November 22, 1961

MEMORANDUM C.1.3.

TO: J. A. Bitterman
Director of Materials

FROM: W. B. Drake
Director of Research

SUBJECT: Evaluation of Color Panels Cast from Various Cement Samples

We have used several methods in an effort to evaluate color differences in the 12 concrete panels that were cast in your laboratory. We have brushed and etched the specimens and have made observations under natural and artificial light. Mr. Milton Evans, Jr., Head of our Concrete Section, has prepared a report on the evaluation.

It appears that there is a significant difference in the lightest and darkest panels. Of course, there is very little difference between the three lightest blocks. I believe that by use of the tables and the accompanying photographs you can determine the range of differences encountered.

We do not have available a scientific instrument that will assign actual color values. We think that a "Tri-Stimulus Colorimeter" might provide actual values for color classification. This equipment is rather expensive and we do not have information as to delivery time either. If you feel that the additional information is required, we will try to obtain this equipment.

As you know, there are several items that influence the color of portland cement concrete. Mr. Evans has mentioned some of them. We have observed cements having considerably greater variations in color than those represented by the 12 panels. We are of the opinion that color differences of the concrete, particularly in structures, is significant. Consideration could be given to checking the color-match on cements when and if a change of material would be requested.

We will keep the panels here for a reasonable time for any additional use that you might find necessary.

WBD:dl
Attach.: Evans' Memo.
cc: A. O. Neiser

November 22, 1961

MEMORANDUM

C. 1. 3.

TO: W. B. Drake
Director of Research

FROM: Milton Evans, Jr. M. E.
Research Engineer Associate

SUBJECT: Concrete Color Variations Observed in Specimens made from 12 Type I Portland Cements

The twelve concrete specimens, provided by the Division of Materials, have been examined to determine color differences. A comparison has also been made among samples of dry cement and among neat cement plates. A copy of Mr. J. A. Bitterman's letter, dated October 17, 1961, which includes a list of sources of the cements, is attached.

The 12- x 12- x 3-in. concrete specimens, as furnished, all appeared to be the same color due to the whitish laitance residue on both the formed and trowelled surfaces. In order to expose the true colors of the concretes, the following methods of surface preparation were employed:

1. One-half of one 12- x 12-in. side was rubbed with a carborundum stone and scrubbed with a stiff-bristled brush, and the other half was left with a formed finish;

2. One-half of the other 12- x 12-in. side was etched with a 10% solution of muriatic acid and scrubbed with a stiff-bristled brush, and the other half left with a formed finish;

3. The bottom edge was scrubbed with a stiff-bristled brush.

All of the surfaces were observed, wet and dry, under natural light (outdoors) and white fluorescent light (indoors). Yellow, green, red, blue and ultra-violet lights were also used, but these did not show any differences not observed under natural and flourescent lights.

The etched surfaces were compared and rated, wet and dry, under both kinds of light. The rubbed surfaces were also compared and rated under these conditions. The surfaces which were scrubbed with a stiff-bristled brush were still so similar, because of the whitish laitance residue, that no comparison or rating was possible. It is felt that the truest colors were observed when the acid-etched, dry surfaces were compared under natural light. Further, it is believed that exposed structural concrete would assume this kind of an appearance for the greater part of its life (the only difference being that the forces of weather would do the etching on a structure).

Although the variation between the lightest specimen and the darkest specimen was very noticeable, it was difficult to rank the intervening specimens. Even though there was some variation in the rankings of the specimens (light to dark), depending upon the method used, the four lighter specimens usually showed up in the lighter one third, and the four darker specimens usually showed up in the darker one third. Table I shows the various rankings of the specimens.

The dry cement powders were observed under natural and artificial lights, and they were ranked according to color. Neat cement plates were made from each cement, and they were observed immediately after mixing (plastic condition), fifteen hours after mixing (hardened condition) and twenty-one hours after mixing (after oven-drying).

In summarizing the color differences among the concrete and cement specimens, average ranks were found for each sample by allowing equal weight for ranking positions in each category - see Table II. Average ranking positions were computed by crediting one point for each first rank, two points for each second, three points for each third, etc., and by summing the points thus obtained in each category for each sample. This was done to determine the degrees of difference between specimens. A mode, indicating the rank in which a specimen occurred most frequently, was also found, i.e. specimen No. 6 occurs most frequently as lightest, No. 12 occurs most frequently as second lightest, No. 10 occurs most frequently as darkest, etc. It can be seen in Tables I and II that the specimens were not ranked in exactly the same order in the different categories, but they are ranked approximately the same. It can be

seen too (Table II) that there are recognizable color differences among the cements. For instance, the difference between cements Nos. 6 and 12 is not as great as the difference between Nos. 6 and 10.

