Review of Traffic-Paint Research

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SYNOPSIS

IN THE early years of the present century it became apparent, with increasing demand for traffic stripes, that paints must be developed which had certain special properties. This paper is an outline of the recorded research for the formulation and testing of traffic-marking paints. Consumers' and manufacturers' opinion on improved properties of traffic paints point the way for additional research.

● IN THE early years of this century, the production and use of motor vehicles increased and construction and improvement of highways expanded so rapidly that it soon became evident that a method for traffic-lane markings must be devised. Centerlines of white concrete, stones sealed with asphalt, reflector buttons, brass spots, plastic inlays, etc., have been tried at various times but none of them have proven as satisfactory as the painted stripe.

It is not definitely known when and where the first traffic line was used, and many claims have been advanced for credit of originating the idea, but the B. F. Goodrich Company, after investigating many claims, presented Edward N. Hines, Road Commissioner for many years of Wayne County, Michigan, with a plaque (1) designating him as "Father of the Center Traffic Line."

In 1925, when the use of traffic paint for highway markings was becoming generally accepted and the volume of such business increasing, Mattimore (2) listed seven properties of a traffic paint which, in his opinion, governed the quality of the paint and for which laboratory tests should be developed.

The paint properties which he discussed and for some of which he gave methods of tests are: (1) consistency, should be suitable for machine application; (2) spreading rate, for the type of spreading apparatus used a paint giving the slowest uniform flow without clogging is desirable; (3) opacity, a thin paint of high hiding power used in a machine that restricts the flow (or operates at a higher speed) would make an ideal combination from an economic point of view; (4) drying time, tests should preferably be made at low temperature and high relative humidity; (5) light resistance, accelerated testing by exposure to the ultra-violet region of the spectrum; (6) visibility (day and night), description of a photometric apparatus is given for testing visibility; and (7) durability, accelerated weathering and abrasion to indicate durability.

The formulation and testing of traffic paints was investigated by Nelson and Werthan (3). The properties of paints designed for traffic-marking purposes, which they considered in more or less detail, are consistency, drying time, hiding power, color and color retention, visibility (day and night), and durability (resistance to weather and abrasion).

By proper formulation the consistency, spreading rate, and opacity are so balanced that complete hiding will result. For drying time the usual requirements of 1/2 hr. to no pickup and thoroughly dry in 1 hr. must be met. Any of the various white pigments may be used except lead compounds, which have a tendency to discolor. If lithopone is desired, the light-resistant variety must be used. To give additional visibility, coarse inerts passing No. 35 sieve and retained on No. 48 sieve are most suitable.

Apparatus is described for testing visibility and accelerated weathering with abrasion is used to determine durability.

No comparative road test was made on the 19 paints formulated but test results of the samples submitted by the Pennsylvania State Highway Department were in relative accord with road tests.

When it became apparent that the increasing demand for traffic stripes would, in time, require a considerable expenditure of money, the California Division of Highways (4) began the search for a satisfactory traffic-paint formula. The goal to be achieved was a paint having such characteristics as rapid drying, no bleeding on asphalt pavements, no brittleness, color retention, and resistance to abrasive action. To meet the drying time requirements, a lacquer-type paint was needed.

At that time no standard specifications for such a paint had been drawn up; therefore, an extensive research program was undertaken to develop a paint formula.

The investigation covered the use of commercially available gums and the solvents to be used with them. The different lacquers developed were subjected to an abrasion test on a machine constructed in the laboratory. Further investigations were conducted in devising an apparatus for measuring relative visibility.

To pass the specifications as finally drawn up, the lacquer was required to pass a severe abrasive test, to dry in 15 to 30 min., have good flowing and covering properties, pass a bend test, a water-resistance test and a nonbleeding test.

Hickson (5) reported the work done on traffic paints by the National Bureau of Standards in cooperation with officials of the District of Columbia. The district officials determined the working properties of many paints in a road distributing machine and the "mileage" per gallon of 4-in. stripes, while the bureau determined physical properties, such as hiding power, reflectance, consistency, drying time, bleeding tendencies, and relative durability in road-service tests. In addition to many commercial brands, eight different types of experimental paints were applied on both concrete and bituminous surfaces.

