Discussion of Results

Under the conditions specified in these model studies it appears that the placement of a coarse backfill over the drain is of little advantage. In fact, the draw-down of the ground-water table seems to be more complete in the cases where the material directly over the drain is the same as the surrounding soil. This statement is made as an observation from the models and may not under all conditions be the most advantageous for actual practice. In a field installation the soil may not be homogeneous, and a large percentage of the total quantity of water entering the drain may be flowing through the more pervious portions of the soil mass. In such a case the porous backfill will act as an interception medium which will conduct the water to the drain and would probably be more efficient than a drain backfilled with native material.

The models showed that a drain placed at each side of the pavement is more effective than placing a single drain beneath the centerline of the roadway. A field condition in which the soil is composed of alternate layers of pervious and impervious material would increase the advantage of the two drains. However, if for reasons of economy only one drain is to be used, then the most effective location is at the centerline, since two drains are not twice as effective as one drain.

The models of the cross-section of a cut section show clearly the advantage of placing a drain at the toe of the slope. In the case where no drain was provided, the water outcropped on the face. Such seepage, as the model shows, causes the soil to "sluff" away. In the field, such conditions would increase maintenance cost and, unless checked, might endanger the entire slope. The placement of a drain at the toe of the slope draws the free water within the soil mass so that it no longer intersects the slope. The elimination of the upper flow of water beneath the pavement is also very important.

While many of the observations made on the models to date are too general to have any direct application, it is believed that they, supplemented by the results of models to be run in the future, will present a visual solution of basic typical problems.

TRAFFIC PAINT STUDIES

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In 1911 Mr. Edward Hines, then Road Commissioner of Wayne County, Michigan, originated the painted centerline for the convenience and safety of the motoring public.* Since that time the use of traffic paint has grown until today millions of gallons are used in the United States annually. It is used not only for centerlines but for obedience lines on curves and hills, traffic lanes on multiple-lane roads and city streets, stop lines at intersections, curb markings, railroad crossing markings, and parking and loading zones as well. The manufacturing and placing of these paints involve the expenditure of many millions of dollars annually in this country.

While most paints are placed upon a surface to enhance its beauty, provide protection, or both, traffic paints have only one paramount purpose—to promote safety. Traffic engineers have recognized the safety value of painted traffic lines and are using them in increasing quantity. The motoring public today demands traffic markings that are adequate and efficient.

General Considerations

Before discussing the problems pertinent to the selection and application of a marking paint, it may be well to consider first the magnitude of the general problem. At first thought, it may seem strange that today, after about thirty years of use, no completely satisfactory marking paint can be obtained. Yet consideration of the problem will show good reason why a satisfactory marking paint must be a highly specialized product.

Concrete and bituminous surfaces are recognized as difficult surfaces on which to apply paint under the best of conditions; and when these surfaces are roadways, the application is even much more difficult. Not only must the paint film withstand the action of weather, rain, hot sun, and freezing and thawing, with the consequent expansion and contraction of the road surface, but it must also at the same time withstand the severe abrasion of traffic. The presence of dust, dirt, and stones on the road surface makes this abrasive action even more severe. Likewise, grease, gasoline and oil drippings, ice control grit and chemicals, and perhaps other foreign materials all play their part in the deterioration of the paint film. Traffic paint must not cause bitumen or tar to "bleed" when it is applied over a bituminous surface, nor must the film contract, crack, curl, or displace under these conditions.

Further than this, a traffic paint is severely handicapped, when compared with paint for other applications, by two very important stipulations. First, it must *dry rapidly,* usually rapidly enough that traffic may pass over it within one-half hour without pick-up. And second, it must be highly *visible,* if it is to serve its purpose. The most durable of traffic paints are of no use whatsoever as measures of safety if they cannot

* According to a committee appointed by the B. F. Goodrich Co. *Roads and Streets,* 79, 52, Dec., 1936.

be readily seen. Autocollimating units such as glass spheres are being used on the paint film for the specific purpose of increasing visibility.

