

MICHIGAN
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COLOR IN CONCRETE PAVEMENTS

By

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Concrete possesses inimitable advantages in strength and durability, combined with flexibility in use and application, possessed by very few other building materials. The addition of color to concrete widens its range of usefulness in highway construction. For example, in matching surfaces on adjacent streets, for producing color effects in parks, driveways and private estates, for constructing permanent colored traffic lines and for coloring certain pavement lanes to aid in traffic control.

Success in coloring concrete pavements depends upon the selection of suitable and satisfactory colors and upon the methods employed in using them. Both must be learned by careful study and practice. Wrong colors or methods will result in such faults as unattractive shades, streaking or fading and an inferior concrete surface. It is the purpose of this report to present the fundamental principles embodied in coloring concrete surfaces as recognized at the present time and including such factors as selection of color pigments and methods of mixing them.

SELECTION OF PIGMENTS

Certain pigments are most suitable for coloring concrete by virtue of their remaining permanent. The three outstanding ones are; green chromium oxide, "cobalt ultra-marine blues" and iron oxides; the last being employed for shades of buff, tan, brown, maroon, red and black.

Iron oxides are of two types; natural and synthetic. Natural iron oxides vary in purity from 10 to 90 per cent, while synthetic oxides recommended for use will run as high as 98 percent pure. This factor makes the synthetic oxides

preferable because their strength gives brighter, more attractive shades and at the same time less of the pigment is required for a given effect which reduces the tendency to weaken the concrete.

Many of the natural pigments, especially those of the type used in coloring mortar, are low in color strength. This necessitates the use of comparatively large quantities of the pigment when a deep color effect is sought. Also the presence of soluble salts in natural pigments sometimes results in efflorescence or blooming.

Pigments cannot always be judged by their appearance in the dry state. Some, apparently light in shade, actually have greater coloring power than darker shades of the same type. For example, a red oxide of 40 percent iron oxide content will sometimes appear to the eye as bright as another one of 98 percent.

The vital difference between colors is not apparent in their dry state, neither is it ascertainable always by simple chemical analysis. Nothing but actual performance under working and prolonged weathering conditions can possibly bring out the characteristics of the different coloring materials. The following discussion of the various pigments is based upon years of research and experience by the Smith Chemical and Color Company of Brooklyn, N.Y. manufacturers of mineral colors. (1)

Colors Recommended for Use:

The colors which are considered safe and satisfactory for use in concrete are as follows:

1. YELLOW. Both natural and synthetic iron oxides may be used. They are available in various yellow and tan shades. The natural yellow oxides are used for light buff and cream tints. For light and dark tan shades with red, yellow

and olive tones, the natural tan shades are used. The synthetic yellow oxide should be used to get the brighter and deeper shades of yellow. To produce deep buff shades use this yellow, with brown tones.

2. RED. Again the natural and synthetic iron oxides are both available. Synthetic red iron oxide, grading 98% plus, is best for the brighter and deeper shades of red. The shade, of course, depends upon the amount of color employed in the mix. A clear pink, for example, is obtainable by using this color in very small proportions. For some work the natural oxide is suitable and quite economical, grades running 80 to 90% in oxide content being procurable at low cost. This will give an attractive dark red shade. Other grades will produce satisfactory dark shades at corresponding cost figures.

3. MAROON. For this color also natural and synthetic iron oxides are available and, with proper attention to grade and mixing, give satisfactory results. The synthetic product, grading 98% plus, produces a clear, clean, attractive maroon color, even when used in very small quantities. It is obtainable in light, medium and dark shades. The natural maroons are not as clean as the synthetic oxides, nor are they as strong.

4. BROWN. Both natural and synthetic oxides may be utilized for this much used color. In the natural oxide a whole series of shades, from reddish brown to very dark, is to be had; also browns with a bluish tone. Synthetic browns run the gamut of shades from very light to very dark.

5. GREEN. Oxide of chromium is the standard green color. It can be had in a variety of grades -- 98 plus, 75%, and other proportions. For this color, the synthetic product, grading 98% plus, is recommended in preference to all others, irrespective of cost. Low price here is no indication of economy. Avoid

by-product chromium oxide. It lacks uniformity and is likely to contain soluble salts and other impurities.

6. BLACK and GRAY. The most efficient black for general purposes is synthetic black iron oxide. It is foolproof, not greasy, mixes readily, with water and is non-fading. Be sure to obtain from your supplier a jet black instead of a blue toned black.