Hickson found that the paints generally did not wear as well on concrete as on bitumen; however, some paints wore better on concrete. Some were satisfactory on concrete but caused the bitumen to bleed. Even though there were wide differences in durability, weathering was of minor importance as compared with wear under the conditions of testing

In repeated trials, one brand of paint was consistently the best of the commercial paints. This paint was used as a control in comparing the durability of other brands and of all experimental paints.

Two of the best experimental paints contained 65 percent pigment and 35 percent vehicle by weight. The pigmentation of the two paints was different, both vehicles contained 40 percent nonvolatile matter but were of different proportions of chinawood oil, linseed oil, and modified phenolic resin.

It was observed that several commercial paints, all passing the same specification based on composition, gave different results during wear tests. Thus, a specification for traffic paint should be based on physical and performance tests rather than on a formula which purports to describe the composition.

In order to test resistance to abrasion, a machine, originally developed to measure relative wear of sole leather, was adapted to test wear resistance of traffic paints. It was essentially a weighed wheel with a rubber tread containing an abrasive which rotated against a movable circular roadbed to which the test paint was applied. A brake device permitted increasing the shearing action if desired. It is suggested that a weathering cycle be introduced into such test for better correlation of results with actual road wear.

A specification for a white traffic paint is given, together with a table of results of examinations of paints submitted under this specification.

As progress was made with traffic-paint formulation, the consumer's problem of choosing the best product increased, and tests for wear resistance were proposed. In addition to apparatus and tests developed by the Bureau of Standards and the New Jersey Zinc Company, several others were suggested.

Sweatt (6) developed a machine which consisted essentially of a circular table to the concrete surface of which the traffic paints to be tested were applied, this surface being rotated against a tire which functioned as an abrading wheel.

Power was applied from a 1/2-hp. motor by means of a wheel with a tire that served as one of the supporting bearings for the table. The abrading wheel was set at a slight angle to simulate the action of a skidding car.

The New York Department of Public Works (7) modified the Standard U. S. Dorry Hardness Machine slightly, so that the holders would be equipped with open, 12-oz., seamless tin cans. Bottoms of the cans, which had to be perfectly level, were painted and left to dry in the laboratory. The cans were accurately weighed, and enough sand placed in the cans to bring the total weight to 100 grams. After being placed in the holders and subjected to 500 revolutions, using double crushed quartz as the test abrasive, the empty cans were again weighed. The loss in weight was considered a measure of the abrasion loss. The test was repeated on the dried paint soaked in water for 18 hr.

The American Gum Importers Association, Inc. adopted a long-range program dealing with research and development work on traffic paints, which was reported by Skett and Holzberger (8). Work was done on both spirit vehicles and cooked-oil vehicles with the California traffic-lacquer specification as the basis of all spirit vehicles. The prime object was the investigation and improvement of paint vehicles; therefore, pigmentation was held constant, with the exception of some comparison between titanium-barium and titanium-calcium pigments.

Eight series of paints were prepared, and in each series one or two of the raw materials were varied in such a way that any differences in results could be attributed to the changes.

The paints were applied on a concrete road on Long Island in transverse stripes with a graph instrument using a calibrated 4-oz. veterinary's syringe for measuring quantities.

The most important conclusion of the preliminary work was that the manila-resin spirit-type paints were best formulated with blown castor oil as plasticizer and using 63 percent titanium-barium and 37 percent magnesium silicate pigment at about 40 percent pigment volume optimum. Titanium-calcium pigments gave very flat paints and better packaging than titanium-barium.

The second part of the work covered a wider range of resins and a wider range of amounts of plasticizers with pigment volume and pigment composition maintained. Further comparison was made between titanium-calcium and titanium-barium pigments and some comparison between magnesium silicate and china clay as inert materials.

