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16. ABSTRACT
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One significant finding was that the presence of as little as 5% passing the No. 70 U.S. Standard Sieve can result in 33 to 50% more dust generation during blasting than that generated if little or no minus 70 material is present in the abrasive prior to blasting. Also, the presence of the minus 70 material did not contribute significantly to the abrasive's cleaning ability. The end result of this research was the development of a specification for blast cleaning abrasives which are used for open dry blast cleaning.

17. KEYWORDS
Blasting, abrasion, air pollution control, beach sands, friability, materials testing, slag, sands

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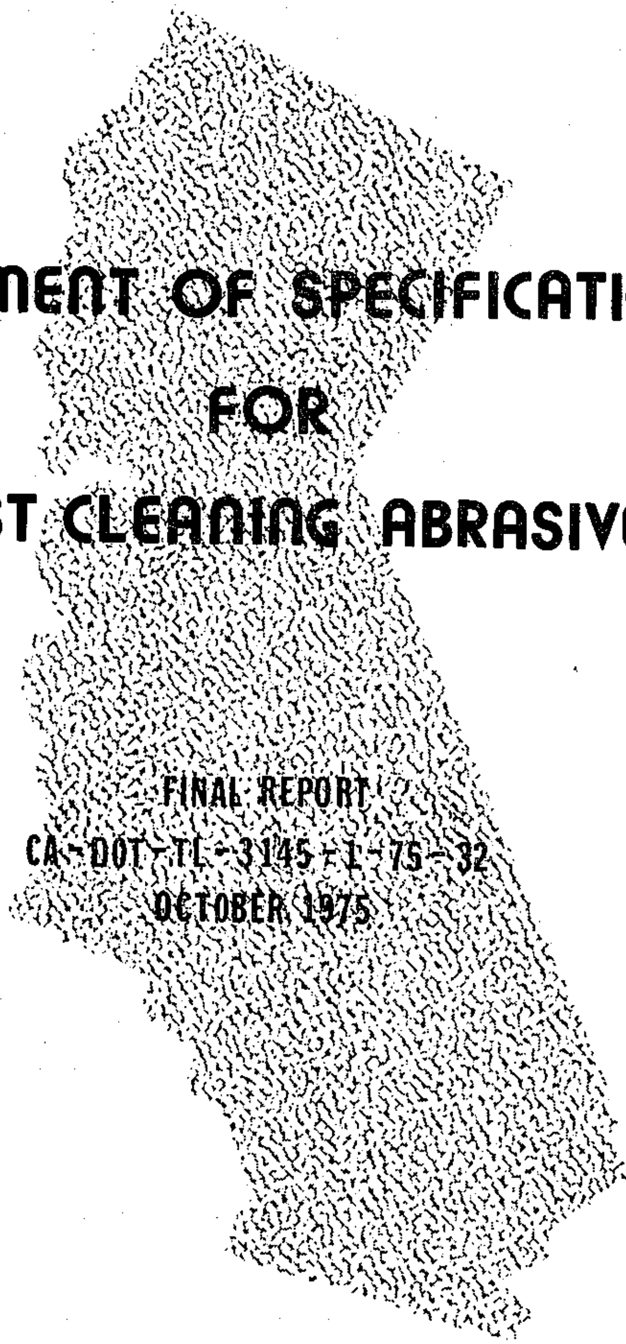

