TECHNICAL ASPECTS, RESEARCHES AND STUDIES CONCERNING THE GENERAL TYPE OF OPEN TEXTURE ROAD AND PLANT MIXED SURFACES

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SYNOPSIS

The Pennsylvania State Highway system was increased in August, 1931, by the addition of 20,825 miles of rural roads These rural roads are being surfaced to a width of 16 feet at a cost of $6,000 to $9,000 per mile, including surveys, grading, drainage and shoulders Base courses are generally at least eight inches thick, the principal materials used being native stone sledged in place to four inch maximum size, crushed stone, slag, crushed gravel and run-of-bank gravel On these base courses either a surface treatment or a two inch compressed depth of one of the types of bituminous surface courses is used The type of surface used depends on traffic and available funds

The report describes the surface courses used and also the bituminous materials which are cut-back asphalts, asphalt emulsions, and tars Hot bituminous surface treatments are used on some native stone bases where traffic is light

The Pennsylvania State Highway system subsequent to August 1931 has been increased by the addition of 20,825 miles of rural roads to the previous system of 13,640 miles These rural roads are being constructed 16 ft wide at a cost of $6,000 00 to $9,000 00 per mile, including surveys, grading, drainage and shoulders, and they are being maintained at very reasonable cost

The binding and waterproofing of the surface courses in the different methods of construction are dependent on the use of a suitable quality of bituminous material. It is, therefore, necessary to summarize briefly the types of bases and surface courses, in order that a clear conception of our practice in the use of bituminous materials may be obtained

The principal types of base courses as designated by the Pennsylvania Department of Highways are native stone, crushed stone, slag or crushed gravel, also run-of-bank gravel screened to remove pebbles in excess of two and one-half inches in size They are generally at least eight inches in depth

The native stone base, which is the principal type of construction, consists of large size stone sledged after placing, and the voids filled with smaller stone and other approved materials followed by rolling The stone is napped or broken to a maximum size of four inches and rolled prior to the addition of choke or filler

The run-of-bank gravel and crushed stone base courses are utilized to a more limited extent. The aggregates for use in the crushed stone base course may be either crushed stone, gravel or slag. Such aggregates are required to contain fragments of the proper maximum size and no excess of fines so as to obtain suitable interlocking under rolling.

The practice is to place over the base either surface treatments or a two inch compressed depth of bituminous surface course of the open texture design with a seal coat. The types of surface courses selected depend primarily on the traffic and available funds.

Figure 1. Condition of Road Prior to Improvement

SURFACE TREATMENTS

The surface treatments are designated as light, intermediate and heavy. Except in the case of heavy surface treatments, the base course, is first primed with a consistency of tar suitable to its surface texture. The grading of the aggregate ranges from a maximum of 1 to 1.25 in. down to 0.25 in. in size.

The light surface treatment consists of 0.25 gal. per sq. yd. of primer and 45 lb. of stone chips with 0.25 to 0.35 gal. per sq. yd. of either cold or hot surface treatment bituminous materials.

The intermediate surface treatment consists of 0.25 gal. per sq. yd. of primer and 65 lb. of stone chips with 0.65 to 0.75 gal. per sq. yd of either cold or hot surface treatment bituminous materials applied in two treatments. The aggregate after the first application of cold bituminous material is dragged and rolled. The additional aggregate required is then spread and the second application of either hot or cold bituminous material is applied. Another rolling is then followed by chipping and rolling.

The heavy surface treatment consists of approximately 100 lb. of aggregate and 0.80 to 1.30 gal. per sq. yd. of bituminous material applied in four applications. The quantity of bituminous material used within the limits furnished is dependent on whether it is cold or hot application material, as more of the cold application material is neces-