In the third part of the program, 193 paints were tested, including spirit paints of Manila, Batu, and pale East India types and cooked paints of various types. Batu was used in place of modified phenolic resin and linseed oil and dehydrated castor oil in 10 to 15 gal. oil length in paints based on the Bureau of Standards formula of 15 gal. chinawood oil, linseed oil, modified phenolic resin. Three different roads were used as test locations.

Based on their investigation, Skett and Holzberger arrived at the following general conclusions: As far as durability is concerned, Batu cooked paints are superior and those containing chinawood oil are more durable than those prepared with other oils.

Batu-linseed paints of about 10 gal. oil lengths compare favorably with modified phenolic resin chinawood- linseed oil paints. All types of pigmentation may be used with Batu-linseed oil vehicle.

Only slightly inferior in durability to the best Batu cooked paints are the best Batu spirit-type paints.

Manila paints require the use of alcohols as solvents, and if due to scarcities Manila paint can't be used, it is recommended that Batu cooked paints be used at a sacrifice of color and nonbleeding characteristics but with better durability.

By 1939, the volume of traffic paint used on highways and streets had increased to the point where proper attention to specification and testing problems was necessary. It followed that there had been increased interest in laboratory and road tests that might be standardized to give accurate information about the service life of paint. However, the satisfactory correlation of laboratory and service results is time consuming, and it is a field where cooperative effort is desirable. Toward this end the Committee on Traffic Zone Paint of the Highway Research Board (9) sent questionnaires to all state highway departments, the District of Columbia, and six cities. Replies were received from 45 of the 55 questionnaires sent out. The pertinent information and the comments of the committee, based on the replies, are:

1. The idea of a complete composition specification still predominates. A few organizations are working on the basis of performance specifications, but experience with them is relatively limited.
2. The use of laboratory tests, either in the form of chemical tests to check composition or laboratory tests to indicate some special service quality, is quite universal.
3. The use of small-scale road tests has become general.
4. Very few depend on practical road service alone in judging the quality of traffic paints.
5. Aside from checking composition by chemical tests, which is quite generally done, at least 14 tests for different properties receive more or less attention in the laboratory. In order of popularity, the most important are: drying time, consistency, bleeding, flexibility, water resistance, hiding power, color stability, spreading qualities, weather and wear resistance, and visibility.
6. In making road tests, parallel and cross lines are almost equally popular, and most organizations put these tests on both concrete and bituminous surfaces. Hand brush, machine, and spray applications are also almost equally used. Four-in. lines are most popular, and the spreading rates most used range from 90 to 175 sq. ft. per gal. of paint (1/10 to 1/20 mi. per gal.).
7. Given in order, drying time, wear resistance, visibility, weather resistance, and color stability are the factors generally used in grading road service tests. Of the organizations that report the use of definite rating schedules, the majority give wear resistance first consideration, followed by drying time, visibility, weather resistance, and color stability.
8. Experience with laboratory wear and weathering tests is not yet very general. However, it is noted that the organizations reporting actual experience with these tests show a marked majority opinion in their favor.

The Highway Research Board (10), in cooperation with the Committee on Research Activities of the American Association of State Highway Officials, has prepared an index of the research activities of organizations interested in the development and improvement of the many phases of highway transportation. Some of the projects have been completed and others are still in progress. Reports of several investigations are available, and information about a few more may be obtained by inquiry to the research agency.

Traffic-paint subjects under study include abrasion tests, accelerated tests, drying time, durability, formula development, lacquer studies, night visibility, and performance tests.

A report on natural resins in quick-drying traffic paints was made by Kopf and Mantell (11). Their study covered natural resins in quick-drying traffic paints, the effect of chinawood and other oils in quick-drying vehicles, and formulations and performance tests of quick-drying vehicles.

Starting with the California vehicle formula, they made changes in resin, oil, ratio of resin to oil, ratio of pigment to binder in the dry film, addition of elemi to improve adhesion, and to a small degree, the volatility of the solvents.