Next to synthetic black iron oxide are the carbonaceous blacks. There are warning signals to give, however, in this connection. These blacks are very light in weight and due to the structure of the pigment, when mixed with water some of the particles noticeably float to the surface making it difficult to handle. A very thorough grinding of the pigment with the cement is necessary, otherwise the results will be spotty.

Black Manganese Oxide has the virtue of not fading, but it does not produce a deep black. The pigment commonly known as Mineral Black used in coloring mortar joints has little strength and is, therefore, undesirable.

7. BLUE. Ultramarine blue is the only blue pigment available for coloring cement. It is not entirely lime-proof, and it may fade. Commercial grades of this color vary in composition and in permanency. The best type for use in concrete products is one containing some cobalt, occasionally known as "cobalt ultramarine blue," which was mentioned -- with the quotation marks at the beginning of this discussion. This grade has more stability of composition and permanency of color than any other thus far found on the market. Pure blue cobalt oxide is entirely permanent, but its prohibitive cost puts it out of the reckoning, except possibly in some small, high priced novelty product.

There is a very definite word of warning to be sounded in connection with the use of this blue color. Heat must not be applied to the product at any stage, if blue color is used. This applies equally to heat from freshly slaked

lime and to steam curing. Blue coloring of cement should be carried out, at all stages, at ordinary temperatures.

8. WHITE. White portland cement, together with white aggregates, give good and economical results. For very fine work, where high white color is sought, suitable white pigments are to be had.

9. Permanent colors in very brilliant shades of green, yellow, orange, crimson and maroon are on the market and are employed on special work where high colors are desired. They are very high priced and seldom used to color the product throughout, only the surface, as a rule, receiving the color. Very beautiful effects can be produced with them in concrete products with glazed or highly polished surfaces, especially where the appearance of brilliantly colored marble or ceramic ware is to be duplicated.

Colors to be Avoided:

Some of the colors which should be avoided are discussed below. These colors may have arguments in their favor, such as the price factor.

1. VERY WEAK IRON OXIDE COLORS. These are not always to be depended upon for permanency, and usually result in a drab appearance in the finished product. Frequently they spoil the work by developing efflorescence or "blooming" because they contain soluble salts. Even though low-priced, they are not economical, since their weak color effect necessitates using considerable quantities. This has the added undesirable result of weakening the cement structurally.

2. IRON OXIDES WITH HIGH PERCENTAGES OF CALCIUM SULPHATE. Look out for "Venetian red". Pigments called by this name are frequently flagrant offenders in this particular, containing 10 to 30% of red iron oxide and the remainder calcium sulphate, soluble and certain to spell disaster in the manufacturer's

finished product. It has a pleasing bright appearance in the dry state and is perfectly suitable for other classes of work than concrete products. It should not be confused with 98% synthetic red iron oxide, which it closely resembles.

3. PRUSSIAN BLUE. This material, while it has a dark brilliant blue color, is very soluble in alkalies and fades entirely in cement.

4. CHROME YELLOW. This is another brilliant color which will fade in cement.

5. CHROME GREEN. This is not to be confused with chromium oxide. Chrome green is a blended mixture of the two colors mentioned in the two immediately preceding paragraphs -- prussian blue and chrome yellow. Of course the mixture fades as easily as the two ingredients.

6. LAMP BLACK. This color has been used in concrete products, but experience has demonstrated its fading properties and its use therefore is now obsolete. Color users prefer the black oxide of iron because of its permanency.

7. BONE BLACK. Soluble salts contained in this material are likely to cause efflorescence.

8. LAKES and TONES. These are manufactured colors of undesirable brilliancy and beautiful shades. But unfortunately they lack permanency and therefore cannot be used safely.

COLOR TREATMENT OF CONCRETE PAVEMENTS

Portland cement concrete pavement surfaces may be colored by any one of the five following methods, namely; the integral mix method, the dust-on method, the mixed-in-place method, by the application of stain to the surface or by an application of some type of colored surface treatment material such as specially prepared concrete paints. The proper method to employ on any given project will

naturally depend upon such factors as intended purpose, expected intensity, permanency of color and funds available.

The Integral Mix Method

The integral mix method consists of combining the cement-color, sand and coarse aggregate integrally in a suitable mixer and applying the mixture as a separate top course at a specified depth. Color may be used in the whole depth of slab, or in the interest of economy, only the top section may be colored to a specified depth. In the latter case, the concrete mixture in both courses is the same except the addition of the pigment. The top course is placed immediately following the bottom course. If the same mixer is used for both courses, the first batch of colored concrete should be placed in the bottom course in order to insure uniform coloring in the top course.