Photographs are attached to better define the various color differences discussed herein.

It appears from these observations that a rubbed surface such as results on most of our structures is mostly white in appearance; and, even when different cements are involved, the color is essentially the same. However, after weathering, this white surface is removed; and the true color of the concrete is then evident. At this time, a difference in color would become pronounced.

In any case, where more than one cement is to be considered for a single project, color comparisons should be made; and the concretes made from the cements selected for the work should be visually matched so as to avoid objectionable color differences. For instance, if the cements analyzed herein were being considered, those cements having nearly the same rank (Table II) could be allowed as alternates; and the risk of getting objectionable contrasts in color would be mini-minized.

It is of equal importance, where color differences of concretes are objectionable, to recognize that a change in the aggregates or even in the mix proportions can effect an appreciable change in the color of the resultant concrete.

ME:dl
Encs. Figs. 1 thru 4
Attach.: J. A. Bitterman's Memo to T. H. Baker dated 10-17-61, and list of cement brands and code numbers.

October 17, 1961

Division of Materials

MEMO TO: Mr. T. H. Baker
Director of Construction

SUBJECT: Cement Color Variations

A series of tests were conducted in the Laboratory to determine the color variations. Twelve (12) different brands were used (names of brands are attached to this memo).

Class "A" Concrete was used in order to make the comparison. The same source of sand and stone was used through-out.

Same type of form, form oil and vibrator used by contractors was used in casting these specimens.

Actually, color differences among the twelve (12) brands are very slight. All specimens are on display on roof of the Division of Materials Building.

John A. Bitterman
Director of Materials

PJG/lw

Attachment

CEMENT BRANDS

IDENT	NAME OF CEMENT BRAND	LOCATION
1	Marquette Cement Manufacturing Co.,	Cape Girardeau, Missouri
2	Marquette Cement Manufacturing Co.,	Superior, Lawrence County, Ohio
3	Universal Atlas Cement Division	Fairborn, Ohio
4	Southwestern Portland Cement Co.,	Fairborn, Ohio (Miami)
5	Volunteer Portland Cement Co.,	Knoxville, Tennessee
6	Penn-Dixie Cement Corporation	Richard City, Tennessee
7	Penn-Dixie Cement Corporation	Kingsport, Tennessee
8	Alpha Portland Cement Co.,	Ironton, Ohio
9	Kosmos Portland Cement Co.,	Kosmosdale, Kentucky
10	Louisville Cement Co.,	Speed, Indiana
11	Lehigh Portland Cement Co.,	Mitchell, Indiana
12	Dundee Cement Co.,	Dundee, Michigan

TABLE I
Color Comparison of 12 Portland Cements

Positions: Light-to-Dark (1)	Dry Cement Powder (2)		Neat Cement Plates (3)					Carborundum Rubbed (4)				Acid Etched (5)			
	[1]Natural Light	[2]Artificial Light	[1]Natural Light		[2]Artificial Light			[1]Natural Light		[2]Artificial Light		[1]Natural Light		[2]Artificial Light	
			Plastic	Hardened	Plastic	Hardened	Oven[e] Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	6	6	6	6	6	6	6	5	12	6	12	12	12	6	12
2	12	12	12	12	12	5	12	6	3	5	7	6	7	5	7
3	11	7	5	8	5	12	8	12	5	12	5	5	6	12	6
4	7	5	8	5	8	8	*1	4	7	8	3	3	5	8	5
5	5	8	7	*1	7	*1	3	7	6	3	8	7	11	3	11
6	8	11	4	7	4	7	7	8	8	7	6	8	3	7	3
7	*1	3	3	3	3	3	4	3	4	4	4	11	*1	4	*1
8	3	2	*1	4	*1	2	11	2	*1	9	9	4	8	*1	8
9	2	*1	11	2	11	4	2	*1	9	*1	*1	2	4	9	4
10	4	4	2	9	2	9	9	11	10	11	10	9	9	11	9
11	9	9	9	11	9	11	10	9	2	2	11	*1	2	2	2
12	10	10	10	10	10	10	x	10	11	10	2	10	10	10	10

*Specimen very rough in texture and difficult to classify.
[1]Outside in sunlight.
[2]Dark Room with only source of light coming from fluorescent (cool white) bulb.
x-No. 5 Specimen omitted because of difference in tone (could not be classified because of olive rather than gray tones).
e-Omitted from Analysis Table II.