Eight series of paints containing more than 30 formulations were given different tests in addition to the road-performance test. Performance-test results in relation to resin changes, pigmentation, oil changes, and volatiles are discussed for the different series of paints.

From their work the conclusion is drawn that the California specification, although popular among the states, can be improved.

Goetz (12) made a progress report of a study to establish a correlation between field performance and laboratory tests and determine the characteristics of the paint film necessary for good durability on the road.

Samples of traffic paint representing the specification materials of eight different states, selected to cover a wide range of type and composition, were obtained and applied in the field at six different locations in the vicinity of Lafayette, Indiana. Old concrete, new concrete, and bituminous surfaces of different widths were used. The paints were applied with both brush and spray gun as transverse lines, as a centerline, and obedience lines on a curve and were also applied at a location where they were subjected to the action of weather only. The paints were given a durability rating on the basis of visual inspection in the field supplemented by a Kodachrome-slide record. The completed tests include settling, mobility, hiding power, weight per gallon, drying properties, pigment, volatile, nonvolatile, pigment volume, abrasion loss, water and alkali resistance, and degree of flexibility. Special attention was given to the abrasion and flexibility tests. The Dorry hardness-abrasion test has been modified to give more reproducible results. A method is presented for determining the degree of flexibility of a traffic-paint film.

It was found that there was a wide difference, amounting to several hundred percent in some cases, in the durability performance of the specification paints. In general, the durability of the paints was independent of the methods of application which were used. It was observed that, in the final analysis, all paints failed on concrete by losing bond with the surface (scaling), even though some of the paints were subjected to long periods of wear before failure took place. Those paints which showed early failure by scaling at one location did so at each location where they were included in road tests on concrete, while the best paints of the group were consistently the best under each type of road service. The modified wet-abrasion and water-resistance tests have shown a positive correlation with the field data. The degree of flexibility of a traffic paint appears to be entirely meaningless from the standpoint of correlation with field durability on concrete pavements. It is indicated that a test for adhesion, with particular attention to the loss of adhesion caused by water and other weathering factors, is desirable.

In a report by Skett and Herbert (13) on accelerated testing of traffic paints, the results of laboratory and road service tests are given. Nine paints were used in the investigation, six white and three yellow. The paints were applied on roads in 12 localities for service tests, and the relative service durability of the paints in the various localities was determined by observation at the end of approximately 20 weeks.

There was not complete agreement on the service results as reported by the different cooperators. The lack of perfect agreement in the service-durability tests was explained by the variation of weather conditions in the localities in which the paints were applied.

Eight laboratories cooperated in laboratory tests of the paints. The tests used were various methods of abrasion and flexibility tests. Five laboratories used both the abrasion test and the flexibility test in evaluating the paints. Two laboratories used only the flexibility test, and one laboratory used only the abrasion test.

The abilities of the laboratories to rate the paints on the basis of the laboratory results, in the order of relative durability as determined by the prevailing service results, were not in agreement. With very few exceptions the laboratories were able to differentiate between the good paints and the poor paints but were not able to exactly classify the paints in order of their relative durability as determined by the service results.

In general, the abrasion tests gave more reliable information on durability than did the flexibility tests.

The general conclusion that can be drawn from this investigation is that no one laboratory test, or combination of laboratory tests, is sufficient to evaluate correctly the relative durability of traffic paints. However, the tests used do differentiate between paints that would be classed good and paints that would be classed as poor.

Additional work on accelerated testing of traffic zone paints was reported by Dawson and Skett (14) in 1943. Ten white paints differing widely in durability characteristics were applied on nine roads in New Jersey, New York, and Pennsylvania. They were observed throughout their life and graded by several observers. Observations were made over 15- to 18-month periods.

The same paints were submitted to seven cooperators for tests, with particular emphasis on the use of abrasion tests and overall ratings and using a variety of laboratory testing methods.

