DURABILITY CHARACTERISTICS OF TRAFFIC PAINTS

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At the annual Purdue Road School last year, a discussion of traffic paints was presented that included some general considerations, traffic-paint formulation, and traffic-paint research.* Both the selection and the application of traffic paints were discussed. The research program on traffic paints of the Joint Highway Research Project was well under way at that time. The scope, purpose, and approach of the study were outlined, but no definite results were then available.

This discussion is a brief of one entitled, "Field and Laboratory Investigation of Traffic Paints," in which the progress that had been made on this research program was presented at the twenty-first annual meeting of the Highway Research Board, December 2-5, 1941, at Baltimore, Maryland. For details of the methods of test, both field and laboratory, as well as the test results for each individual paint, the reader is referred to this more complete article.

Purpose of Study

The study was undertaken because it was felt that traffic-paint specifications are not always adequate to insure a satisfactory material. The results of this study substantiate this statement. In the past, the formulation or composition of the paint has been stated in practically all traffic-paint specifications. Paint, however, is a complicated colloidal mixture that is very difficult to analyze, and even though the raw materials that make up the vehicle are known, it is impossible to determine what reactions have taken place in the processing. Therefore, specifications based on composition have not been entirely satisfactory, and many states have abandoned this type of specification in favor of a field-service test as the basis for award of contract. This latter procedure is open to criticism because it requires several months and because there are no positive assurances that the same paint will be supplied as was tested. There also is no control of the quality of separate batches of the paint supplied by the manufacturer.

These considerations, together with the rapidly-changing market conditions of today, make it logical to base a traffic-paint specification on laboratory tests that measure definite properties of the paint film. It was the object of this study, then, to establish the correlation between field performance and laboratory tests and to determine the characteristics of the paint film necessary for good durability on the road.

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Further, it was a purpose of the study to evaluate the factors affecting the service life of traffic paints, because it was felt that a better testing technique then could be developed in the laboratory.

To accomplish the purpose of this study, samples of seventeen paints, 11 white and 6 yellow, were obtained, which represented the specification materials of eight different states. They were chosen to cover a wide range of type and composition as well as the range of specification types in common use. In addition, they were selected from states with general climatic conditions comparable to those of Indiana.

Road Tests

The seventeen paints acquired for study were placed in service by using two methods of application—hand brushing and spraying. A variety of service conditions was included in an attempt to determine the relative amounts of traffic and weathering action that paints must endure under each type of service. Transverse stripes, centerline stripes, and obedience-line markings were included, as well as a location where there was no traffic. The type of road surface to which the paints were applied was also varied to include new broomed concrete, old smooth concrete, and bituminous surfaces. The roads were also of varying widths. The primary object of all the road tests was to secure a field rating for each paint to compare with the laboratory results.

Test Sections. Figure 1 is a map of Lafayette, Indiana, and vicinity showing the locations of the paint-test sections. The pavement at locations Nos. 1 and 2 is portland-cement concrete approximately one year old at the time the paints were applied. It is 22 feet wide and has a heavily broomed surface. The average annual traffic on the road is approximately 3,600 vehicles per day (total of both directions), of which about 25 per cent are trucks. Only the white paints were applied to this surface. At location No. 1 they were placed as transverse lines making an integral part of the railroad markings. At location No. 2 they were placed as a centerline. Both methods of application were used at each location.

The pavement at locations Nos. 3 and 4 is portland-cement concrete approximately 12 years old at the time the paints were applied. It is 18 feet wide and was finished with a relatively smooth surface. The average annual traffic on this road is approximately 4,800 vehicles per day (total), of which about 25 per cent are trucks. At location No. 3 both the white and yellow paints were applied as transverse lines by the two methods of application. At location No. 4 the yellow paints were applied with the spray gun as obedience lines on a curve.