DEVELOPMENT OF SPECIFICATIONS FOR BLAST CLEANING ABRASIVES

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION AND RESEARCH
TRANSPORTATION LABORATORY

October 1975

Final Report
TL No. 643145

Mr. R. J. Datel
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

DEVELOPMENT OF SPECIFICATIONS
FOR
BLAST CLEANING ABRASIVES

Study made by . . . . Pavement Branch

Under the Supervision of . . . . John Skog

Principal Investigator . . . . Robert N. Doty

Co-Investigator . . . . Brian D. Murray

Report Prepared By . . . . Brian D. Murray

Very truly yours,

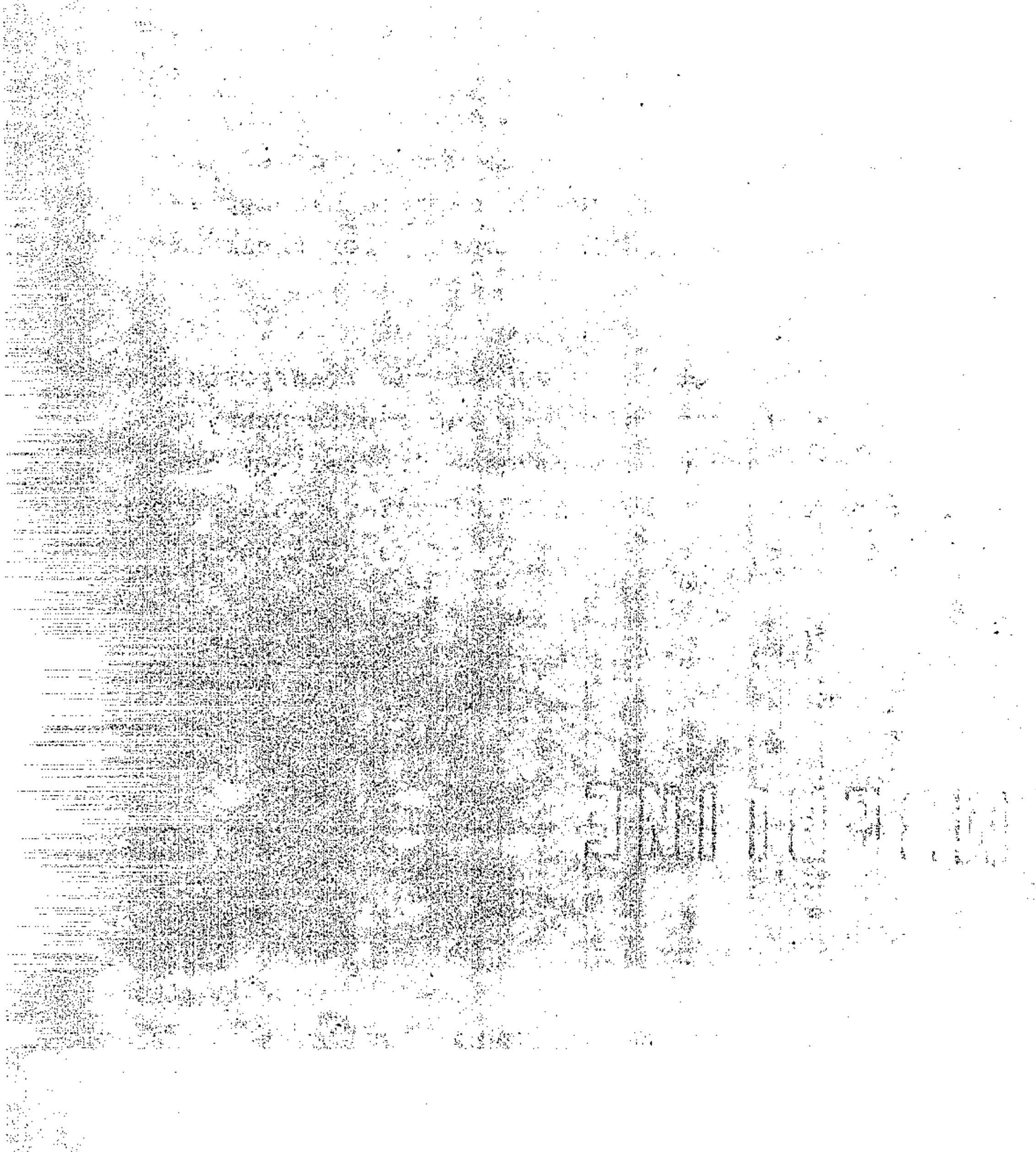
George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

ACKNOWLEDGMENTS

This study, titled "Development of Specifications for Blast Cleaning Abrasives", was conducted by the Transportation Laboratory of the Division of Construction and Research of the California Department of Transportation. Credit should be shared with the personnel involved with the blasting chamber fabrication and the abrasives testing, in particular Floyd Martin and Lennart K. Andersson of the Transportation Laboratory Machine Shop who contributed numerous ideas during fabrication of the blasting chamber, and Jack W. Knott and Carl W. Wishman who performed the abrasives testing. The author also wishes to express his appreciation to representatives of the blasting industry for their cooperation and suggestions.



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I. INTRODUCTION

The Department of Transportation is charged with the responsibility of maintaining highways and bridges within the state system. This maintenance function necessitates periodic blast cleaning of segments of the transportation network. During this blasting operation, pollution, in the form of a plume of airborne particles, is usually generated. The sources of these particles are the abrasive being used and the surface material being removed. During the last five years, open dry blasting has been both hindered and curtailed in various areas of the state by pollution ordinances. This has created an environment of uncertainty both within the Department of Transportation and within the contracting industry. Recent contract bids have been unusually high as insurance against possible delays and adverse rulings.

