A UNIQUE APPROACH TO EVALUATING ROAD STRIPE MATERIAL ON TWO-LANE RURAL ROADS

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Comparisons were made of side-by-side double yellow lines on rural 2-lane roads. One line was a reference line of 0.015-in. wet paint film with 6 lb/gal of conventional glass spheres applied by the drop-on method. The experimental line either was unbeaded or had various amounts of several types and sizes of glass beads. One experimental line consisted of a 0.010-in. wet paint film with 4 lb/gal of glass spheres applied by the drop-on method. Evaluations were made under night driving conditions at normal speeds on dry and wet pavement. The methods of application, control, and evaluation are also described. Both colored movies and slides were made at regular intervals for a documentary record. Samples of the photographs are included. This approach has been found to have many advantages over existing techniques and few disadvantages.

•LITTLE emphasis has been placed on maximizing the effectiveness of stripe material for 2-lane rural roads. Those roads are inadequately designed for the traffic that they now carry and lack many basic safety improvements. Those who drive on rural 2-lane roads are familiar with the deficiencies and the dangers of traveling on them, particularly at night.

A rural 2-lane road at night frequently looks like the picture shown in Figure 1; a driver on such a road is uneasy because there is nothing to guide him. There is a high probability of cars running off the road, head-on collsions, intersection collisions, and pedestrian accidents. Almost 4 times as many deaths per 100 million vehicle-miles occur on rural 2-lane roads as on turnpikes. Nighttime travel on rural roads accounts for only 15 percent of all travel but for more than 35 percent of all highway deaths.

Figure 2 shows a well-delineated 2-lane rural road that has yellow reflectorized lines at the center and white lines at the edges. That picture was taken from the same location and under the same illumination as the one shown in Figure 1. The reflectorized lines help the driver by indicating passing zones, curves, pavement edges, and intersections.

Because of the need for good reflectivity and durability of stripes on rural 2-lane roads, a study was initiated to maximize the effectiveness of those markings. This test program was unique because of the following new and unusual approaches that were attempted:

1. All testing was performed on 2-lane rural secondary roads;
2. It was the largest commercially sponsored road-marking research project ever conducted;
3. More than 50 miles of rural roads were employed in the field tests;
4. Yellow paint was used according to the Manual on Uniform Traffic Control Devices, and its importance is highlighted by the new 2-lane road-marking system;
5. Observation of dual stripes, where one is a control stripe and one is a test stripe, has not been reported before;

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6. The stripes were visually evaluated under normal driving conditions;
7. Color movies and slides were obtained periodically from application to failure;
8. An accident reduction study was conducted on a previously unmarked road that was marked and on other unmarked roads that served as controls; and
9. A survey of public response to new road markings was conducted.

Traditionally, the evaluation of the night-visibility performance of road-marking systems using paint and glass spheres has been by means of alternate skip lines or group skip lines. In Pennsylvania, for example, the practice is to apply a 50-ft skip line for each variable tested. The location is usually along a level and straight, divided 4-lane highway requiring white paint. Evaluations were made at night by drivers traveling at 5 to 10 mph because of the short length of the test sections.

In the spring of 1971, Potters Industries, Inc., conceived and instituted a road-striping test program directed toward evaluating the materials used on accident-prone rural roads. The purpose was to explore the performance of a variety of paint-sphere systems with regard to night visibility and durability and to accident reduction and motorist response.

The site chosen was in the township of West Milford, located in the northernmost portion of the state of New Jersey and containing a large number of rural arterial secondary bituminous concrete roads. There is sufficient daily traffic of 1,000 to 5,000 cars, depending on road sections, for normal wear to occur over a manageable period of observation. Overhead lighting is infrequent. A genuine interest was shown by county and municipal governments. The site also offered a variety of climatic conditions from heavy snow in the winters to hot and dry weather in the summers and typical annual rainfall.

The township of West Milford previously had either unmarked roads or roads marked with a single, solid, nonreflectorized white stripe. Local county and state authorities gave permission to apply the test stripes according to the then-current edition of the Manual on Uniform Traffic Control Devices. The single, solid, nonreflectorized white line was replaced by reflectorized double yellow lines in regular no-passing zones. The double, no-passing yellow line provided means for a unique way of assessing performance characteristics, i.e., the comparison of 2 side-by-side lines differing in some known and deliberate way.