The surface at location No. 5 is rock asphalt, which was new and not yet opened to traffic when the paints were applied. The street is 32 feet wide and carries a total of about 2,250 vehicles per day, with truck traffic amounting to about 12 to 13 per cent of this figure. Both white and yellow paints were applied to this surface as transverse lines with the spray gun.

At location No. 6, all the paints were applied to both a concrete and a bituminous surface exposed to weather without the action of traffic.

Results of the Road Tests. It was found, first of all, that the width of the pavement to which the paints were applied as transverse lines determined, to a great extent, the type of

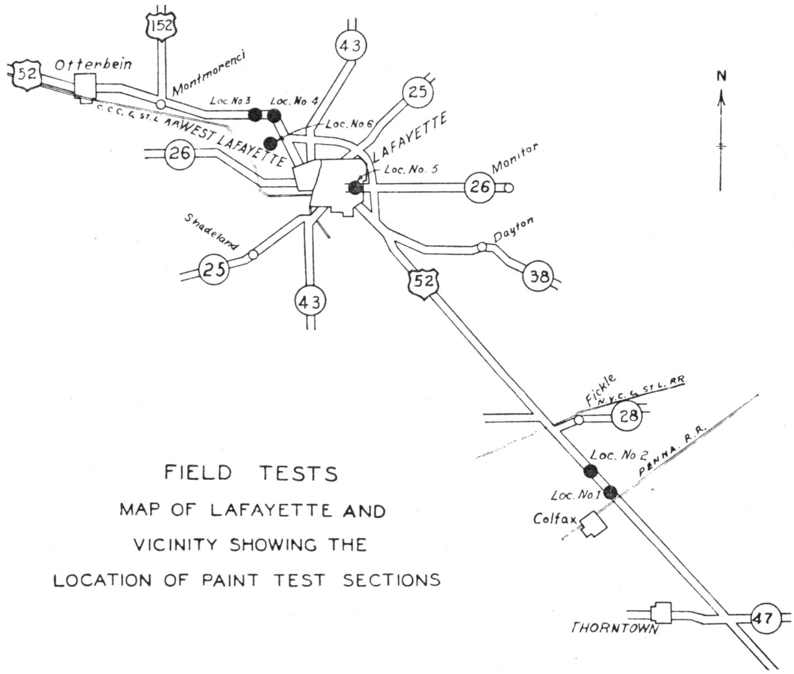

Fig. 1. Field tests map of Lafayette and vicinity showing the location of paint test sections.

failure obtained and so made a direct comparison between the effects of the two pavement textures impossible. On the 18-foot pavement, the traffic action was more concentrated, so that the paints failed first in the wheel track areas, while on the 22-foot pavement the paints failed rather evenly over the entire length of the line. The smoother concrete pavement was found to be much better adapted to traffic-paint evaluation than the broomed concrete surface. For these reasons, the attempt to rate the relative durability of the paints, after different periods of service, was confined to the transverse stripes on old concrete (location No. 3). The results of the other exposures were compared with this detailed study. It was found that the two methods of application used had very little effect upon the performance of the paints as a group.

The detailed results of the service tests for the transverse lines on the 18-foot pavements are shown in Figs. 2 and 3. The percentage of failure, that is, the estimated amount of paint removed from the road, is plotted against days of service for both the wheel-track area and the area between the wheel tracks. The results plotted are an average of the results on the sprayed and brushed lines and, for the wheel-track area, are an average of the areas of both wheel tracks. The graphs