The thickness of color section will be governed somewhat by construction procedure and equipment. The thickness of color section recommended by the Portland Cement Association for concrete pavements is 2 inches.

The amount of pigment needed for the desired shade is determined in advance by trial, with the cement and aggregates that will be used in the work. From 2 to 4 pounds of color pigment is commonly used for 1 sack of cement. However, amounts of color pigment up to 10 percent the weight of cement may be used without detrimental effect.

Only commercially pure mineral pigments made expressly for coloring concrete and guaranteed by the manufacturer should be used. These colors should be sunfast and limefast.

Two methods are employed to incorporate the pigment in the concrete mass. One method in common practice is to scatter the pigment over the materials in

the mixer skip, premixing dry until the entire batch is of uniform color then adding water to bring the mixture to the proper consistency.

Another method preferred over the first method, is to intimately mix the pigment with the portland cement by suitable means and then add the color cement mixture to the dry aggregates in the mixer skip.

It is important to have a stiff concrete mixture to prevent settlement of the heavy mineral oxides.

The concrete is cured as in ordinary concrete construction.

The Dust-On Method

The dust-on method refers to dusting a dry mixture of color pigment and cement on to the surface of the finished concrete and troweling it into the concrete.

Dusting the color on to the surface gives deep colors with less pigment than would be required if it were admixed. The cement and color are intimately mixed dry using up to 15 pounds of color per sack of cement. The colored cement is then mixed with sand in the proportion of 1 sack of cement to 125 pounds of sand.

As soon as the concrete is finished, the colored cement-sand mixture is dusted evenly over it to a depth of 1/8 inch and floated until it becomes a part of the concrete beneath. It is then cured in the usual manner. The above mixture of color-pigment and sand on a basis of 1 sack of cement will cover approximately 22 square yards of pavement surface.

This method is extensively used for floors, walks and small concrete areas where quantity of materials and workmanship can be controlled to a high degree, thereby producing satisfactory results. In the case of concrete pavements, two factors make this method of questionable value; first, construction procedure

workmanship and nature of the work are not especially adaptable to this method and secondly, the abnormal abuse which a pavement surface receives from traffic and weather as well as the inherent characteristics of a concrete surface to scale and spall easily, would ultimately result in areas of uncolored concrete which would have to be continually maintained to preserve the continuity of the color scheme.

The dust-on method and the integral method are recommended for use in the construction of colored concrete traffic strips.

Mixed-In-Place-Method

The method consists of scratching or raking the fresh concrete to a depth of $\frac{3}{8}$ inch and applying the color pigment dry as a powder. The pigment is spread with a brush and then rubbed into the concrete with a wood hand float. The pavement is cured in the ordinary manner.

This method has been used quite successfully by the Texas Highway Department in the construction of colored traffic strips. They use 2 pounds of color per 5 to 6 square yards of pavement surface.

Studies by the Michigan State Highway Department have proven that this method is not inductive to uniform results because of the difficulty in obtaining uniform distribution of the pigment throughout the surface. Consequently, there will exist areas in which the color pigment may be highly concentrated or very sparse.

The Staining Method

This method consists of applying to the prepared concrete surface a stain material which will combine chemically with the cement paste to produce a color effect of desired intensity and durability.

The stains may be applied to the concrete surface when fresh, or at any time after the concrete has set up.

The stain material is commonly made from water soluble salts of various metals. Some stains may be harmful to the concrete especially those which are prepared from salts of sulphuric acid and also those stains containing organic materials should be avoided.

In the proper application of stain materials, the surface of the concrete should be prepared by etching with a 10% solution of muriatic acid, or equivalent, and thoroughly rinsed to open the pores of the concrete.

The depth of color is obtained by a succession of stain coats. After each coat the excess residue or powder deposited on the surface is flushed off with clean water and if necessary a scrubbing brush is used.

The final process is to treat the dry surface with a color developer to bring out and preserve the color effect.

It is sometimes necessary to add lime to the concrete (2 - 5 percent) or flush surface with lime water after etching to assist in color reaction.

Various materials such as shellac, clear lacquer, waxes, oils, resin emulsions, etc. are generally used for color developers.