To resolve the current situation, the California Air Resources Board has adopted performance standards for blast cleaning abrasives. Provisions have been made for amending those standards by adding specifications to restrict the use of high dust-generating abrasives for open, dry blasting.

Initial state-financed research performed in this area of abrasive evaluation (expenditure authorization 643142) was completed and the results submitted to the "Committee on Air Pollution Standards for Abrasive Blasting Operations" on August 12, 1974. The Committee indicated satisfaction with the general approach to evaluation of blasting media friability but requested that further work be performed with certain suggested technical modifications of the testing procedure. The results of this testing are documented herein.

II. CONCLUSIONS, RECOMMENDATIONS, AND IMPLEMENTATION

It was concluded that there are three characteristics of abrasives which influence the amount of fine particulate matter that is discharged into the air during open dry blast cleaning operations. The first is cleanness, the amount of fine dust in the abrasive as produced. The second is friability, the tendency of the abrasive particles to chip and break during handling and blasting, which is related to their mineral properties. The third characteristic is the particle size of the abrasive, as the finer grades of abrasives break and chip into correspondingly smaller particles.

The following statements are based on the findings of this work. It is recommended that they be included in future regulations for abrasive material used for dry, open abrasive blasting operations.

1. No more than a trace of an abrasive material shall pass a U. S. Standard No. 70 sieve prior to being blasted.

2. Abrasive material tested in accordance with the procedures given in Tentative Test Method No. Calif. 371-A shall contain not more than an average of 2.0 percent by weight of five micron or smaller particles for three individually tested samples. Also, no individual sample shall contain more than 2.5 percent by weight of the five micron or smaller particles.

III. DISCUSSION

Test Procedure and Equipment Development

The primary purpose of this work was to determine the quantity of abrasive material introduced into the atmosphere during a typical abrasive blasting operation. The guidelines establishing what represents a typical blasting operation were to be determined by the "Committee on Air Pollution Standards for Abrasive Blasting Operations" (Committee) which reports to the California Air Resources Board. After two Sub-committee meetings and one full Committee meeting, with industry representatives present, tentative blasting criteria were established. These included 1) the use of a 3/8 inch diameter venturi style nozzle (Clemco #CFSD-x-6), 2) 100 psi nozzle pressure and 3) a mild steel impingment plate oriented perpendicular to the nozzle axis at a distance of approximately two feet from the nozzle tip. Abrasive was to be shot at the rate of 1200 pounds per hour. Additional criteria were 1) to minimize any fracturing of the particles due to secondary impacts with the chamber walls, 2) to collect all the material blasted, and 3) to minimize the moisture and oil content of the compressed blasting air.

Using the designated criteria, two blasting chamber designs were prepared along with scale models of each. Also prepared was a tentative test procedure for abrasive friability evaluation. The models of the proposed test chambers and the tentative test procedure were submitted to the full committee on November 26, 1974 for their review and approval. After eight hours of discussion by the committee and representatives of the blast cleaning industry, one of the chamber designs was selected. Minor modifications of the tentative testing procedure were also requested. The final test procedure accepted is designated as "Test Method No. Calif. 371-A".

Equipment Fabrication and Preliminary Testing

The test chamber was fabricated within a period of two months by the Transportation Laboratory Machine Shop. Simultaneously, a Clemco SCW-1028 sand pot was modified in that its 1/2 inch diameter lines were replaced with 1-1/4 inch pipe. In lieu of a variable control abrasive feed valve, provision was made for replaceable fixed-size abrasive feed orifices. The completed blasting chamber and sand pot are shown in Figures 1 and 2.

Following fabrication of the equipment, initial shakedown testing was performed to develop a standardized testing procedure. A feed rate of 1200 lbs/hr of abrasive was used during this initial testing. The pot was slightly choked to achieve this feed rate. Appropriate orifice sizes, pot choke rates, and the minimum impingment plate thickness were determined during this initial testing. Modifications were also made in the after-blasting sample retrieval system to eliminate any loss of airborne fines. These modifications consisted of replacing the pipe cap design, which had been modeled after the U. S. Navy's blasting apparatus, with ball valves and sample-bag mounts.

The exhaust air filtering system was also modified. Initially, heating and cooling system high efficiency air filters with 6.6 sq. ft. surface area and rated for 1100 C.F.M. were used. These were difficult to extract the sample from and clogged during the blasting period. A cotton-sateen air bag was then fitted to the exhaust air vent. The air bag's 30.5 sq. ft. of surface area did not clog, was highly efficient, and was easy to clean after each blasting test.