TABLE II
Color Comparison of 12 Portland Cements

Position: Light-to-Dark	Average Rank Including Columns 2, 3, 4 & 5			Average Rank Including Columns 3, 4 & 5			Average Rank Including Column 2	
	Rank	Total Pts.	Mode	Rank	Total Pts.	Mode	Rank	Total Pts.
1	12	27	6	12	23	6	6	2
2	6	29	12	6	27	12, 5, & 7	12	4
3	5	43	5	5	34	5	7	7
4	7	61	8	7	54	8	5 & 11	9
5	8	73	7	8	62	7	5 & 11	9
6	3	82	7 & 8	3	66	7	8	11
7	4	107	3	4	87	3	3	15
8	1	110	1	1	94	1	1	16
9	11	120	1	11	110	1 & 4	2	17
10	2	138	9	9	117	9	4	20
11	9	139	9 & 2	2	121	2	9	22
12	10	164	10	10	140	10	10	24

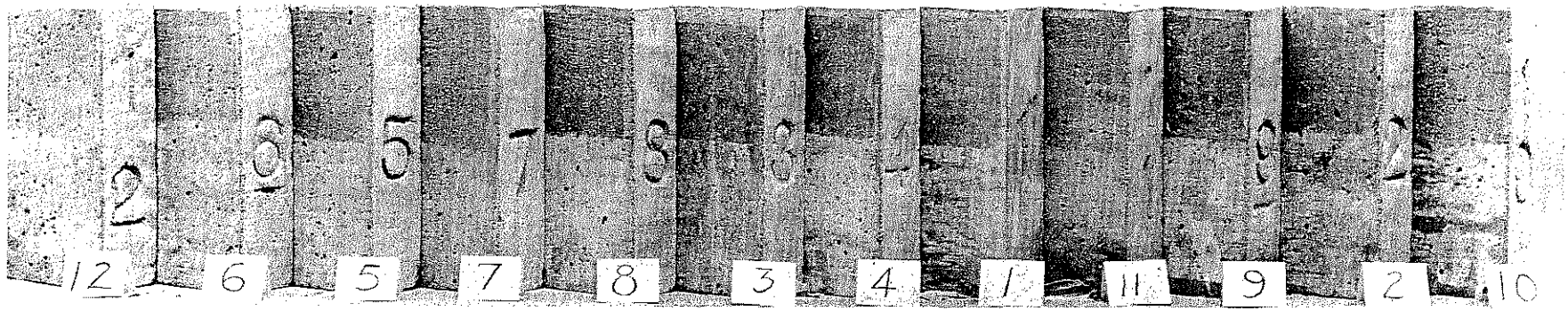

Fig. 1. Specimens Arranged According to Average Rank. From Left to Right: Light to Dark. Top areas are acid etched and dry.

