An Investigation of Fastness of Concrete Colors

SERIES J-131

by

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Colored concrete has become popular among engineers and architects for such applications as sidewalks, driveways, floors, concrete products and other architectural uses. the ability to produce permanent color without adversely affecting other properties of concrete must be determined before coloring agents can be confidently and safely used. An investigation of limited scope was conducted in the Joint Research Laboratory of the NSGA and NRMCA at the University of Maryland to study this problem through tests of concretes containing four different mineral pigments.

The pigments were finely ground, natural and synthetic oxides of iron. Pigments Nos. 1 and 3 produced red concrete; pigments Nos. 2 and 4 produced black or slate concrete. The other concrete constituents were quartz sand and gravel graded to a one-inch maximum size and Type 1 cement, a blend of equal amounts of five local brands.

All concrete was proportioned, without adjustment for the pigments, to have a 3 to 4 inch slump, to contain 5 sacks of cement per cubic yard and not purposely entrained air. Each pigment was incorporated in the concrete at the manufacturer's recommended rate and at twice that rate as shown in Table 1. Batches were designed to yield three 3 by 16 inch prisms.

Two rounds, designated A and B, were mixed 56 days apart to provide a direct comparison of color between new concrete and that two months old. the pigments were added to the aggregates and were mixed with a portion of the mixing water for 2 minutes. Cement and the remainder of the mixing water were then added and the batch mixed for an additional 6 minutes. Specimens were molded according to standard methods except that the exposed surfaces of prisms were given a steel-troweled finish.

Specimens were treated in the following manner. Compressive strength tests were made on the cylinders after 28 days of curing in a standard moist room. All four prisms from each batch were cured in the standard moist room for 7 days. At that time the prisms were exposed to different environments to determine their effects on the fastness of the coloring. One was left in the moist room; a second was exposed to 70˚F air at 40 to 60 percent R.H.; the third to 100˚F air at 20 to 30 percent R.H.; and the fourth to an outdoor exposure site for storage on the ground.

Characteristics of the plastic concrete and strength test results are shown in Table 1. The effects of the four pigments on mixing water requirement, at either the recommended or twice the recommended rate, were quite small. Pigment No. 3 reduced mixing water about one gallon per cubic yard while entraining about 1.5 percent more air than the control concrete. The other pigments increased mixing water requirement about one-half gallon per cubic yard, but had no significant effect on air content. Compressive strengths averaged slightly higher when coloring pigments were used. When expressed as percentages of the control values, strengths of concrete containing pigments at recommended dosages ranged from 98 to 110 percent and averaged 102 percent; at twice recommended rates, the range was 106 to 113 percent with an average of 109 percent. The significance of these differences in either a statistical or practical sense is questionable, but they suggest at least that the pigments were not detrimental to strength.

Color comparisons were made a various times during the year since this study began. They were made by gathering all specimens together to permit visual comparisons one to another by the same technician. The specimens continuously stored in the standard moist room were used as the standard color after being allowed to dry. The most significant color differences were between wet and dry specimens. In all cases, including specimens without pigments, the wet prisms were much darker. Delayed mixing of Round B to facilitate comparison at two ages did not result in distinguishable differences. Double dosages of pigment caused a slightly darker color, but the difference was barely noticeable to the eye. Specimens stored in different laboratory environments were uniform in color and did not appear to fade from the standard color. When placed outdoors colors lightened only slightly, to about the same extent as the differences between single and double dosages. In general, all pigments produced fast colors which were not altered greatly by the different exposures.

Uniform coloring was not obtained on surfaces steel-troweled shortly after molding. At the time the concrete had not set nor hand bleeding terminated. Finishing was done under this adverse condition - which is not consistent with good practice - to determine its effect on the colored surface. It was found that the finished surface was somewhat mottled while surfaces formed against the steel molds were of uniform color. this result was not unexpected; it suggests the need for special care in finishing surfaces of colored concrete.

In summary, the pigments were found to be relatively inert when incorporated in concrete and were not detrimental to its more important properties. Variations in mixing water requirements were small. Strength showed slight improvement when pigments were used, but the magnitude was probably of little practical importance. The colors were reasonably permanent even when the concrete was exposed to natural weathering. The outdoor exposure is being continued.

Table 1. Characteristics of Plastic Concrete and Results of Strength Tests (Series J-131)

Concrete, incorporating 4 different pigments, was mixed in 0.75 cubic foot batches for 6 minutes in a small tilting mixer. Compressive strength tests were made on three 3 by 6 inch cylinders after 28 days of moist-room curing. Color fastness was studied using 3 by 4 by 16 inch prisms exposed to different environments in the laboratory and to matural weathering.

Pigment No. & Color	Rate, lb./ cu. yd.	Round	Cement, sks./ cu. yd.	Water gal./ cu. yd	Slump in.	Air Cont., %	Compressive Strength at 28 Days, psi				Str. % Cont. Cont.
							1	2	3	Av.	
RECOMMENDED RATE											
None Gray		A	4.97	37.9	3.2	1.8	3438	3477	3522	3479	-----
		B	4.95	38.2	4.2	1.8	3498	3419	3605	3507	-----
		Av.	4.96	38.0	3.7	1.8				3493	100
1 Slate	25	A	4.96	38.3	2.9	1.4	3665	3734	3801	3733	-----
		B	5.00	36.2	2.7	1.9	3850	4048	3888	3928	-----
		Av.	4.98	37.2	2.8	1.6				3830	110
2 Red	15	A	4.96	38.6	3.8	1.4	3465	3454	3522	3480	-----
		B	4.94	38.1	4.1	2.0	3571	3661	3612	3614	-----
		Av.	4.95	38.5	4.0	1.7				3547	102
3 Slate	8	A	4.89	37.8	3.7	2.9	3610	3438	3372	3473	-----
		B	4.89	35.9	3.8	3.8	3064*	2699*	3382*	------	-----
		Av.	4.89	36.8	3.8	3.4				3473	100
4 Red	15	A	4.95	38.4	3.7	1.6	3405	3438	3464	3435	-----
		B	4.95	38.4	5.0	1.4	3246	3468	3479	3397	-----
		Av.	4.95	38.4	4.4	1.5				3416	100
TWICE RECOMMENDED RATE											
None Gray		A	4.95	38.0	3.2	2.1	3434	3368	3327	3376	-----
		B	5.00	38.5	5.7	1.4	3373	3339	3315	3342	-----
		Av.	4.98	38.2	4.4	1.8				3359	100
1 Slate	50	A	4.95	39.0	2.9	1.0	3789	3818	3668	3758	-----
		B	4.95	38.5	3.5	1.1	3761	3869	3811	3813	-----
		Av.	4.95	38.8	3.2	1.0				3785	113
2 Red	30	A	4.95	38.8	3.6	1.3	3612	3540	3549	3567	-----
		B	4.94	38.2	3.8	1.5	3726	3911	3709	3782	-----
		Av.	4.94	38.5	3.7	1.4				3674	109
3 Slate	10	A	4.86	38.0	3.8	2.9	3458	3457	3479	3464	-----
		B	4.87	36.1	4.3	3.7	3721	3663	3653	3679	-----
		Av.	4.86	37.0	4.0	3.3				3571	106
4 Red	30	A	4.95	38.8	3.2	1.1	3686	3713	3547	3648	-----
		B	4.94	38.4	3.9	1.5	3631	3670	3635	3645	-----
		Av.	4.95	38.6	3.6	1.3				3646	109

*Cylinders badly honeycombed; apparently not properly rodded;excluded from average.