Upon completion of shakedown testing, the full Committee assembled on March 11, 1975 to observe a demonstration of the blasting chamber. After observing the equipment and after much discussion,

Figure 1. Abrasive Blasting Chamber

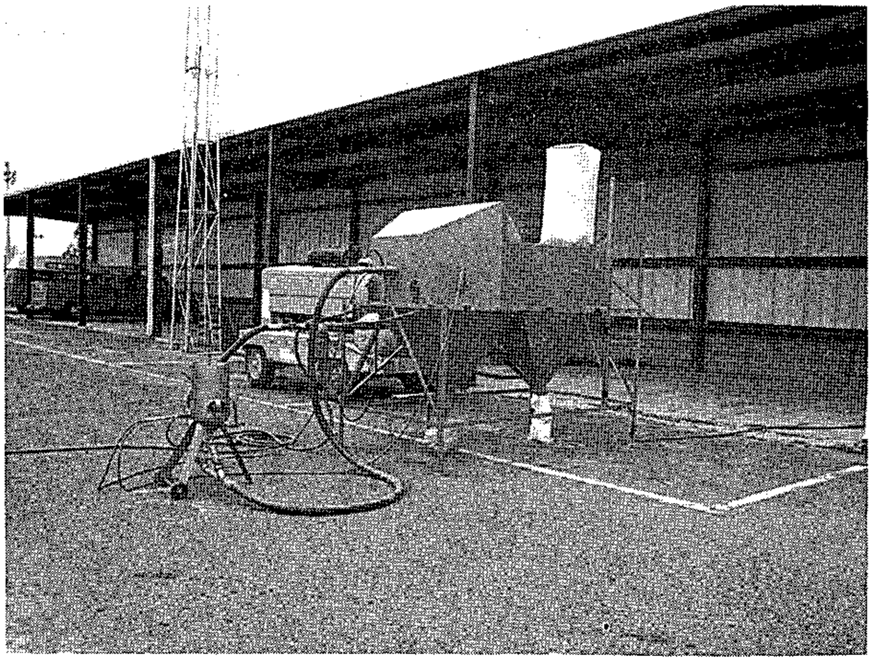

Figure 2. Abrasive Blasting Chamber

the Committee decided to amend the testing criteria to, in their judgement, more closely simulate typical field conditions. The abrasive feed rate was reduced from 1200 pounds per hour to 600 pounds per hour and the choked abrasive feed condition was changed to a gravity feed arrangement from the abrasive pot. Also, it was further requested that the testing of all abrasives begin immediately and be conducted as quickly as possible.

Blast testing of the abrasives was immediately begun using the 600 pounds per hour rate but it was found that the abrasive flow rate was inconsistent. That is, the total shooting time would sometimes be less when using smaller orifices than when using the larger ones. This necessitated that the testing be discontinued.

During an examination of the equipment, it was suspected that the location of the main air supply valve might be creating a turbulent air condition at the pressure equalizing inlet to the abrasive pot. The main air supply valve was then moved five feet up the air supply line towards the compressor to permit the dissipation of any turbulent action due to the valve prior to entering the abrasive pot plumbing. This eliminated the inconsistent abrasive flow rate problem and testing was resumed.

Abrasive Procurement

The Committee directed the Air Resources Board staff to solicit abrasive samples for testing purposes from all the abrasive suppliers distributing materials in California. Fifteen abrasive suppliers were contacted and fourteen responded with a total of fifty-three grades of abrasives. The majority of the samples were five hundred pounds each. The forty-nine samples received during the period September 20, 1974 to April 4, 1975 were tested for cleanness and friability. The remaining four samples received after blast testing was completed on April 4, 1975 will not be tested as part of this project.

Laboratory Procedures -- Pre-Blasting

Upon receipt of the samples, approximately two hundred pounds of each grade was separated for testing with the remainder stored as back-up material. The two hundred pound samples were dried at 120°F to a constant weight. They were then split into grading and specific gravity samples, and into three 25,000 gram blasting samples. The specific gravity and grading were determined at that time using Test Method Nos. Calif. 202-G and 208-B, and the blasting samples retained in sealed polyethylene bags for later blast testing. When the Committee requested the reduced abrasive blasting rate of 600 pounds per hour, the three 25,000 gram samples for each of the previously split thirty-nine materials were recombined and resplit into four 18,750 gram samples. This yielded an additional sample for back-up testing if necessary and, combined with the reduced feed rate, increased the total sample blasting time 50%, which had been limited by the abrasive pot size at the 1200 lbs/hr rate. The materials received after the Committee requested the 600 pound per hour rate were split into 18,750 gram samples directly.