One test site of 2.4 miles was divided into 6 sections and striped in sequence. The first section was striped, and the same type of beads was used in the center and edge lines. The next section was striped the same way, and a different type of beads was used. Those 6 sections could be compared with one another sequentially rather than side by side as in the other sections.

There were 28 test sections striped during the spring of 1971; each section averaged ½ mile in length. A total of 54 miles of stripes were applied, counting the double center and edge stripes. In the fall, the total number of sections was increased to 56. Test sections are shown in Figure 3.

Because of the magnitude of the many tests conducted in West Milford, certain results have been omitted from this report for the sake of brevity. Many results are being duplicated by additional tests added in the spring of 1972. Separate documentation is available on accident reduction and public response to road marking.

VARIABLES

In the comparative tests, one line was the reference line. It consisted of a 4-in.-wide yellow stripe applied at 0.015-in. wet thickness and on which were dropped the equivalent of 6 lb of glass beads per 1 gal of paint. One gallon of paint will produce about 310 ft of 4-in. stripe at 0.015-in. wet thickness. The beads had a 1.5 refractive index and a sieve analysis as given in Table 1. This is typical of drop-on specifications.

Variables tested and evaluated with this reference line are as follows:

1. A nonreflectorized line,
2. Different sphere gradations,
3. Beads with various coatings,

4. A wet paint film thickness of 0.010 in. with 4-lb/gal drop-on bead application,
5. Glass beads with other refractive indexes including 1.6 and 1.9,
6. Various quantities of beads,
7. Premix lines with and without drop-on beads, and
8. Thermoplastic lines.

All striping was placed on aged bituminous concrete roads in a reasonable state of repair. The lines were applied with commercially available standard equipment operated by experienced personnel. No stripes were applied unless air temperature was at least 50 F and relative humidity was below 80 percent.

EQUIPMENT AND PROCEDURES

A Wald model 36 striper was used for all the comparative test stripes. A Wald custom liner was employed for edge lining and sequential test sections.

The model 36 striper, having separate bead hoppers, is particularly adaptable to the simultaneous application of 2 different double yellow stripes. The stripes can differ in type of paint, thickness of paint, and type and quality of glass spheres applied. Calibrations of paint thickness and sphere quantity were carried out prior to each test section application.

Paint thickness adjustments were made with the aid of wet-paint thickness gauges. The paint was applied by the striper in motion at its normal traveling speed (about 8 mph). Bead quantity adjustments were made by weighing the quantity of beads ejected from the bead dispenser while the striping machine was moving at normal speed over a measured 20-ft distance. Duplicate and sometimes triplicate runs were made to ensure reproducibility. Weighings were made on a triple beam balance accurate to 0.1 gram.

The standard paint used was a high-grade, quality commercial paint that would meet most state specifications. In certain test sections, premix paint or thermoplastic binders were applied.

During application of each test section, 4- by 8-in. aluminum test panels were placed in the path of the striper, and the resulting striped panels became a permanent record of the stripe as initially applied to the road.

If, in the course of test section application, a malfunction was observed, the application was stopped, the malfunction was corrected, and the operation was then resumed. In no case, however, was a mistake or accident corrected by overstriping.

EVALUATION PROCEDURES

Formal evaluation of the test stripes was begun when applications were completed on the last test sections. A committee was appointed to conduct monthly evaluations and consisted of the township engineer, 2 township policemen having responsibility for traffic safety, and 3 employees of Potters Industries, Inc. Occasionally, interested visitors were invited to become part of the evaluation group. Two committee members were assigned to a car, and they were not allowed to discuss the ratings while traveling the test course at a normal speed. In every section, each of the yellow lines was rated on a 0 to 10 scale, 10 being the best. This procedure was followed once each ensuing month. In August, a heavy rain prevailed during the entire inspection. Consequently, a second inspection under dry conditions was made during the following week.

After each evaluation, the results were tabulated, and averages for each section were computed and plotted graphically. Some examples of results obtained will be described later.