Generally satisfactory reproducibility was obtained in the road-service tests. One of the abrasion-testing methods showed fair correlation with the service tests and warranted further investigation. The abrasion-testing method previously thought to be of interest showed less satisfactory correlation in this series of tests than in the series of tests reported on by the committee in 1941.

Two cooperators rated the durability of these paints fairly well, using testing methods based on weighings of abrasion, adhesion, and flexibility measurements.

Exposure of these 10 paints to the weather on concrete and under circumstances where practically no wear due to traffic was involved resulted in evaluation of the paints in approximately the same order as road service tests. Need for further study of accelerated-weathering tests as applied to traffic-zone-marking paints was indicated.

Some effects of pigmentation upon the durability of traffic paints were studied by Herbert (15). In order to get reliable evaluations, he decided to subject each paint to exactly the same conditions of test as far as practically possible. The evaluations were made on cross stripes instead of centerlines, and the tests were conducted on fairly uniform, smooth roads in the middle of long, flat, straight stretches over which the motorist travels at uniform speed. For this work a smooth concrete road and a fairly rough macadam road were selected.

All paints were applied at 80 Krebs unit consistency with a graph instrument. The quantity of paint applied for each line was governed by measuring with a veterinary's syringe.

For this study four different vehicles were used: (1) Bureau of Standards specification; (2) California clear traffic lacquer; (3) California formula with the chinawood oil replaced by blown castor oil; and (4) 15 gal. chinawood-oil--ester-gum varnish.

The problem of studying the effect of pigmentation upon the durability of traffic paints was divided into four parts: (1) effect of various inert extenders; (2) effect of pigment volume; (3) effect of white prime pigments; (4) effect of colored pigments.

From the results of the road exposure tests the following conclusions were drawn: (1) Of the six extenders investigated, magnesium silicate and micaceous talc are the best (whiting also gave good results). (2) A pigment volume of 40 percent appeared most desirable in the four vehicles studied. (3) Titanium-barium pigment was the best of five widely used pigments with titanium dioxide plus extender second. (4) There is little choice between chrome-yellow light and chrome-yellow medium; "Hi-way" Red (lead molybdate), though not previously employed in traffic paints, showed the most outstanding durability performance of any of the prime pigments in the study.

During the years of World War II, many of the raw materials for paints were not available or required high priorities. This necessitated relinquishing of composition requirements and accepting available substitutes with consequent decrease of essential qualities. Under these circumstances it was Werthan's (16) opinion that, when evaluation methods for use by both consumer and supplier were being considered, they should be limited to properties of direct practical interest to the consumer. For instance, while the resistance of a traffic paint to wear undoubtedly depends upon a proper balance of such properties as film hardness, distensibility, adhesion, and resistance to moisture and temperature changes, a customer should not be confused or burdened with tests covering these individual properties if there is a single test for determining the wear resistance of the paint.

Description of apparatus and methods of test are given for three important properties of paints, namely, night visibility, drying time, and resistance to wear. Tables are given showing good agreement between the abrasion test and road-service test for paints of different formulations.

Laboratory tests showed that cold-cut zinc resinate and Z-bodied linseed oil in a 1 to 1 ratio made paints of equal durability to those prepared from solutions of natural gums. Abietate and terpene vehicles can also be used to formulate durable paints.

In the search for substitutes during the war period, zinc resinate with heavy-bodied, blown soya oil (17) in the vehicle was tried as a substitute for the more costly chinawood, oiticica, and other oils. Zinc resinate (18) was used in spirit-formula paints and also with linseed cooked varnishes.

The Federation of Paint and Varnish Production Clubs prepared a consolidated report (19) of formulations of traffic paints made with available raw materials that could be applied to different types of roads for camouflage purposes.

Slate (20) made a study to find the causes of failure of the concrete paints then in use and to find paints and painting methods to overcome these causes.