Also, the nine materials which required retesting due to the inconsistent abrasive flow rate were split directly into 18,750 gram samples after drying.

Blast Testing

Each of three 18,750 gram samples was shot until exhausted. Each was shot at a different feed rate which was set by using fixed size feed orifices in the abrasive feed at the sand pot. The orifice sizes chosen for each abrasive were based on feed rate information obtained during preliminary testing and the actual testing as it progressed. The three feed rates were approximately 15 to 25% overfeed, standard feed (600 lbs/hr) and 15 to 25% underfeed. The fourth 18,750 gram sample was shot in the event an error was made in test procedure or in the feed rate. The samples were shot through a 3/8 inch diameter venturi style nozzle at 100 psi nozzle pressure and impacted against a replaceable flat mild steel plate located twenty-three inches from the nozzle tip. The impingment plate was changed after each test so that each sample was shot against an unblasted surface. The impingement plate was weighed before and after shooting to determine the grams of steel abraded. Each sample, after being shot, was sealed in a single sample bag and retained for later mechanical analysis.

Post-Blasting Gradation Determination

Approximately two hundred samples were blasted. This includes the preliminary testing samples, those samples shot during which testing errors were made, and the one hundred and fifty-seven samples chosen to represent the forty-nine abrasives evaluated. Three or four samples of each abrasive were selected for particle analysis. The samples were each split into two 105± 10 gram samples and one 250 ± 25 gram sample. One of the 105 ± 10 gram samples was retained in the event that back-up testing might be necessary. The other two samples were examined for moisture and grading in accordance with the procedures outlined in Test Method Nos. Calif. 203-C "Method of Test for Mechanical Analysis of Soil" and 202-G "Method of Tests for Sieve Analysis of Fine and Coarse Aggregates".

The data obtained appeared to have inconsistencies and, after further examination, it was found that Test Method No. Calif. 203-C as written did not provide the degree of accuracy required. The test method is used for classification of soils which possess significantly higher percentages of fines. For soils, this yields a greater effective depth of the hydrometer in the solution and a shorter settling distance for soils than for the abrasives examined. Since Test Method No. Calif. 203-C incorporates a shortcut procedure and is solely used for soils classification, it was found to be inappropriate for testing of the abrasives. Therefore, the second group of 105± 10 gram samples which had been retained as back-up samples was examined using the procedures presented in ASTM D-422-63, Particle Size Analysis of Soils. Hydrometer readings for those abrasives with a specific gravity of 2.6 to 2.7 were taken at the following approximate times: 4, 8, 16, 30, 60, 120, and 240 minutes. Those abrasives with a specific gravity greater than 2.7 were read at 3, 6, 12, 30, 60, 120, and 240 minutes. This yielded the information necessary to calculate and plot a grain size accumulation curve for each sample for a range of approximately three to twenty-five microns. The hydrometer readings were visually estimated to the nearest one-tenth of a percent. The error introduced at this point is estimated at plus or minus two-tenths of a percent. That is, a reading taken as 1.6 percent would have a true reading within the range of 1.4 percent to 1.8 percent. Some of this error was minimized when plotting best fit grain size accumulation curves through the points.

Data Analysis

The gradation information obtained from both the sieve analysis and the mechanical analysis for each of the samples for each abrasive was used to plot percent passing versus shooting time curves. An example of this is presented in Figure 3, with percent passing on the vertical axis and shooting time on the horizontal axis. The particle sizes are represented in U. S. Standard Sieve sizes for larger particles and in micron sizing for the smaller particles.

