bulk specific gravity (oven-dry basis)} = \frac{A}{B - C}$$

Where:
A = weight in grams of sample in oven-dry condition
B = weight in grams of sample in saturated surface-dry condition, and
C = weight in grams of saturated sample immersed in water

2. For Portland Cement Concrete aggregates, calculate the bulk specific gravity, saturated surface-dry basis, from the following formula:

$$\text{Bulk specific gravity (saturated surface-dry basis)} = \frac{B}{B - C}$$

3. For Rock Slope Protection material, calculate the apparent specific gravity from the following formula:

$$\text{Apparent specific gravity} = \frac{A}{A - C}$$

4. Calculate the percentage of absorption from the following formula:

$$\text{Percent absorption} = \frac{B - A}{A} \times 100$$

F. Precautions

When tare weights are used to compensate the weight of the basket and/or apparatus used to suspend the basket from the balance, be certain the correct tare weight is used.

Reporting of Results

Report specific gravities to the nearest hundredth (2.65, 2.52, etc.), and absorptions to the nearest tenth (1.4, 2.3, etc.) on Form Nos. T-287, T-346, T-374 or T-375.

REFERENCE

AASHO Designation: T 85

End of Text on Calif. 206-D

METHOD OF TEST FOR DURABILITY INDEX

Scope

This method describes the precedure for determining the relative resistance of an aggregate to producing detrimental clay-like fines when subjected to the prescribed methods of degradation.

Procedure

A. Apparatus

1. All of the equipment, except the balance or scale, listed under "Apparatus" of Test Method No. Calif. 202 [1] is required.
2. All of the equipment, except the Manually Operated Sand Equivalent Shaker, listed under "Apparatus" of Test Method No. Calif. 217 is required. It may be necessary to bypass the timer on the Mechanical Sand Equivalent Shaker in order to have the machine run continuously for 10 minutes.
3. Modified Agitator: A Tyler portable sieve shaker, modified as shown in Figure I and set to operate at 285 ± 10 cycles per minute. Other types of agitators may be used provided the length of time and/or other factors are adjusted so that results can be obtained which duplicate the results obtained with the modified agitator.
4. Liter measure: A liquid measuring device calibrated to read 1000 ± 5 ml. of wash water.
5. Vessel: A round pan suitable to collect the wash water from the washed test specimen.
6. A balance or scale with a minimum capacity of 5000 grams and sensitive to 1 gram or less.

B. Materials

1. The two Calcium Chloride solutions listed under "Materials" in Test Method No. Calif. 217 are required.
2. Water: Use distilled or demineralized water for the normal performance of this test. If it is determined, however, that the local tap water is of such purity that it does not affect the test results, it is permissible to use it in lieu of distilled or demineralized water except in the event of dispute.

C. Test Record Form

Record test results on Form T-200 or T-361.

D. Control

Temperature of all solutions and water should be maintained at 72 ± 5 F during the performance of this test. If it is not possible to maintain the solutions and water at this temperature, samples should be frequently submitted to a laboratory where proper temperature control can be maintained.

[1] When reference is made to another test method by California number, it shall mean the other test method in effect at the time this test is performed.

E. Preparation of Test Specimens

1. Prepare the sample as described in Test Method No. Calif. 201.

   a. Use care in cleaning the coarse aggregate and breaking up of clods to avoid excessive degradation of the individual particles.

   b. When sieving the sample, separate on the ½-in. sieve in addition to the prescribed sieves.

2. Preparation of the Coarse Aggregate Test Specimen.

   a. Determine the grading of the ¾-in. x No. 4 sieve portion of the sample.

   (1) If each of the aggregate sieve sizes listed in Table No. 1 represents 10 percent or more of the ¾-in. x No. 4 sieve portion of the sample, use the oven-dry weights of material specified in Table No. 1 for preparing each preliminary test specimen.

   (2) If any of the aggregate sieve sizes listed in Table No. 1 represents less than 10 percent of the ¾-in. x No. 4 sieve fraction of the sample, use the same percentage of that sieve size material in fabricating the preliminary test specimen. Proportionally increase the remaining sieve size or sizes to obtain the 2500-gram preliminary test specimen weight. (See examples following Table No. 1).

TABLE NO. 1

BASIC TEST SPECIMEN GRADING

Aggregate Sieve Size *Passing*	*Retained on*	*Oven Dry Weight In Grams*
¾-in.	½-in.	1,050 ± 10
½-in.	⅜-in.	550 ± 10
⅜-in	No. 4	900 ± 5
Test Specimen Weight		2,500 ± 25

Example 1—Less than 10% of ¾-in. x ½-in. aggregate sieve size material.