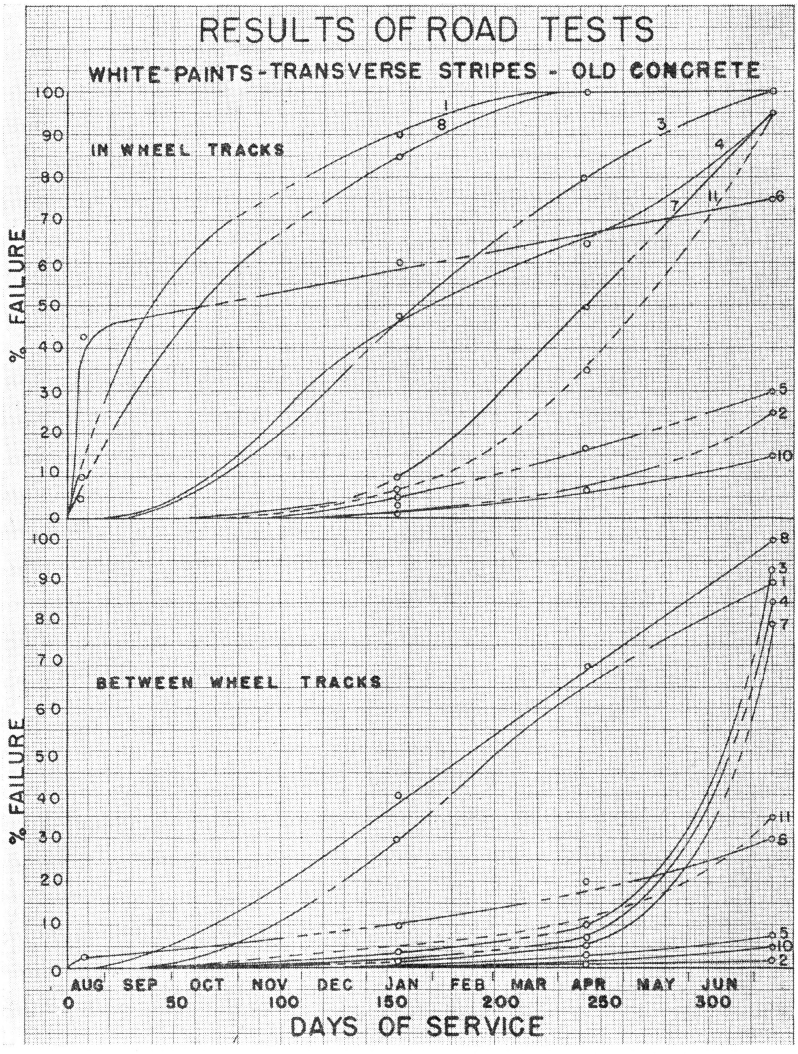

Fig. 2. Results of road tests—white paints—transverse stripes—old concrete.

are not to be used to draw conclusions too much in detail, but they do present an interesting picture of the failure record of the paints with time.

The paints were first inspected after they had been in service for seven days. The failure that had taken place on some of the paints was very pronounced at this time. Extensive failure was confined to paints Nos. 1, 6, 8, and 12, with paints Nos. 6 and 12 showing the greater degrees of failure. Inspection 30 days after application revealed very little new failures, but did show that the failure of paints Nos. 1, 8, and 12 had