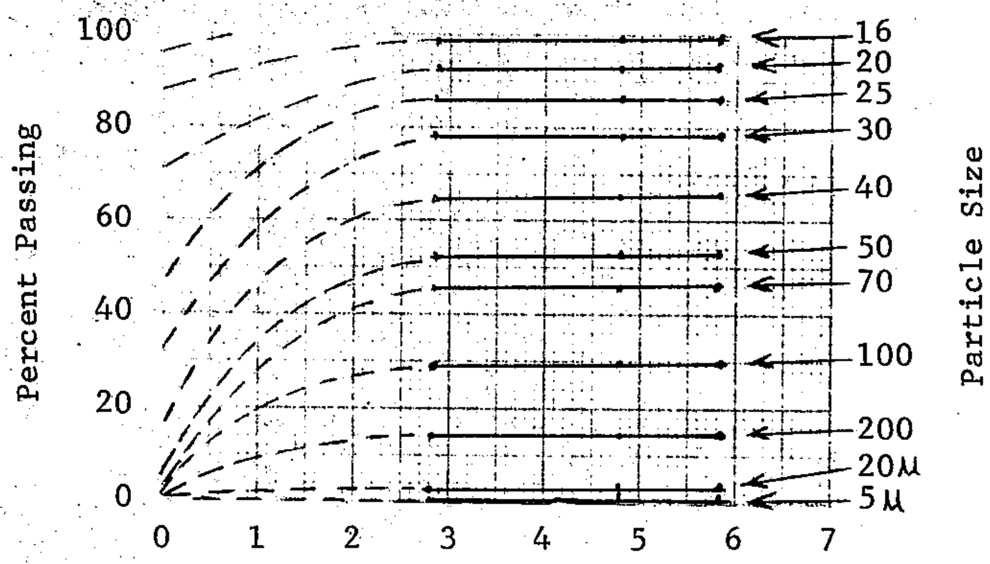

Figure 3. Gradation vs. Shooting Time

So that all the abrasives might be compared at the same shooting rate, the after-blasting gradation was picked from these curves where they intersected with a shooting time of four minutes and ten seconds. This shooting time corresponds to a blasting rate of six hundred pounds of abrasive per hour for an 18,750 gram sample.

The abrasives were grouped into eight material types using information obtained from the manufacturers. For discussion purposes a summary of the before and after blasting gradation for twenty-two typical abrasions is presented in Table 1. A complete tabulation of the before and after blasting gradation data is presented in the Appendix in Table A-1.

The grams of steel abraded from each impingment plate during the blasting was also plotted against shooting time in a manner identical to that used for the gradation. The abrasion value corresponding to a four minute and ten second shooting time is also presented in Table 1.

Table 1 - Selected Typical Abrasives -
Gradation and Abrasion Loss Results

Material	Percent Passing Before Blasting #50	#70	#100	Percent Smaller After Blasting 20	10	5	Grams Steel Abrasion
Ocean Sands							
#1	0	0	0	4.1	2.0	1.0	6.2
#5	1	0	0	5.1	2.6	1.3	9.5
#6	2	0	0	7.0	3.2	1.5	9.9
#9	3	0	0	7.0	3.5	1.7	16.5
#13	8	1	0	7.7	4.0	1.9	15.7
#16	15	3	1	7.6	3.8	2.0	17.2
#18	21	4	0	8.8	5.0	2.0	17.6
#10	14	6	2	10.0	5.1	2.6	18.2
#23	60	18	2	10.6	5.3	2.6	18.2
Silica Sands							
#25	1	0	0	6.4	3.3	1.7	19.2
#24	4	2	1	7.6	5.1	3.0	15.0
#28	54	28	11	9.8	5.0	2.6	26.0
#29	80	42	13	10.8	5.6	2.6	23.1
Nickel Slags							
#34	0	0	0	2.5	1.0	0.3	28.9
#35	1	0	0	3.0	1.3	0.4	35.8
Copper Slags							
#36	1	0	0	2.5	1.1	0.3	37.0
#37	5	4	3	4.0	1.9	0.6	26.7
#38	6	4	4	3.6	2.0	1.0	27.2
Steel Slags							
#42	6	2	1	2.5	1.0	0.4	39.5
#48	0	0	0	4.6	1.8	0.5	32.1
#46	9	3	1	3.0	1.4	0.5	45.4
#45	7	1	0	4.3	3.0	2.2	41.9

To facilitate the analysis, the data in Table A-1 was assembled in numerous rank orders. These rank orders were functions of the abrasion loss values, before-blasting gradation, and after-blasting gradation, for various particle sizes. An examination of the ranked data indicated a number of relationships. One significant finding was that those natural abrasives which contained more than a trace of particles passing a No. 70 U. S. Standard Sieve before blasting had significantly more 5 micron and smaller material after blasting than did those natural abrasives which did not contain the passing No. 70 material before blasting. It was also noted that the natural abrasives produced, on the average, two to three times more 5 micron material than that produced by the slag abrasives. The 5 micron and smaller particles were the primary size evaluated as they form the bulk of the air pollution considered most hazardous to health according to members of the California Air Resources Board staff. This is due, at least in part, to the tendency of these very small particles to remain in suspension in the air for extended periods of time and, as such, to be inhaled into respiratory systems.