Color effects may be obtained on concrete surfaces such as highways and airport runways by the staining process without the preliminary etching process previously described but it is doubtful that a uniform, durable and permanent surface would be obtained under such methods where the stains are applied directly to the finished concrete surface.

The staining of concrete surfaces for camouflage purposes has become quite common in certain parts of the United States. The stain method has proven quite satisfactory for camouflage purposes because it is a quick and economical method

of applying color to large areas such as airports, and it is adapted to produce harmonizing blends and mottled effects desirable in camouflage work.

The stain material penetrates only slightly into the concrete surface and thus such a colored surface would not be desirable where durability and permanency are desired.

Surface Treatments

This method consists of painting the existing concrete surfaces with some suitable type of material which will adhere to the concrete and produce at least temporarily, the desired results.

Paints applied to such surfaces are subjected to severe weathering conditions as well as wear and tear and the durability is dependent upon the binder employed.

This method is ideal for camouflage purposes where temporary color surface treatments are desired at low cost. Cold water paints such as kalsomine, casein base paints or mixtures of ferrous oxides, lime and water are employed for surface treatments. Even ordinary white wash is effective where white surfaces are desired.

COLORED CONCRETE TRAFFIC LINES (2)

Permanent traffic lines can be made of white or colored concrete. They are used extensively in cities to outline traffic lanes, pedestrian walks and street car safety zones and for highway center and edge lines.

White concrete lines are most common. They are made with white portland cement, white sand and white stone having a maximum size of 3/4 in. Proportions commonly used are about 1 sack of cement to 200 lb. of sand and 250 lb. of stone, requiring approximately 7 sacks of cement per cu.yd. Some engineers omit the stone,

using just a mortar.

The traffic lines are flush with the surface of concrete pavement or raised above a concrete base to come flush with the surfacing.

A groove is made in the pavement by embedding a board, usually a 1 x 6 in the surface. This is forced into the concrete following screeding. The concrete edges along the board are rounded to a 1/8 to 1/4 in. radius and the board is left in place until finishing of the slab is completed. Then it is removed and replaced with white concrete.

Bond between the white and grey concrete is the most important feature. It is secured by casting the white concrete as quickly as possible after the grey concrete is in place. That will be after finishing is completed and as soon as the grey concrete will remain vertical.

The grey concrete foundation may be roughened before the white concrete is placed or cleats may be fastened to the under side of the board used in forming the groove, to increase mechanical bond.

The white line is then troweled. To increase the line's visibility on unlighted highways the surface is corrugated transversely, the corrugation being about 1/8 in. deep and spaced about three to the inch. Straight edges are essential to good appearance.

Special precautions are desirable to keep white concrete from overlapping grey. Two boards, held apart the width of the traffic line, and having on their inner edges a metal lip extending about 1/4 in. vertically into the groove, make an excellent device for that purpose. These are laid on the slab before the white concrete is placed.

If colored lines are desired, colored concrete for the lines may be used, prepared as described in preceding section, or the "dusted on" type of lines may be used, as described below.

Either white or colored lines may be made by troweling into the fresh concrete a white or colored dry mixture of sand, cement and color. White lines are made with white portland cement and white sand. For colored lines, a colored portland cement may be used or 15 lb. of mineral color may be mixed with a sack of normal grey portland cement. The cement and pigment are just mixed with a shovel; then mixing is completed by passing the mixture through screens until the color is uniform. A tier of three galvanised wire fly screens is convenient.

For red colors, grey cement is satisfactory. For lighter colors, such as yellow or buff, white cement is better. A sack of the colored cement is mixed with 125 lb. of the sand being used on the job, but with all sand particles coarser than the No. 8 sieve and finer than the No. 30 sieve removed.

The dry cement-sand-color mixture is dusted onto the fresh concrete immediately after finishing is completed and to a depth of about 1/8 in. Two 10 or 12 ft. boards, held apart the width of the traffic line are laid on the pavement and coloring mixture is spread between them. With the boards still in place, the traffic line is thoroughly rubbed with a wood hand float until the mixture is incorporated in the concrete beneath. The line may be corrugated to form transverse ridges that will make it readily visible even on rainy nights.

Yellow and buff are the best colors for colored traffic lines.

The batch made with 1 sack of cement will cover 350 lin.ft. of traffic line 6 in. wide.

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SUPPLEMENT SPECIFICATIONS FOR COLORED CONCRETE
PAVEMENT

Description: This work shall consist of furnishing black color pigment and mixing it with the concrete to produce colored concrete for the sections of pavement shown on the plans.