PHOTOGRAPHIC DOCUMENTATION

An attempt was made to photographically document the history of test stripes from application to failure. Day and night color movies and slides were obtained at regular intervals from day of application until failure. In addition, color macrophotographs were taken of each stripe at regular intervals.

Colored movies and slides were made of all calibration and application procedures. The pictures include safety precautions, the coding of the roadways, equipment filling, adjustment and calibration of spray guns and bead dispensers, and actual road-striping procedures.

The colored movies and slides to be obtained at night presented special technical problems requiring professional assistance. Proper color balance and illumination for color movies were obtained with a van equipped with special high-intensity, balanced lights and camera mount (Fig. 4). That required some experimentation before satisfactory results were obtained. During actual filming, traffic in both directions of the test section was stopped by police cars. The van was driven at 35 mph over the section and was normally trailed by a police car. A portion of each test section of approximately 1,000 ft in length was chosen and marked in advance for repeated filming during the life of the stripes. Attempts made to take movies in wet as well as dry weather were not successful.

Colored slides were obtained under similar conditions at selected and constant positions for each test section. In addition, close-up colored photographs yielding a 1x magnification on the film were taken of each stripe at a preselected position. That position remained unchanged during the history of the test program. Wet weather slides were successful.

All photographs were used for documentation only and were not used as a basis for numerical evaluation.

TYPICAL RESULTS

A few examples have been chosen to demonstrate the usefulness of this evaluation technique. Those examples are from the side-by-side comparisons. One line in each case was the standard reference line of 15-mil wet paint film with 6 lb of typical drop-on specification beads. The other line was nonreflectorized, was flotation coated and had different bead gradation, or had smaller quantity of beads on a thinner paint line. All lines were inspected from May through December except for 2 sections that were resurfaced in late fall. All lines showed gradual deterioration in November. Just prior to Thanksgiving, the first major snowstorm occurred in the area and necessitated extensive plowing, sanding, and salting. Accelerated deterioration was observed from December on.

The first comparison is between the reflectorized line and the nonreflectorized line (Fig. 5). Their history in terms of night visibility evaluated as previously described is shown in Figure 6. The x-axis corresponds to the month in which the evaluation was conducted, and the y-axis corresponds to the average of the individual ratings. The vastly different ratings indicated between the beaded and unbeaded line are not unexpected.

It has been reported that a 10-mil wet line with 4 lb/gal of drop-on beads gives a satisfactory line. One of the test sections was devoted to examining that possibility. Figure 7 shows photographs taken in January of 2 test sections that had received applications in October. The evaluation results are shown in Figure 8. The performance of the test line was consistently below that of the standard line for the duration of this test. This may be due to the fact that the number of beads per linear foot in the test line is less than half the number in the standard line.

It has also been suggested that a narrow size gradation (40 to 80 mesh) with a flotation coating has desirable attributes. Test lines were applied to evaluate that concept. The beads were applied on both lines at the rate of 6 lb/gal and a wet thickness of 0.015 in. (Fig. 9). The evaluation results are shown in Figure 10. As observed in normal nighttime driving, the narrow gradation with a flotation coating was rated slightly higher than the adjacent reference line initially, but the rating tended to decrease at a somewhat more rapid rate. At the conclusion of the test, which was premature due to road resurfacing, the reference-line rating was actually somewhat higher than that of the narrow-gradation line. Figure 11 shows a test line that has 6 lb/gal of the standard gradation that was flotation coated, and Figure 12 shows the evaluation results. Its performance under dry conditions is essentially equal to that of the narrow gradation initially, and it did not deteriorate so fast.

Figure 1. Newly resurfaced road before being striped.

Figure 2. Same road as shown in Figure 1 after being striped with yellow lines at center and white lines at edge.

Figure 3. Test sections in West Milford, New Jersey.