Aggregate Sieve Size	*Percent Each Size*	*Calculations*	*Oven-Dry Weight-Grams*
¾-in. x ½-in.	6	.06 × 2500	150 ± 10
½-in. x ⅜-in.	26	$\frac{550\ (2500 - 150)}{550 + 900}$	891 ± 10
⅜-in. x No. 4	68	$\frac{900\ (2500 - 150)}{550 + 900}$	1459 ± 5
Totals	100		2500 ± 5

Example 2—Less than 10% of ¾-in. x ½-in. and ½-in. x ⅜-in. aggregate sieve size materials.

Aggregate Sieve Size	*Percent Each Size*	*Calculations*	*Oven-Dry Weight-Grams*
¾-in. x ½-in.	4	.04 × 2500	100 ± 10
½-in. x ⅜-in.	7	.07 × 2500	175 ± 10
⅜-in. x No. 4	89	2500 — (100 + 75)	2225 ± 5
Totals	100		2500 ± 25

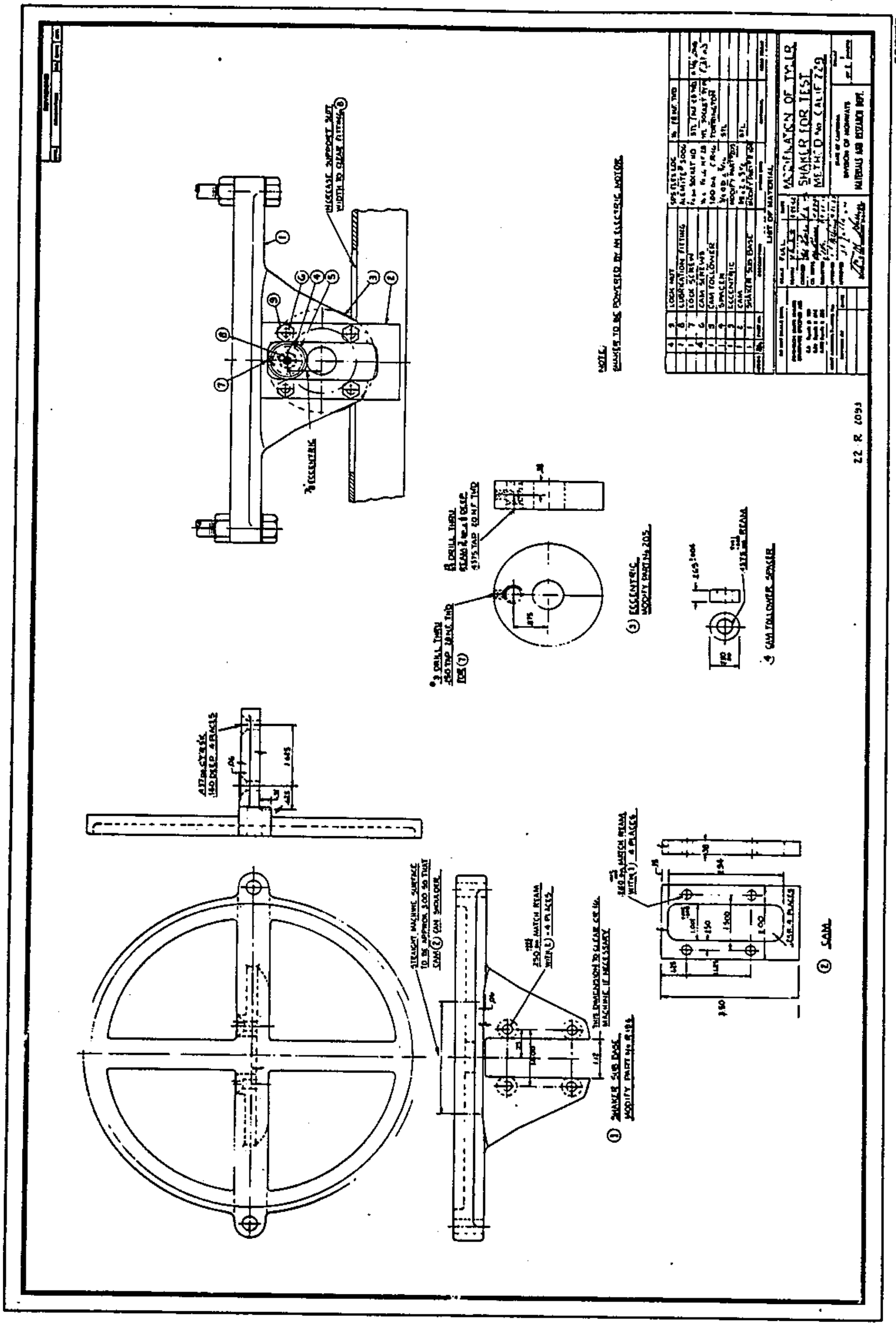


FIGURE I

b. From each aggregate sieve size listed in Table No. 1, oven dry a sufficient amount of the material to constant weight at a temperature of 230 ±9 F (110 ± 5 C) to prepare two test specimens to the prescribed test specimen grading. Allow the material to cool to room temperature.