With these thoughts in mind, the problem of the selection and application of a traffic paint is viewed with more respect. Only the best of traffic paints, consistent in cost with the service they render, and careful workmanship in the application of these paints will produce consistently satisfactory results.

Traffic Paint Formulation

Traffic paints are usually heavily pigmented so that they dry to flat or semi-gloss finishes. High gloss is not desirable. The opaque pigments of white paint are selected for efficient hiding power and suitable color and color retention at a minimum cost. The pigments most often used are lithopone, titanium-base pigments, and zinc oxide. Silicate-base pigments, such as china clay, magnesium silicate, and silica are used with these to increase resistance to wear. Sand and pumice are sometimes added to impart roughness to the film and thereby increase visibility. Chrome yellows and chrome oranges are almost always used as the coloring pigments of yellow marking paint. Large amounts of silicate-base pigments are added to these yellow or orange pigments as diluents. White pigments, such as zinc oxide, may also be added.

The liquid portion, or vehicle, of a traffic paint is a quick-drying varnish. Two general classes of vehicles are used which may be designated as "kettle-treated" and "cold-cut". The kettle-treated products may be processed with rosin, ester gum, gum copals, or synthetic resins. The oil portion usually consists of linseed and china wood oil. Dryers and a large amount of volatile thinners, selected to promote rapid drying, are added. The thinners are usually low-boiling fractions from petroleum or coal tar and include gasoline, mineral spirits, and benzine. The cold-cut vehicles employ natural resins such as East India, Manila, or Damar gums dissolved in mineral spirits or such solvents as alcohol, acetone, or butanol. Blown linseed, tung, or other oil may be added as a plasticizer.

Traffic Paint Research

With the increased use of traffic paints, engineers and persons responsible for traffic paint purchases have come to realize the importance of satisfactory specifications for this material. Paint is a complicated colloidal mixture that defies analysis by simple composition tests. It is impossible to determine accurately the formulation of a traffic paint from an analysis of the product. The result is that progressive thought has abandoned the idea of composition specifications for traffic paints, particularly in the kettle-treated vehicle class, in favor of laboratory and road tests that may be standardized against service performance. It is of primary importance to users of traffic paints that they be able to determine quality not only for the purpose of original selection, but for the control of subsequent shipments as well. Reliable laboratory tests that have been correlated with field performance are, then, of primary importance.

Selection of the Paint. The research program on marking paints undertaken by the Joint Highway Research Project does not attempt to develop a better material. Rather, the primary purpose of the study is to develop basic information that will enable testing engineers to determine the quality of a marking paint in advance of its use on the road. Also, since paint is a material that cannot be purchased in the form used for service, but is subject to many variables in application, the study includes an evaluation of surface preparation and methods of application as well as weather conditions and other controlling variables.

To facilitate this study, paints that are representative of the material manufactured under the state specifications have been acquired from eight different states. These paints have been placed in service as centerline stripes, transverse stripes, and obedience-line markings, and have also been placed on road sections where they are not subjected to traffic. The surfaces to which the paint were applied included a new section of concrete that had a rough broomed surface, an old smooth concrete section, and rock asphalt. The centerline and transverse markings on new broomed concrete are on U. S. 52 about 21 miles south of Lafayette. The transverse and obedience-line markings on old smooth concrete are on U. S. 52 about three miles north of Lafayette. The rock asphalt surface that was used is on S. R. 26 in the city of Lafayette. Sections of concrete and bituminous surfaces at the Project test road site near the city were used for the study of weathering action without traffic. From these road tests it is hoped that the relative amounts of abrasive and weathering action which a paint must endure under different types of service can be determined. If the variables which affect the serviceable life of traffic paints can be isolated and their relative importance determined, it will then be an easier task to test paints in the laboratory satisfactorily. Different types of surfaces have been included to find the influence of this variable on the life of a painted traffic line. Also, each paint was applied both with a spray gun and by hand brushing to see if the performance varied with the method of application.