Both laboratory and field tests showed that paints fail principally by scaling, due to loss of adhesion between the paint film and the concrete in the presence of water. The water, coming from the moist soil beneath the pavement travels upward through the concrete and evaporates from its surface. The water traveling upward carries soluble salts with it; these salts are deposited upon evaporation of the water. The paint film offers resistance to the passage of the water vapor and to the growth of the salt crystals, and the resulting forces may break the bond between paint and concrete. The surface of the concrete itself may be disintegrated by the growth of these salt crystals. The thickness of the paint film, which governs its resistance to the passage of water vapor, has a marked influence on the rate of scaling of some paints.

Laboratory and field tests, designed to compare the durability of standard and proposed concrete highway paints, showed that the thermosetting and thermoplastic synthetic-resin paints tested had far better water, alkali, and abrasion resistance than standard paints. It was concluded that the baking-type paints and the strongly polar, thermoplastic-resin paints tested were suitable, satisfactory, and superior for concrete highways.

The American Society for Testing Materials started its work on traffic paints in 1942 by appointing Subcommittee IV of Committee D-1. In a progress report of Group 2, Allen (21) presented work done on tests for abrasion, adhesion, flexibility, and hardness of traffic paint. The purpose of the study was to determine, if possible, the value of these tests in estimating the behavior of traffic paint in service and possibly to recommend to ASTM methods of tests that proved to be of value.

In June 1942, eight samples of traffic paint from eight different producers were distributed to each member of the group for testing. The paints were also included in the 1942 Ohio field-service tests on portland-cement concrete, bituminous concrete, and brick-pavement. These paints were widely different in both pigment and vehicle composition, and considerable difference in service was anticipated.

No attempt was made to standardize the procedure to be followed in each type of test, and each cooperator was at liberty to choose the method of test he felt would give best results.

No correlation could be drawn between the hardness, adhesion, and flexibility tests investigated and abrasion tests or field-service tests. Close correlation was found between the abrasion results of two cooperators and the field-service tests and fair correlation between several others.

For further study, six additional samples, which had been included in the 1943 Ohio field-service test and which represented a wide range of durability, were submitted to three cooperators for abrasion tests. The results of these abrasion tests showed close correlation with field-service behavior of the samples of traffic paint examined.

Various groups of subcommittee IV have developed the following methods of test for traffic paints: Dry to no-pick-up time; light sensitivity; conducting road service tests; evaluating degree of resistance to abrasion, erosion, or a combination of both, in road-service tests; evaluating degree of resistance to bleeding; evaluating degree of settling; evaluating degree of resistance to chipping; laboratory test for degree of resistance to bleeding, and night visibility.

Custer and Zimmermann (22) have made a progress report of a long-range program for field evaluation of traffic paints.

A Kelly-Creswell traffic-painting machine has been modified so that the rate of application can be controlled by changes only in the paint tank and atomizing pressure, and a field laboratory checks the amount of each paint applied before actual road striping.

The effect of various pigment compositions with comparable pigment volume concentration and vehicle composition, the effect of pigment volume concentration with both alkyd and oleo-resinous vehicles, and the comparison of alkyd and oleo-resinous vehicle binders were studied.

With paints based on rutile titanium-calcium pigment and alkyd-resin vehicle, further studies are contemplated with pigment extenders and on the use of this type of paint for glass-bead application.

In a report of questionnaire replies received from 34 states and 174 manufacturers of traffic paint, Ashman (23) listed the relative order of emphasis proposed for paint properties. The properties listed are improved service life, rate of dry, night visibility, storage stability, cost per gallon, bleeding resistance, and day visibility; however, manufacturers and consumers do not give the same relative importance to each of these properties. The consumer is concerned about better service properties in the paint film and the manufacturer about better liquid paint properties at lower cost.

There is opportunity for both producer and consumer for further study and research on traffic paint, the producer to attempt to improve the quality of traffic paint with the raw materials now in use and to seek new materials to increase durability, decrease drying time, and improve night visibility and suspension. The most important problem for the consumer is to develop an accelerated test which will definitely indicate relative durability. Such a test would permit specifications to be written in general rather than detailed terms as to composition and would give the progressive producer a better chance to supply a superior product.

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