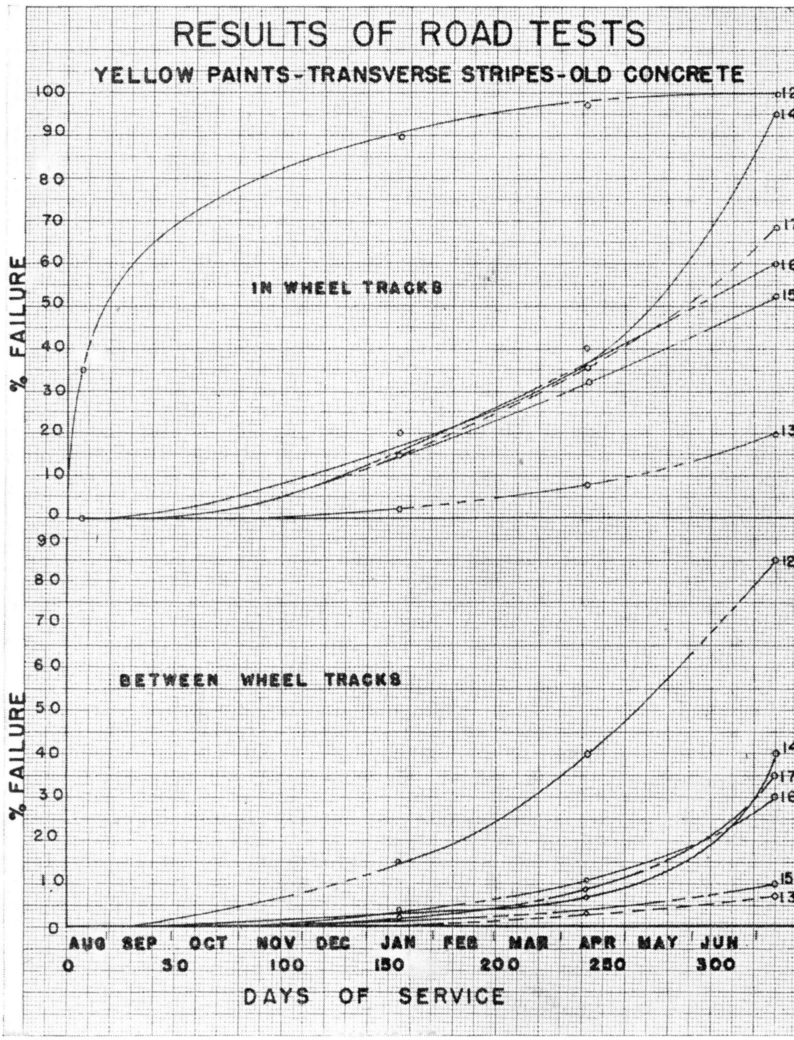

Fig. 3. Results of road tests—yellow paints—transverse stripes—old concrete.

progressed considerably. All this failure was definitely of a scaling nature, whereby the paint lost bond with the concrete. Small pieces of the paint film as large as one-half inch in diameter could be found along the shoulder of the road. The lines were also inspected after 155, 242, and 329 days of exposure. These results are plotted in Figs. 2 and 3. The yellow paints, as a group, performed slightly better than the white paints; but the best white paints showed equal or better durability than the best yellow paints. It is significant to note that over the entire service life of the paints most of the failure seemed to result from a scaling action. No doubt much wear or abrasion did take place over the length of time that the paints were exposed, but in practically every case it seemed rather conclusive that the final failure resulted from scaling.

With regard to the white paints (Fig. 2), Nos. 2, 5, and 10 were definitely the best at the end of 329 days of service, both in the wheel-track area and in the area between the wheel tracks. Paints Nos. 1, 6, and 8 are definitely the worst paints of the group because of their early failure. However, the failure of paint No. 6 did not progress in the same way as did the failure of paints Nos. 1 and 8, so that it cannot be classed with these paints at the end of the 329 days of exposure, especially with regard to the area between the wheel tracks. Paint No. 6 also gave good service in the centerline tests. In the wheel-track area, paints Nos. 2, 5, 7, 10, and 11 may be regarded as giving good service for a period of 155 days, or approximately 5 months. In the area between the wheel tracks, paints Nos. 2, 3, 4, 5, 7, 10, and 11 showed good durability for a period of 242 days, or approximately eight months. Paints Nos. 3, 4, and 7, while showing good service in the area between the wheel tracks for 242 days, failed rapidly after this time, so that failure was nearly complete at the end of 329 days. These paints also showed less resistance to weathering in the tests, without traffic, and the sudden change in the slope of these failure curves, therefore, may be due to this fact.

With regard to the yellow paints, Fig. 3 shows paint No. 13 to be definitely the best in the wheel-track area. Paint No. 15 is grouped with paint No. 13 as the best of the yellow paints in the area between the wheel tracks. Paint No. 12 was definitely the poorest of the group. All yellow paints except No. 12 gave good service in the area between the wheel tracks for a period of 242 days, while paint No. 13 showed its superiority in the wheel-track area over most of the period the paints were in service. Fig. 4 shows the sprayed stripe on the 18-foot pavement after 155 days of service.