The laboratory tests that are being made on these paints include tests for abrasion resistance, adhesion, flexibility, consistency, water resistance, alkali resistance, drying properties, hiding power, color stability, and weathering resistance. It is hoped that a satisfactory test may be developed to measure visibility. The results of these tests will be correlated with the field test results to find what properties of the paint film are essential to satisfactory performance under each type of service. Further tests for film characteristics will be made if it seems necessary. The ultimate goal is to find a laboratory test or series of tests that will definitely predict the durability performance that may be expected from a paint when it is placed in service on the road.

Application of the Paint. Thus far we have been concerned primarily with the quality of a marking paint. However, since paint is one of those materials which cannot be purchased in the form used for service but is subject to many variables in application, this phase of the problem is worth emphasizing. It is well known that the service life of even the best of any paints may be ruined through faulty application. Because of the severity of service conditions, this fact is especially true in the case of marking paints. Whereas faulty application may not be apparent in the case of a house paint, for instance, for many months, failure to observe the rules of good marking-paint practice may become apparent in a few weeks or even days. Paint crews often do not fully appreciate these facts and do not use the care that is demanded for the satisfactory road performance of even the best marking paint.

Traffic paints are usually very carefully balanced formulations. They very often contain special gums and oils that make it imperative that only the proper thinner and the proper amount of thinner be used. Most paints are processed to a form ready for application on the road. Some are made purposely thick so that they can be thinned on the job. Even these paints should not be thinned excessively, however, or their durability will suffer. A heavy-bodied traffic paint, provided it is thin enough to be brushed or applied by machine, is apt to wear longer than a thin-bodied one because a thicker film is formed. If thinning is necessary, care should be taken to secure a thinner that is compatible with the paint being used. In any case, whether the thinner be gasoline, naphtha, or some other solvent, it should be a water white distillate free from residue. The use of colored and leaded gasolines definitely should be avoided. Of course, the paint should always be stirred well before use, and if thinner is added, care should be taken to mix it thoroughly with the paint. Turning the cans over periodically in storage, and placing them on the truck upside-down from their storage position, will help to prevent undue settling and save time in mixing for use.

It is essential that the marking paint show good adhesion for the surface on which it is applied. To accomplish this the paint must be brought into intimate contact with the surface. The surface, then, must be clean and dry. A method of application must be chosen such that the intimate contact is established. Since pavement surfaces almost always contain rather large amounts of dust and dirt, time spent in carefully cleaning the surface before application of the paint will often prolong the service life of the paint and therefore prove profitable. The air temperature at the time of painting is important in that it materially affects drying time.

Conclusion

In conclusion, it may be pointed out that it is the job of the purchasing and testing agencies to provide the best paint possible consistent with cost and serviceable life on the road. It is the duty of the maintenance agency to apply the marking paint in the best way possible. Co-operation between these two agencies and care in the selection and application of a marking paint are essential to satisfactory results. The research of the Joint Highway Research Project is designed to provide basic information that will enable the co-operating agencies to give the motoring public more service and greater safety for their marking-paint dollar.

FUNDAMENTALS OF SURFACE-TREATMENT CONSTRUCTION

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Bituminous surface treatment may be defined as the application of bituminous material and mineral aggregate to an existing road surface or pavement. The term "surface treatment" as used in this paper applies to the use of these materials to form a wearing course less than one inch in thickness. The purposes of such a treatment are as follows: to eliminate dust, to harden and improve the ability of the wearing surface to withstand the abrasive action of traffic and disintegration by weathering, and to maintain a smooth-riding, skid-proof wearing surface. This paper reviews briefly the development and extent of this type of work in Indiana and summarizes some of the more important findings of the Joint Highway Research Project affecting surface treatment, design, construction, and performance.

Development in Indiana

While the practice of surface treating existing road or pavement surfaces was first started early in the twentieth century, it was not until after the World War and the uni-