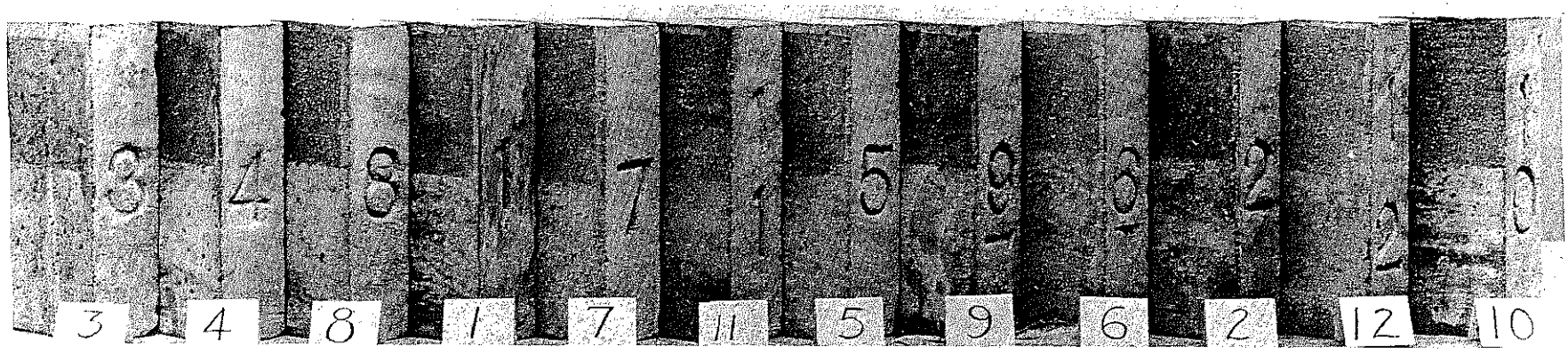

Fig. 2. Alternating Specimens. From Right to Left: Darkest, Lightest, Second Darkest, Second Lightest, Third Darkest, Third Lightest, etc. Most extreme contrast shown on right, descending to least contrast on left. Top Surfaces -- Acid Etched, Dry.

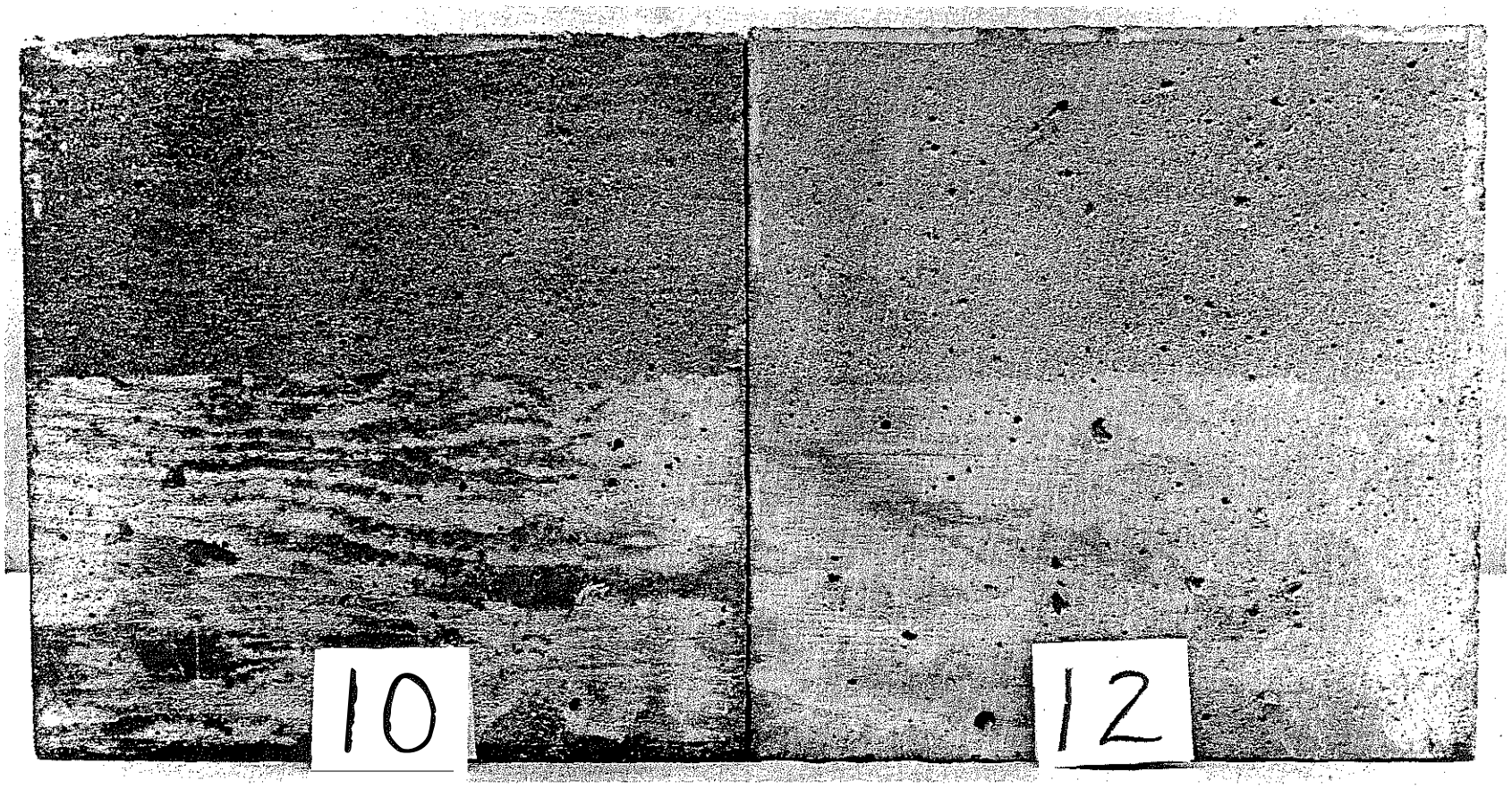

Fig. 3. Lightest Specimen (12) and Darkest Specimen (10). Top Surfaces are Acid Etched, Dry.