Material: The color pigment shall be commercially pure natural or synthetic black oxide of iron or Ferroso - Ferric Oxide of proved satisfactory quality recommended by the manufacturer for use in coloring portland cement concrete. The composition and color of the pigment shall be approved by the Engineer before use.

The dry pigment material shall have a blue-black color and not a brownish hue.

Not more than 2% of the pigment shall be retained on a 325 mesh sieve by washing method in accordance with ASTM Designation D 185-37.

A representative sample weighing approximately 1/2 pound shall be submitted for testing purposes to the State Highway Department Testing Laboratory. The pigment shall be delivered to the work in approved sealed containers plainly marked with the manufacturer's name and address together with the trade name of the product.

Construction Methods: The construction of colored concrete pavement shall be as specified for concrete pavement, Section 4.14 of the 1942 Standard Specifications except that the 9" uniform pavement shall be built in two courses. The bottom course shall be of 6" and the top course 3" thick, and the top course shall be colored with black oxide of iron pigment. The amount

of black pigment to be used is estimated at 4.16 pounds per sack of cement or 25 lbs. per 6 sack batch. The pigment shall be added at the mixer and shall be thoroughly mixed with the other ingredients of the concrete until a uniform color is secured. If necessary the mixing period shall be increased over that required for standard pavement concrete in order to secure uniform dispersion of the pigment in the concrete when used in concentrations necessary to produce the desired intensity of color.

After the bottom course has been struck off, the colored concrete shall be placed on top and finished as required for standard concrete pavement. The colored concrete shall be poured in sufficient time to thoroughly bond with the underlying concrete and in no case shall the interval of time between the placing of the two courses exceed one-half hour. The mixing and placing of the colored concrete shall be handled in such a manner as to produce a surface having a uniform color throughout.

If the same mixer is used for both courses, it may be required that the first batch of colored concrete be placed in the bottom course in order to insure uniform color in the top course.

Basis of Payment: Black oxide of iron pigment will be paid for at the contract unit price per square yard of pavement, for all pavement to which the pigment is added. The contract unit price shall be payment in full for furnishing the material, placing, mixing, and for all incidental work necessary to produce the colored concrete surface.

Black Iron Oxide Pigments Available to Contractors. These Prices are not to Considered as Final Quotations for Bidding Purposes.

S-50 Black Iron Oxide C.P. Manufactured by Smith Chemical and Color Company, Inc., 55 John Street, Brooklyn, N.Y.

Pigment in 50 lb. bags, ton lots, 15¢ per lb., Lansing

Pigment in 25 lb. bags, ton lots, 17¢ per lb., Lansing

"264" Magnetic Iron Oxide. Manufactured by Reichord-Coulston, Inc. 95 Madison Avenue, N.Y. Detroit representative C.F. Heilman, Paint Manufacturers Supply Company, Detroit.

Pigment in 50 lb. bags, ton lots, Detroit, 8 1/2¢ per lb. f.o.b. factory

Native Black. Manufactured by Binney-Smith Company, 41- East 42nd Street, New York City, Detroit representative C.W. Hess Company, 1900 E. Jefferson

Pigment in 50 lb. bags, ton lots, 8 1/2¢ per lb. f.o.b. Trenton, N.J.

Black Raven. Manufactured by C.K. Williams & Company, Easton, Pa.

Pigment in 50 lb. bags, ton lots 8 3/8¢ per lb. f.o.b. factory

COST PER SQUARE YARD OF COLORED CONCRETE PAVEMENTS

Unit Price of Color Pigment per lb. Cents	COST PER SQUARE YARD FOR COLOR MATERIAL IN CENTS		
	Thickness of Color Course		
	3"	2"	1"
1	1.8	1.2	0.6
2	3.6	2.4	1.2
3	5.4	3.6	1.8
4	7.2	4.8	2.4
5	9.1	6.0	3.0
6	10.9	7.2	3.6
7	12.7	8.4	4.2
8	14.5	9.6	4.8
9	16.3	10.8	5.4
10	18.2	12.1	6.1
11	20.0	13.3	6.7
12	21.8	14.5	7.3
13	23.6	15.7	7.9
14	25.4	16.9	8.5
15	27.3	18.1	9.1
16	29.1	19.3	9.7
17	30.9	20.5	10.3
18	32.7	21.7	10.9
19	34.5	22.9	11.5
20	36.4	24.2	12.2