c. Prepare two preliminary test specimens to the prescribed test specimen grading. NOTE: It is frequently possible to prepare the washed test specimen (described below) from one preliminary test specimen. This is permissible providing the basic test specimen grading shown in Table No. 1 is used and the weights of each aggregate sieve size in both the preliminary test specimen and the washed test specimen do not exceed the prescribed tolerances.

d. Place one of the preliminary test specimens in the mechanical washing vessel, add 1000 ± 5 ml. of water, clamp the vessel lid in place and secure the vessel in the modified agitator.

e. Begin agitation after a time of *one minute ± 10 seconds* has elapsed from the introduction of the wash water. Agitate the vessel in the modified agitator for *two minutes ± five seconds.*

f. After the two-minute agitation time is completed, remove the vessel from the modified agitator, unclamp the lid and pour the contents into a No. 4 sieve. Rinse any remaining fines from the vessel onto the sieve and direct water from a flexible hose onto the aggregate until the water passing through the sieve comes out clear.

g. Wash the second preliminary test specimen in the same manner as described above, then combine all of the washed material obtained from both preliminary test specimens and dry to constant weight at a temperature of 230 ± 9 F (110 ± 5 C). Allow the material to cool to room temperature.

h. Separate the washed material on the ½-in., ⅜-in. and No. 4 sieves. Discard the material passing the No. 4 sieve.

i. Prepare the washed test specimen as follows:

(1) If the preliminary test specimens were prepared to the basic test specimen grading shown in Table No. 1, prepare the washed test specimen to this same grading from the washed test specimens. If necessary to wash a third preliminary test specimen to obtain the required weight of material of a specific size, use the same procedure as prescribed for obtaining the other preliminary test specimens.

(2) If the basic test specimen grading shown in Table No. 1 was not used in preparing the preliminary test specimen, use *all* of the material representing the deficient aggregate sieve size or sizes obtained from washing the two preliminary test specimens. Proportionally increase the remaining aggregate sieve sizes to obtain the required 2500-gram washed test specimen.

3. Preparation of Fine Aggregate Test Specimen

a. Prepare a preliminary test specimen from the passing No. 4 sieve portion of the sample by performing a sieve analysis on the fine aggregate in accordance with the general provisions of Test Method No. Calif. No. 202 and these provisions.

(1) A 500 ± 25 gram oven dried test specimen shall be used.

(2) The test specimen shall be mechanically sieved over a nest of sieves containing the Nos. 8, 16, 30, 50, 100 and 200 sieves and a sieve pan. Additional sieves may be used if necessary to conform to the test requirements. NOTE: The modified agitator will not meet the sieving apparatus requirements of Test Method No. Calif. 202 when reasonable agitation times are used. For this reason, it is necessary that either an agitator which provides a suitable action for sieving of fine aggregates or a modified agitator which may be adjusted to produce a suitable sieving action be used.

b. Combine and thoroughly mix all of the washed material from the preliminary test specimen which was retained on each fine series sieve with the material in the sieve pan.

c. Prepare a washed test specimen by splitting or quartering a sufficient amount of the washed fine aggregate to fill the 3-ounce measuring tin to the brim or slightly rounded above the brim. When filling the tin measure, tap the bottom edge of the measure on a work table or other hard surface to cause consolidation of the material and to allow the maximum amount to be placed in the measuring tin. Use extreme care in this procedure to prevent segregation of the material. If the quartering method is used, follow the procedure for "Hand quartering of samples weighing less than 25 lb." in Test Method No. Calif. 201.

F. Test Procedure

1. Procedure for Testing Coarse Aggregate: Test the washed coarse aggregate test specimen in the same manner as prescribed for testing 1" x No. 4 concrete aggregates under "Test Procedure" of Test Method No. Calif. 227, except as follows:

In lieu of agitating the vessel for 2 minutes ± 5 seconds in the sieve shaker as prescribed in Test Method No. Calif. 227, agitate the vessell for 10 minutes ± 15 seconds in the modified agitator.