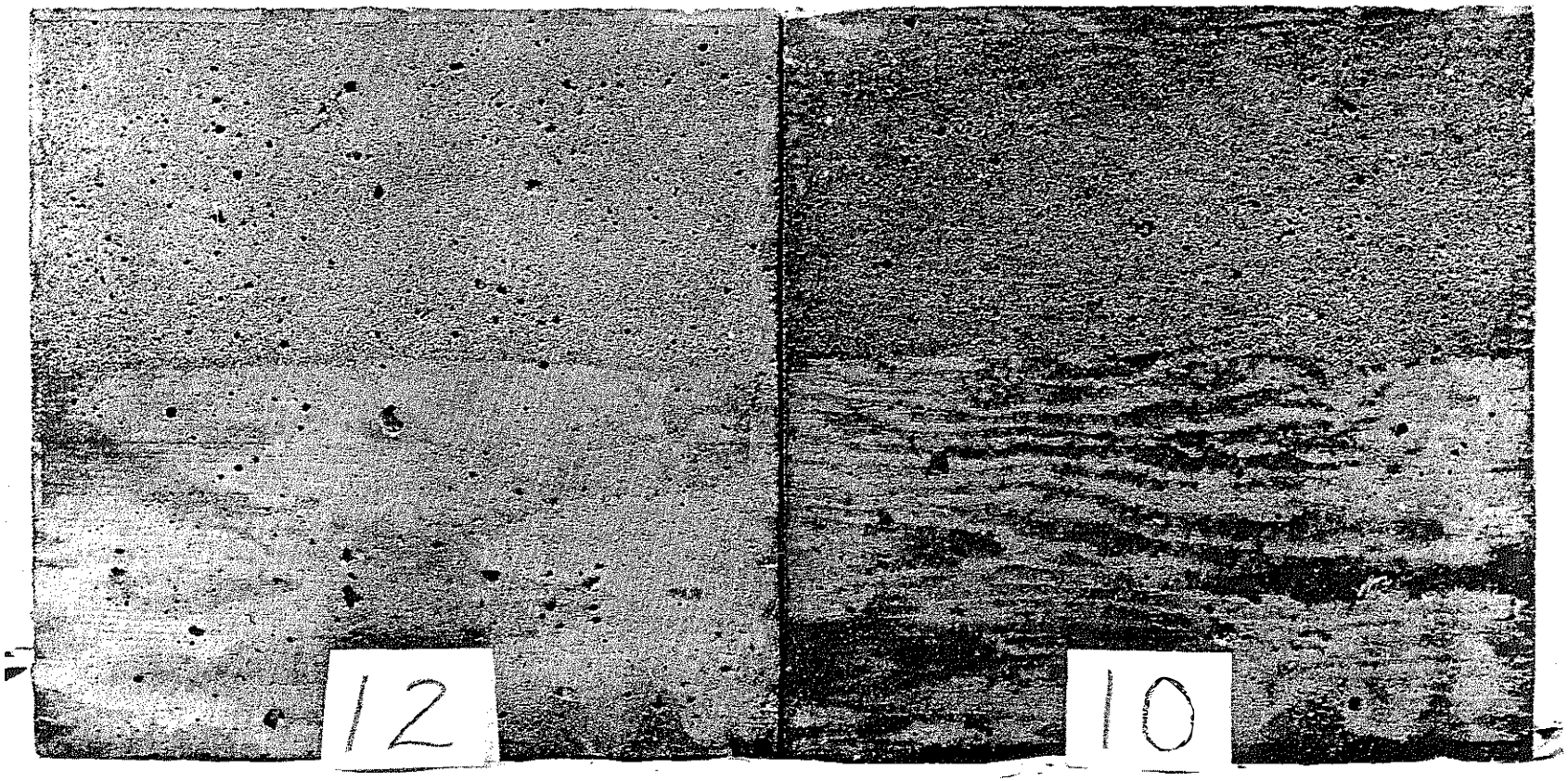

Fig. 4. Lightest Specimen (12) and Darkest Specimen (10). Top Surfaces are Acid Etched, Wet.