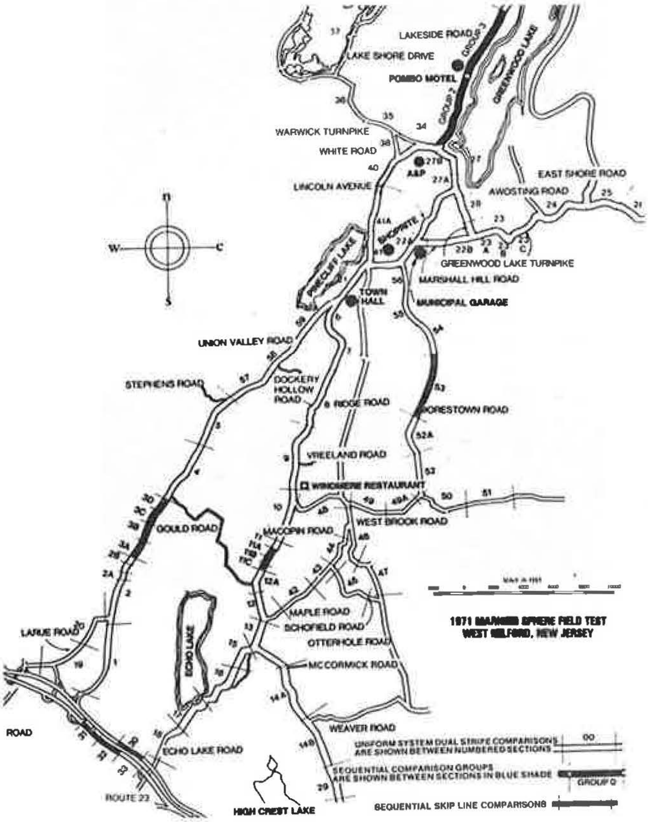

Table 1. Specification and analysis for standard spheres used in test.

U. S. Sieve	Specification (percent on)	Analysis (percent on)
20	Trace	—
30	10 to 15	12.2
50	45 to 55	50.4
80	15 to 25	21.0
100	5 to 15	11.3
Pan	5 to 10	5.1

Figure 4. Van used for motion picture photography.

Figure 5. Standard reflectorized line (left) and nonreflectorized line (right).

Figure 6. Monthly average night-visibility ratings of standard reflectorized line and nonreflectorized line.

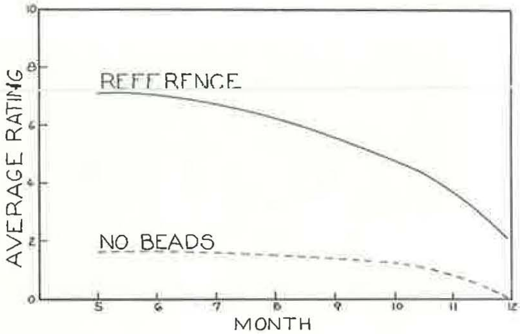

Figure 7. 0.010-in. beaded test line (left) and standard reference line (right).

Figure 8. Monthly average night-visibility ratings of 0.010-in. beaded test line and standard reference line.

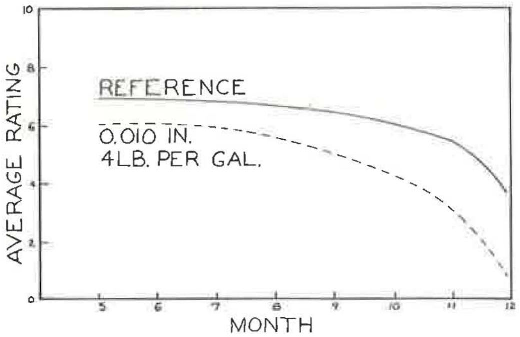

Figure 9. Narrow-gradation, flotation test line (right) and standard reference line (left).

Figure 10. Monthly average night-visibility ratings of narrow-gradation, flotation test line and standard reference line.

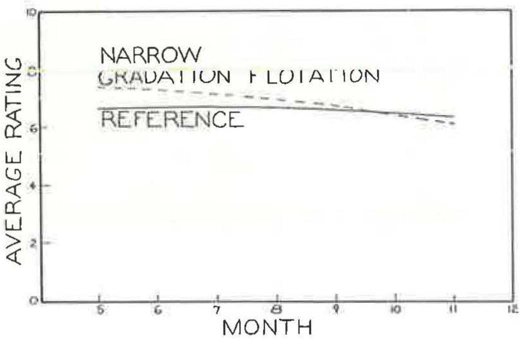

Figure 11. Standard-gradation, flotation test line (right) and standard reference line (left).