The tests at the other locations gave no further information so far as the relative durability of the paints was concerned. The best paints of the group were consistently the best under each service condition, while those paints that scaled early on the smooth concrete pavement did so at each location where they were included in road tests on concrete. In general, it required a much longer time to develop significant differences in the paints placed as a centerline than when these same paints were applied as transverse stripes. The paints on the whole showed better durability on the rock-asphalt surface than on the portland-cement surfaces. The failure on the rock-asphalt surface was mostly a wearing action in contrast to the scaling failure on concrete. However, some of the paints cracked badly when first applied to the rock asphalt, and these did scale to a marked degree.

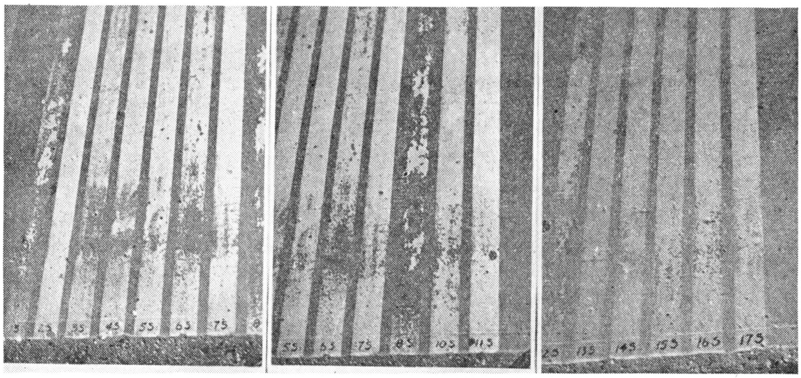

Fig. 4. Sprayed transverse stripes on old concrete after 155 days of service.

Laboratory Tests

Laboratory tests were made on the identical paints applied in the field to obtain test constants for comparison with road performance. These tests may be divided into two general groups: (1) tests for characteristics of the paint itself, such as hiding power, mobility, weight per gallon, settling characteristics, volatile and non-volatile composition, pigment content, and drying properties; and (2) tests for characteristics of the paint film, such as pigment volume, abrasion resistance, alkali and water resistance, and flexibility. Some of the tests for characteristics of the paint are important to insure a good traffic paint because definite requirements, as regards drying properties and covering power for instance, must be met. However, for the purposes of this investigation the tests for the characteristics of the paint film are of primary interest.

The pigment volume of the dry film was calculated from the results of the composition tests by using the pigment analysis as supplied by the various states or, if this was lacking, the pigment analysis as given in the specifications. The results showed that, while pigment volume for any one vehicle may be important, it is not necessarily indicative of good and poor paints in itself. It is significant that two of the three poorest paints had the two highest pigment volumes.

The New York State abrasion test, as used by the Bureau of Materials and Tests, State Highway Commission of Indiana, was used to determine both the wet and dry abrasion resistance of the paints. In adapting the test to the variety of paints studied in this investigation, the merits of the Indiana modification of the New York test were first checked. It was found that they aided in increasing the duplicability of results, and they were therefore adopted for this investigation. The study brought out a better technique for determining the loss in the wet abrasion test.

In making the alkali- and water-resistance tests, the paint films were formed on 1 x 6-inch test tubes. These were then placed in hot water, cold water, and sodium hydroxide solutions of 0.1 per cent (by weight), 0.5 per cent, 1 per cent, and 3 per cent concentration. The films were examined for discoloration, softening, blistering, peeling, cracking, loss of adhesion, swelling, and disintegration after being removed from the liquids. Degrees of resistance were recognized that varied from very good to very poor.