The silica sands, due to their angular shape, abraded considerably more steel from the impingment plates than the other sands; however, they also tended to produce a greater percentage of 5 micron material than the other sands. One exception to this was the natural grain Ottawa Sand which is spherical shaped and produced no measurable 5 micron material; however, abrasion of the steel plate was only 50% of that abraded using a similarly graded silica sand. It should be noted that abrasion of a steel plate placed perpendicular to the axis of the blasting nozzle does not necessarily reflect removal rates for paints and coatings normally removed by blast cleaning. This is due to the fact that coatings are removed by a combination of chipping and abrading with the nozzle normally positioned at a 70°-80° angle to the surface being cleaned. However, it is felt that the steel abraded from the impingment plate is indirectly related to the abrasive's coating removal ability.

The data in Table 1 also support the finding in previous work that, for a given material, the greatest factor affecting dust generation is the initial sizing of the abrasive. The finer the initial sizing, the greater the percentage of 5 micron size material.

The results of this work and these findings, as they became available, were reported to the "Committee on Air Pollution Standards for Abrasive Blasting Operations", during a series of six meetings from April 15, 1975 to May 27, 1975.

TABLE A-1

ABRASIVE GRADATION BEFORE AND AFTER BLASTING AND ABRASION LOSS

Material	#8	#10	#12	#16	#20	#25	#30	#40	#50	#70	#100	#200	20μ	10μ	5μ	Grams, Steel Abrasion
Ocean Sands: 50-60% Quartz 35-40% Feldspar 10% Others																
1 Before	100	89	62	19	2	1	0									
After			100	98	94	89	85	71	57	44	32	18	4.1	2.0	1.0	6.2
2 Before	100	92	67	25	11	7	6	4	2	0						
After			100	97	94	90	85	72	58	46	34	30	4.2	2.0	1.0	6.8
3 Before		100	99	49	4	2	1	1	0							
After				100	98	95	92	79	64	52	38	22	4.9	2.3	1.0	7.4
4 Before			100	77	17	3	1	1	0							
After				100	99	97	95	85	71	56	42	24	5.1	2.7	1.4	9.2
5 Before			100	80	22	6	4	2	1	0						
After				100	99	97	95	84	69	54	40	23	5.1	2.6	1.3	9.5
6 Before			100	81	20	13	10	5	2	0						
After				100	99	98	96	85	72	58	44	26	7.0	3.2	1.5	9.9
7 Before			100	93	36	6	2	1	1	0						
After					100	98	97	88	75	59	45	26	6.0	2.8	1.2	9.8
8 Before			100	93	60	29	18	5	1	0						
After					100	99	97	89	75	60	43	24	5.9	3.0	1.2	13.3
9 Before			100	98	86	72	60	21	3	0						
After					100	99	99	95	83	68	51	28	7.0	3.5	1.7	16.5
10 Before			100	99	93	82	70	32	14	6	2	0				
After						100	99	96	88	76	60	36	10.0	5.1	2.6	18.2
11 Before				100	51	17	7	1	0							
After					100	99	98	91	78	62	46	27	6.0	2.8	1.2	10.7
12 Before				100	78	45	20	2	0							
After						100	99	94	81	66	49	28	6.6	3.4	1.6	12.7
13 Before				100	81	59	41	20	8	1	0					
After						100	99	95	86	72	55	32	7.7	4.0	1.9	15.7
14 Before				100	87	56	26	6	2	0						
After						100	99	96	84	69	52	30	7.2	3.5	1.6	14.0
15 Before				100	95	82	67	22	3	0						
After						100	99	96	85	69	51	28	7.5	3.6	1.5	16.8
16 Before				100	96	87	75	44	15	3	1	0				
After						100	99	97	88	75	56	31	7.6	3.8	2.0	17.2
17 Before				100	99	73	39	6	1	0						
After							100	95	84	68	51	29	6.5	3.1	1.4	15.0
18 Before				100	99	93	74	40	21	4	0					
After							100	97	89	77	60	36	8.8	5.0	2.0	17.6
19 Before					100	97	86	35	4	0						
After							100	98	89	73	54	30	7.2	3.6	1.6	17.2
20 Before					100	98	94	71	29	5	0					
After							100	99	92	78	58	32	7.0	3.8	1.6	21.8
21 Before						100	98	43	16	2	0					
After							100	99	93	80	62	36	8.6	4.3	1.9	18.2
22 Before						100	98	62	20	4	1	0				
After							100	99	93	82	62	35	7.8	3.9	1.7	18.5
23 Before							100	99	60	18	2	0				
After								100	98	89	70	39	10.6	5.3	2.6	18.2