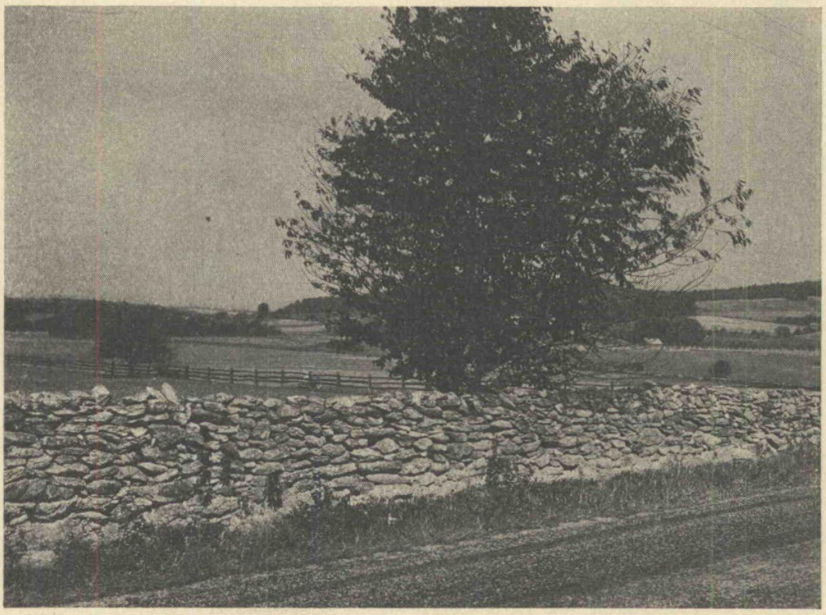

Figure 2. Stone Fences—One of the Sources of Material for Native Stone Base Construction.

sary than the hot in view of less bitumen content. The treatment consists in placing approximately 70 to 80 lb. per sq. yd. of aggregate ranging from 0.25 in. to 1.5 in. in size, applying approximately 0.5 gal. of cold bituminous material in two applications, dragging and rolling. There is then placed an additional amount of bituminous material followed by an application of one-half inch commercial chips and rolling. A fourth application of either hot or cold bituminous material follows, after which a small additional quantity of one-half inch commercial chips is spread and rolled. There is no primer required on the base for this type of surface course as sufficient bitumen is used to provide for both priming and coating the aggregate.

OPEN TEXTURE BITUMINOUS SURFACES

Stone aggregate ranging from 1.5 to 0.25 in. in size is used in the open texture bituminous surfaces. The particles are coated with the rquired type and quantity of bituminous material either by premixing in an approved type of plant or by penetration methods. A double seal coat is generally required in which one-half inch commercial size stone is used for the choke or covering. In construction by the penetration method the bituminous coated aggregate is either bladed or dragged.

Figure 3. Placing Native Stone on Prepared Subgrade

BITUMINOUS MATERIALS

(a) *Asphalt Cut-Backs*

A cut-back asphalt containing an 85 to 100 penetration base, as determined by tests on the distillation residue, and a light volatile naphtha is used in the construction of bituminous surface courses.

The surface course mixtures are prepared by either plant mix or penetration methods. This type of material is also used as an alternate type of bituminous material for intermediate or heavy surface treatments.

It is not desirable to have an asphalt cement of a harder consistency than 85 penetration, for it has been found that by utilizing an asphalt of 85 to 100 penetration, disintegration in these pavements thru impact and cold weather conditions is prevented. An asphalt cement of this consistency in a cut-back, if used in the proper amounts, also precludes the possibility of pushing in the surface course under warm temperatures.

The naphtha used in the preparation of asphalt cut-backs serves the following purposes:

1. It acts as a liquid medium for the asphalt, thus permitting application at low temperatures.

2. It permits more uniform distribution over the aggregate with greater coverage.

3. Excess bitumen that may be applied will tend to drain and waterproof the base from underground seepage instead of remaining at the surface to furnish fatty spots or excess bleeding.

Figure 4. Native Stone in Place Prior to Napping. Note care used in placing stone along edges.

4. The asphalt is deposited on the aggregate thru evaporation of the naphtha furnishing a binding medium with the required stability and waterproofing properties.

Heavier naphtha, which does not readily volatilize, would be trapped by the seal coat, thus delaying the ultimate stabilization of the pavement.

It is essential in specifications for asphalt cut-backs to cover thoroughly the qualifications which are required. The properties of such cut-backs can be specified and determined by viscosity, and distillation together with tests on the distillation residue. These procedures have recently been standardized.

It is necessary, however, in such type cut-backs to specify the minimum distillation fractions at 320°F. and 374°F., so as to control the volatility by means of the lower boiling point fractions, to provide for a maximum difference in fractions between 600°F. and 680°F., and to preclude the use of naphtha having an excess of heavier end fractions, which would prevent the required evaporation.

If the mixture is dragged during construction so as to expose the underlying coated aggregate, a cut-back containing a somewhat heavier naphtha could be successfully utilized. It should not be inferred, however, that cut-backs should be used which contain a kerosene fluxing medium.

We utilize another type of asphalt cut-back for thin film surface treatments and penetration construction when the surface course is to be

Figure 5. Napping Native Stone. All nappers required to wear goggles

dragged. This type contains an asphalt cement the distillation residue of which has a penetration of 120 to 150 and a somewhat heavier naphtha. It is necessary in this type of asphalt cut-back to specify a maximum percentage of distillate at 320°F. and both a minimum and maximum distillate at 374°F. This must be done in order to control the desired volatility of the naphtha and also to provide for a maximum difference in fractions between 600°F. and 680°F., so as to preclude the use of naphtha having an excess of heavier end fractions which would prevent the required evaporation.