Special attention was given to the flexibility test because it is the performance test most often included in traffic-paint specifications and because there seems to be no general agreement as to the degree of flexibility that a traffic-paint film must possess for good performance on the road. Tests for the flexibility of the paint film included in traffic-paint specifications make no attempt to measure the degree of flexibility. Moreover, important variables of the test, such as film thickness, usually are not controlled. The degree of flexibility of the paints used in this study was determined by controlling film thickness, method of drying, degree of bend, and method of viewing the panels for cracks. Two film thicknesses, 0.001 and 0.002 inches; two mandrels, one-half and one-eighth inches, two methods of drying, air-drying and bake, and four methods of viewing the panels for cracks, eye, 10-, 50-, and 100-power magnifications, were used. Thus, in reality, 32 separate flexibility tests were made on each paint.

These data were analyzed statistically. It was shown that the degree of flexibility of a traffic paint could be determined on the basis of 12 statistically significant tests using the two film thicknesses, the two mandrel sizes, one drying method, and all methods of viewing except the 100-power. Also, it was shown that a more limited degree of flexibility could be obtained by eliminating the 0.002-inch film thickness and thereby having only six test variations.

Correlation of Field and Laboratory Results

On the basis of the road tests, the paints tested on concrete may be divided into four general classes of durability ranging from very good to poor. The correlation obtained between the field and laboratory tests will be discussed with reference to these four classes. Dividing the paints into two general groups on the basis of the vehicle employed, kettle-treated or heat-processed vehicles designated by the symbol "KT," and cold-cut vehicles designated by the symbol "CC," it is interesting to note that all of the best and all of the poorest paints are in the kettle-treated vehicle class.

TABLE I

CORRELATION WITH HARDNESS, WATER AND ALKALI RESISTANCE

Road Durability	*Very Good*	*Good*	*Fair*	*Poor*
Class	I	II	III	IV
No. of Paints	5	5	3	3
Type of Vehicle	KT	KT & CC	KT & CC	KT
Hardness after 24 Hours of Air Drying	Soft	Hard	Hard	Hard to Very Hard
Water Resistance	Very Good to Good	Good to Fair	Good to Poor	Fair to Poor

Table I shows the correlation of the road results with the hardness, water and alkali resistance of the paint films. Although the tests for film characteristics presented in this table are only qualitative, enough has been learned to show that it would probably be worthwhile to develop quantitative tests for these characteristics. The results of the test for hardness of the paint film after 24 hours of air-drying show that all the class I paints had a comparatively soft film, while the class IV paints had hard to very hard films. Also, there is positive correlation between the road durability of these paints on concrete and the resistance of the films to water. Class I paints have very good to good water resistance, while the water resistance of class IV paints has been determined to be only fair to poor. The alkali-resistance test shows negative correlation in general, but it is significant that all the best paints show good to very good results in this test.

TABLE II

CORRELATION WITH DEGREE OF FLEXIBILITY

Road Durability		*Very Good*	*Good*	*Fair*	*Poor*
Class		I	II	III	IV
No. of Paints		5	5	3	3
No. of Tests passed out of 12 Test Variations	Ave.	6.2	2.2	3.3	6.7
	Max.	9	7	9	8
	Min.	2	0	0	4
No. of Tests passed out of 6 Test Variations	Ave.	4.0	1.4	2.0	4.7
	Max.	5	4	5	5
	Min.	2	0	0	4

Table II shows the degree of flexibility of a traffic-paint film, as determined by the method herein discussed, to be entirely meaningless as a criterion of road durability on concrete. As a matter of fact, the averages show the class IV paints to have a slightly higher degree of flexibility than do the class I paints. Class IV paints have an average degree of flexibility, based on 12 test variations, of 6.7, while class I paints have an average degree of flexibility of 6.2 on this basis. Also, note that there exist wide extremes in degree of flexibility for paints in each class.