2. Procedure for Testing Fine Aggregate: Test the washed fine aggregate test specimen in the same manner as prescribed under "Test Procedure" of Test Method No. Calif. 217 except as follows:

In lieu of shaking the cylinder and contents by the methods described in Test Method No. Calif. 217, place the stoppered cylinder in the mechanical sand equivalent shaker and allow the machine to shake the cylinder and contents continuously for 10 minutes ± 15 seconds.

G. Calculations and Reporting

1. Determine Dc to the nearest whole number by the following formula:

$Dc = 30.3 + 20.8 \cot (0.29 + 0.15H)$

Where:

Dc = Value obtained on coarse aggregate

H = Height of sediment obtained from testing the washed coarse aggregate test specimen
ctn (0.29 + 0.15H) = Cotangent of given value expressed in radians

Solutions to the above equation are given in Table No. 2.

2. Determine Df (value obtained for fine aggregate) in the same manner as prescribed for determining sand equivalent under "Calculations and Reporting" of Test Method No. Calif. 217.

3. Reporting

a. When reporting the values obtained on the submitted material, place an asterisk (*) after the reported Dc or Df, whichever is lower in value. The value so indicated by the asterisk shall be the durability index of that material for determination of compliance with specification requirements. In no case shall the Dc and Df be "weighed" or "averaged" to obtain a combined durability index.

H. Precautions

1. Refer to precautions listed in Test Method Nos. Calif. 202 and 217.

2. Frequently check the play between the cam and eccentric on the modified agitator by grasping one of the hanger rods and attempt to move the sieve base. If any play is noticed, check the cam and bearing and replace if necessary.

3. Lubricate the modified agitator at three-month intervals.

REFERENCES

A California Test Method
Test Method No. Calif. 201
Test Method No. Calif. 202
Test Method No. Calif. 217
Test Method No. Calif. 227

End of Text on Calif. 229-E

TABLE NO. 2
DURABILITY FACTOR OF COARSE AGGREGATE

$D_c = 30.3 + 20.8 \text{ ctn } (0.29 + 0.15H)$

Sediment height (inches)	D_c	Sediment height (inches)	D_c	Sediment height (inches)	D_c	Sediment height (inches)	D_c	Sediment height (inches)	D_c
0.0	100	3.0	53	6.0	39	9.0	29	12.0	18
0.1	96	3.1	52	6.1	38	9.1	29	12.1	18
0.2	93	3.2	52	6.2	38	9.2	28	12.2	18
0.3	90	3.3	51	6.3	38	9.3	28	12.3	17
0.4	87	3.4	51	6.4	37	9.4	28	12.4	17
0.5	85	3.5	50	6.5	37	9.5	27	12.5	16
0.6	82	3.6	49	6.6	37	9.6	27	12.6	16
0.7	80	3.7	49	6.7	36	9.7	27	12.7	15
0.8	78	3.8	48	6.8	36	9.8	26	12.8	15
0.9	76	3.9	48	6.9	36	9.9	26	12.9	14
1.0	74	4.0	47	7.0	35	10.0	26	13.0	14
1.1	73	4.1	47	7.1	35	10.1	25	13.1	13
1.2	71	4.2	46	7.2	35	10.2	25	13.2	13
1.3	70	4.3	46	7.3	34	10.3	25	13.3	12
1.4	68	4.4	45	7.4	34	10.4	24	13.4	12
1.5	67	4.5	45	7.5	34	10.5	24	13.5	11
1.6	66	4.6	44	7.6	33	10.6	24	13.6	11
1.7	65	4.7	44	7.7	33	10.7	23	13.7	10
1.8	63	4.8	43	7.8	33	10.8	23	13.8	9
1.9	62	4.9	43	7.9	32	10.9	23	13.9	9
2.0	61	5.0	43	8.0	32	11.0	22	14.0	8
2.1	60	5.1	42	8.1	32	11.1	22	14.1	7
2.2	59	5.2	42	8.2	31	11.2	22	14.2	7
2.3	59	5.3	41	8.3	31	11.3	21	14.3	6
2.4	58	5.4	41	8.4	31	11.4	21	14.4	5
2.5	57	5.5	40	8.5	30	11.5	20	14.5	4
2.6	56	5.6	40	8.6	30	11.6	20	14.6	4
2.7	55	5.7	40	8.7	30	11.7	20	14.7	3
2.8	54	5.8	39	8.8	29	11.8	19	14.8	2
2.9	54	5.9	39	8.9	29	11.9	19	14.9	1
								15.0	0