The components in this slower curing asphalt cut-back differ from those used in the more volatile type, which contains harder asphalt cement and more volatile naphtha. This is to provide for increased manipulation or more prolonged blading in mixed in place construction, by means of the slower volatilization of the naphtha and consequent slower set of the asphalt cement. The naphtha required is not a low volatile or even a medium volatile material. It differs primarily from the naphtha used in the more rapid setting cut-backs in that it has higher initial boiling point fractions; but at the same time it does not necessarily contain a larger percentage of the heavier ends. The specifications which have been developed for this type material require a narrower naphtha cut than that used in the more volatile cut-backs.

Figure 6. Rolling Native Stone Prior to Application of Filler Material

The softer asphalt in conjunction with heavier naphtha provides for longer blading. The softer asphalts, however, are not primarily specified for this purpose as we are more dependent on the naphtha volatility.

It is not considered desirable to use a medium curing cut-back or one containing heavier naphtha than that specified for mixed in place construction in open texture surface courses, because the naphtha would probably be retained in the bituminous coating and delay rolling, thereby handicapping large scale production. The use of heavier naphthas than specified would also result in some being held or trapped for a considerably longer period, which would probably produce a roughened surface under traffic at the expense of riding qualities of the pavement.

This type of asphalt cut-back is most desirable for thin film surface treatments for the following reasons:

1. A large percentage of chips is retained by being embedded before the asphalt film obtains its initial set. If a very rapid setting cut-back is used for such surface treatments the chip spreader as a rule cannot follow the oil distributor close enough so that the chips can be applied before a thin impregnable skin forms over the surface. The chips, in this case, will remain on the surface without having an opportunity to

Figure 7. Native Stone Base after Application of Filler Material

adhere to the asphalt, for the residual film is not of sufficient thickness to permit the chips to puncture this elastic skin when formed.

2. The softer asphalt provides for a more elastic film and also does not harden to the same extent as the harder asphalt would under cold temperatures, thereby preventing excess loss of chips.

3. This type of asphalt cut-back is somewhat similar in its bleeding properties to tar cut-backs in that sufficient bleeding occurs to make it possible to produce a tight and waterproof surface for seal coat or retreatment work.

It is desirable to use an even slower curing asphalt cut-back than discussed in the construction of the open texture pavements, when the surface courses consist of aggregates of denser grading. The slower curing cut-backs under such conditions are necessary to provide for the prolonged blading needed to produce adequate and uniform covering on aggregates of greater surface area.

(b) *Bituminous Materials for Hot Surface Treatments*

The Pennsylvania Highway Department discontinued the use of these materials a number of years ago for surface treatment on main travelled highways, on account of the excess bleeding, which occurred under traffic, in warm weather. It has been found, however, that such

Figure 8. Penetration Stone after Spreading but Prior to Penetration with Bituminous Material.

materials furnish excellent results for surface treatment on our native stone bases where the traffic count is low. The material under such conditions does not bleed excessively and it is anticipated that no retreatments will be necessary for at least three years when such materials are used. These types of materials are held at the surface and form an excellent mat. It is also possible to use larger chips than in the cold surface treatments, and they are retained very well if the chip application closely follows the distributor so that a bond is secured before the bituminous material chills and sets. The use of the larger chips provides for a more non-skid surface.

(c) *Asphalt Emulsions*

Considerable quantities of asphalt emulsions have been used in the preparation of plant mixed bituminous surface course by both mixing and immersion processes. Only the quality of the asphalt cement based on tests made on the distillation residue is specified.

The properties of the emulsion for the intended construction are left to the judgment of the producer, since the specifications stipulate the required amount of asphalt cement coating to be retained on the stone aggregate after the emulsion has broken. It has been found essential to collect samples of the asphalt emulsion coated aggregate from the pavement after the emulsion has broken or set, since, for successful

Fig. 9. Showing First Application of Bituminous Material

results, we are primarily interested in the amount of asphalt on the aggregate. It is not possible to collect from trucks samples of this type of mixture which will be representative of its condition after placing and after the emulsion has broken, for there is always the possibility of considerable drainage occurring during transportation and even after placing prior to the break of the emulsion.