TABLE III

CORRELATION WITH DRY AND WET ABRASION LOSS

Road Durability		*Very Good*	*Good*	*Fair*	*Poor*
Class		I	II	III	IV
No. of Paints		5	5	3	3
Dry Abrasion	Ave.	0.044	0.044	0.041	0.092
Loss in Grams	Max.	0.067	0.054	0.052	0.151
	Min.	0.015	0.027	0.033	0.052
Wet Abrasion	Ave.	0.059	0.069	0.078	0.136
Loss in Grams	Max.	0.076	0.095	0.100	0.164
	Min.	0.035	0.044	0.052	0.118

The abrasion losses shown in Table III were determined by means of the New York State Dorry Hardness Test, modified to give more reproducible results. The dry abrasion test shows negative correlation in general, the minimum loss for class IV paints being less than the maximum loss for class I paints. However, these data show that those paints that are durable on concrete have a low dry abrasion loss even though the converse is not true.

On the other hand, the results of the modified wet abrasion test show positive correlation with durability on concrete. The average losses increase from .059 grams for class I paints to .136 grams for class IV paints. In addition, the minimum loss for class IV paints is .118 grams, while the maximum loss for class I paints is only .076 grams. It is to be noted that the average, the maximum, and the minimum losses increase from left to right, or as we go from very good paints to poor ones.

The paints may also be divided into two general groups of durability, which might be termed satisfactory and unsatisfactory. The first three classes would then form this satisfactory group. With the division on this basis, it can be shown that the average wet abrasion loss for satisfactory paints is 0.067 grams with a corresponding loss for unsatisfactory paints of 0.136 grams. The maximum wet abrasion loss for satisfactory paints is 0.100 grams, while the minimum wet abrasion loss for unsatisfactory paints is 0.118 grams, a difference of 0.018 grams. Thus it seems that with the establishment of proper limits, the test would have merit in a specification by eliminating unsatisfactory paints.

SUMMARY

To summarize the progress of this investigation very briefly, two laboratory tests that show positive correlation with road durability are concerned with the resistance of the paint film to water. Inasmuch as all of the failure on concrete surfaces seemed to be by a scaling rather than a wearing action, it is indicated that it would be very desirable to measure the adhesion of traffic-paint films for concrete, with particular emphasis on loss of adhesion by water and other weathering factors. Such a test is now being investigated.

A few of the more important results of the study may be stated as follows:

1. There was a wide difference, amounting to several hundred per cent in some cases, in the durability of the seventeen specification paints secured from eight different states.
2. With the limited number of paints studied, there was no definite correlation between the type of specification and the durability of the paint.
3. In the final analysis, all paint failures on concrete appeared to have taken place by scaling rather than by a wearing action, even though some of the paints were subjected to a long period of wear before failure took place.
4. The best paints of the group were consistently the best under each type of road service.
5. In general, paints that showed early failure by scaling at one location did so at each location where they were included in road tests on concrete.
6. The width of the pavement to which the transverse line is applied has an important bearing on the amount and extent of failure produced.
7. It is possible to rate traffic paints satisfactorily by the use of transverse lines. This is particularly true when the paints are placed on narrow pavements and different portions of the line are subjected to extreme variations in the amount of traffic.
8. It is possible to determine the degree of flexibility of a traffic-paint film by controlling film thickness and by using the one-half- and one-eighth-inch mandrels and three methods of viewing. The three methods of examining the bent panel for cracks, by the naked eye and ten-power and fifty-power magnifications, have been shown to produce results that are statistically significant.
9. There is a positive correlation, without exception, between the performance of class I paints and class IV paints and the wet abrasion loss as determined by the modified procedure.
10. There is positive correlation between the road durability of the yellow paints and the resistance of these paints to water. The correlation between the road performance of the white paints and their water resistance is good, with one exception.
11. All five of the paints that were rated as very good (class I) air-dried to a comparatively soft film in 24 hours. There is no apparent correlation between pavement durability and the time required for the paint film to set to touch and to dry firm.
12. The degree of flexibility as measured by 32 test variations shows no correlation whatever with road durability on concrete pavements. In fact, the results show class IV paints to have a greater degree of flexibility in general than do the class I, II, and III paints.