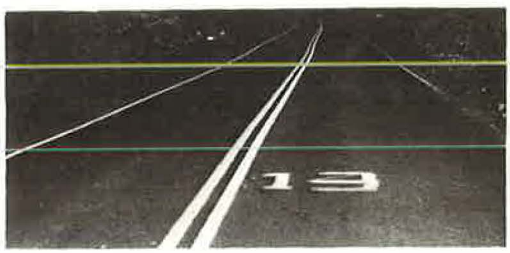

Figure 12. Monthly average ratings of standard-gradation, flotation test line and standard reference line.

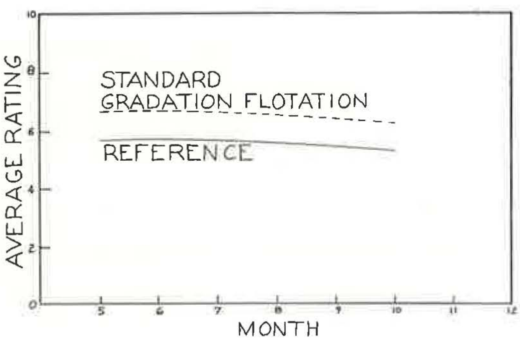

Table 2. Average night-visibility ratings for dry and wet conditions.

Line	Dry	Wet	Decreased (percent)
Standard reflectorized	5.5	2.5	55
Nonreflectorized	1.2	0.3	75
0.010-in. beaded	5.1	2.4	53
Narrow-gradation, flotation	6.8	2.0	71
Standard-gradation, flotation	6.3	3.5	45

The reference line used as a standard was comparable in most of the test sections. There were, however, differences from section to section because of road surfaces, viewing environment, and equipment variations. In almost all test sections, the difference between reference lines and the average of all 3 reference lines varied by less than 1 rating unit.

Inspection during a moderate rain in August 1971 revealed a surprisingly large decrease in night visibility of the narrow-gradation, flotation test line compared with the standard line. A subsequent inspection under dry conditions was made within 1 week. The dry and wet ratings for the 5 varieties of lines discussed previously are given in Table 2. The test lines that had the largest beads had the smallest percentage of decrease in visibility under wet conditions, and the lines that had narrow-gradation (smaller beads) or no beads had a significantly larger percentage of decreased visibility. The standard beads and narrow-gradation beads, both flotation coated, have essentially the same night visibility under dry conditions. Under wet conditions, however, the standard beads with a broader size range perform in a distinctly superior manner.

ADVANTAGES AND DISADVANTAGES

This double-yellow-line method compares favorably with the traditional alternate-skip-line method for the evaluation of road-marking systems. We have observed the following advantages and disadvantages of the dual-stripe method.

Advantages

1. It offers continuous comparison of a test line with an adjacent reference line and does not require recall of a previous test section.
2. Photographic records of the test can be made because the variables of photography are eliminated by the presence of the reference and the test lines together.
3. Exceptionally long straight roads are neither required nor desirable.
4. This test is useful for yellow paint systems.
5. The procedure is readily usable for smaller government units.
6. Test results are immediately useful on 2-lane rural roads.
7. Test evaluations are conducted under normal driving speeds and conditions.
8. The test stripes have a longer, useful life because of lower average daily traffic counts and, thus, offer longer evaluation periods.

Disadvantages

1. Greater distances are required for each test section.
2. Photographic documentation requires police protection and professional services and equipment.
3. Because of road topography where double yellow lines are painted, long-distance visibility becomes more difficult.
4. Uneven wear patterns occur on curves.

CONCLUSION

Based on experience obtained with the dual-stripe comparison method for road-marking evaluation, this method of test can be highly recommended. The test method is directly applicable for use on 2-lane rural roads; test stripes that conform to the Manual on Uniform Traffic Control Devices can be used, and, thus, motorists are spared undue confusion.

The road-marking testing began in West Milford in the spring of 1971 and has produced well-documented records and data because of the ease with which side-by-side lines can be compared and evaluated. The procedure was found to be so useful that the test program has been continued. Color photographs of the dual stripe comparisons are very useful for illustrative purposes.