TABLE A-1 (Continued)

ABRASIVE GRADATION BEFORE AND AFTER BLASTING AND ABRASION LOSS

Material	#8	#10	#12	#16	#20	#25	#30	#40	#50	#70	#100	#200	20µ	10µ	5µ	Grams, Steel Abrasion
Silica Sands:																
90-100% Quartz 0-10% Others																
24 Before	100	94	65	22	10	8	7	6	4	2	1	0				
After				100	98	95	92	80	67	54	41	25	7.6	5.1	3.0	15.0
25 Before		100	98	75	25	12	7	2	1	0						
After					100	98	96	87	74	60	45	26	6.4	3.3	1.7	19.2
26 Before				100	93	69	47	15	6	2	1	0				
After						100	99	96	86	72	55	32	6.4	3.0	1.3	25.5
27 Before				100	99	95	78	8	1	0						
After						100	97	78	57	38	25	11	2.3	0	0	13.3
28 Before							100	87	54	28	11	0				
After								100	98	92	77	45	9.8	5.0	2.6	26.0
29 Before								100	80	42	13	1				
After								100	98	93	78	45	10.8	5.6	2.6	23.1
Crushed Rock:																
30 Before		100	97	62	31	17	9	2	1	0						
After			100	98	91	84	78	61	47	35	26	17	4.8	2.5	1.3	21.5
Garnet:																
31 Before				100	75	46	28	3	0							
After				100	96	88	81	66	52	40	28	14	2.7	1.0	0.3	27.7
Nickel Slags:																
32 Before	100	95	70	17	2	1	0									
After			100	99	96	91	86	70	55	42	31	16	3.2	1.5	0.6	9.4
33 Before	100	96	78	39	14	6	2	0								
After			100	99	96	90	85	67	51	37	27	14	3.2	1.6	0.5	14.0
34 Before			100	98	60	31	12	1	0							
After				100	99	98	96	83	66	49	34	17	2.5	1.0	0.3	28.9
35 Before				100	94	64	41	8	1	0						
After					100	99	97	86	70	51	35	17	3.0	1.3	0.4	35.8
Copper Slags:																
36 Before	100	99	96	77	44	26	17	4	1	0						
After				100	98	95	91	76	59	44	30	15	2.5	1.1	0.3	37.0
37 Before		100	91	43	18	12	9	6	5	4	3	2				
After			100	97	90	86	79	63	48	36	26	14	4.0	1.9	0.6	26.7
38 Before			100	81	32	20	14	8	6	4	4	3				
After			100	99	93	86	79	64	47	35	25	14	3.6	2.0	1.0	27.2
39 Before			100	94	70	51	37	13	2	0						
After				100	99	96	93	81	63	47	32	16	2.7	0.9	0.2	42.0
40 Before			100	94	71	52	37	13	2	0						
After				100	99	96	93	81	63	46	31	15	2.5	1.2	0.5	42.8
41 Before			100	99	76	53	38	14	7	5	4	3				
After			100	97	89	84	78	63	49	38	27	15	2.8	1.3	0.6	26.3
Steel Slags:																
42 Before	91	80	69	59	49	41	32	15	6	2	1	0				
After		100	99	97	93	89	85	73	59	45	32	16	2.5	1.0	0.4	39.5
43 Before	98	92	84	74	64	52	42	20	8	3	1	0				
After		100	99	98	96	92	89	77	63	49	35	17	2.7	1.0	0.1	43.5
44 Before	100	99	90	49	16	8	4	1	1	0						
After			100	98	92	86	81	64	49	36	25	13	2.9	1.7	0.7	41.1
45 Before		100	99	94	79	66	55	27	7	1	0					
After				100	99	98	96	85	66	43	26	12	4.3	3.0	2.2	41.9
46 Before			100	96	76	61	47	22	9	3	1	0				
After				100	99	97	94	83	69	54	38	19	3.0	1.4	0.5	45.4
47 Before			100	99	93	66	41	12	2	0						
After					100	99	98	90	75	60	42	21	3.8	2.1	0.8	43.0
48 Before				100	87	57	33	3	0							
After							100	95	85	71	51	26	4.6	1.8	0.5	32.1
Rock Wool By-Product																
49 Before		100	98	77	31	12	7	1	0							
After				100	97	93	88	79	59	44	30	15	3.7	1.6	0.6	25.0