The use of asphalt emulsions for seal coat on plant mixed pavements of the open texture type has been discontinued since, slower curing asphalt cut-backs provide a better seal in view of the greater chip retention. The asphalt emulsions observed in our construction harden to an excessive extent when applied in thin films, which causes a considerable loss of chips.

(d) *Tars*

Tars are utilized within a range of three consistencies: 5 to 13 Engler at 40°C., 14 to 26 Engler at 50°C., and 26 to 36 Engler at 50°C.

The base used in the thinnest consistency of these tar cut-backs is a lighter grade than the bases of the other two types of tars. The lightest grade tar based on consistency is utilized for prime application only when a material of considerable penetrative properties is required and the base course to be treated is of close or dense surface texture.

The intermediate consistency tar is used for primer on native stone base course.

Figure 10. The Completed Road after Seal Coat

The heaviest consistency tar is used mainly for retreatments on primary routes having high traffic counts and as alternates to asphalt cut-backs for light, intermediate and heavy surface treatments on native stone base course construction.

In the heavy surface treatments on native stone base courses, however, a more general practice is to use asphalt cut-backs because of their more rapid setting properties. These permit earlier rolling and therefore quicker ultimate stability of the finished surface is obtained.

Heavy consistency tars require heavy base stock and in a large number of tars of this class, which have been supplied, the base is a semi-solid of 110 to 150 seconds float at 50°C.

The tars will naturally set or cure more slowly than the asphalt cut-backs The type of flux generally used in the preparation of tar cut-backs is a water-gas or coal tar having an Engler specific viscosity of 1 to 4 at 40°C This type of flux evaporates more slowly than the petroleum naphthas used in the asphalt cut-backs These fluxes, although somewhat retarding the setting time of the semi-solid base, assist in providing a more flexible or less brittle material in the film than would occur if the semi-solid base had been used without such addition.

It is the practice in the Pennsylvania Highway Department to specify the requirements for tars under component specifications covering the quality of the flux, base and mixture, for it is possible under most conditions to meet specifications, which are based on mixture requirements only by furnishing a dehydrated crude tar A dehydrated crude tar will set slower than a cut-back of the same consistency made from a refined base fluxed with a lighter material

The general trend of the tar industries is toward the utilization of heavy refined base stocks, which have a lower temperature susceptibility factor, and are more ductile at low temperatures than the present straight refined semi-solid tars These types of bases in combination with suitable fluxes, together with certain other changes in refining practice, would be expected to give more satisfactory results and would probably tend to overcome some of the objections in the present construction where quicker set and increased durability are vital factors

Tar cut-backs have advantages over semi-solid tars for certain types of construction for the following reasons

1 Application at lower temperatures can be more readily accomplished
2. Greater coverage and more uniform distribution
3 Elimination of mat surfaces

DISCUSSION ON RESEARCH ON BITUMINOUS MATERIALS AND COMBINATIONS FOR FLEXIBLE TYPE ROADS

Mr Prevost Hubbard, *The Asphalt Institute* The wealth of material presented in these four papers would necessitate for any adequate discussion a rather lengthy paper in itself, so I shall confine myself to one or two remarks in connection with certain details which were mentioned by the authors Mr Kelley very capably outlined the different problems that confront the engineer in connection with these flexible pavements I believe, however, that to one who has had no experience in flexible pavement construction his outline might appear very discouraging as indicating a need for so much information before satisfactory flexible pavement could be constructed at the present time I know Mr Kelley did not intend to convey this idea which of course is far from being the truth As a matter of fact, while we do need additional information along the lines of Mr Kelley's outline, our oldest most satisfactory pavements in existence now belong to this class of flexible design In the low cost types of construction which have been developed during the last eight or ten years, results obtained on thousands of miles of highways have shown that it is not a difficult proposition at low cost to produce a flexible pavement which in many cases is carrying traffic for which we ordinarily consider a high type of design is necessary

In connection with two details mentioned by the other authors, I should like to speak very briefly first on the theory of design of mixtures This has been touched upon by Mr Stanton and Mr Allen There are two theories of design or proportion of mixtures that have come into existence and are being used—the voidage theory and the surface area theory Both have proved useful as applied to a certain limited field of measures The voidage theory has been quite satisfactory as applied to dense aggregate hot mix construction, whereas it has fallen down if applied to the low cost types where the aggregate may be either dense or open in character and the binder a fluid material rather than a semi-solid To my mind some combination of these two theories will ultimately be accepted as a rational basis for proportioning mixtures and I think that there are two factors in connection with the theory of design which have so far been overlooked and need to be studied One is the relationship of viscosity of the bituminous material to the aggregate, particularly with reference to the size of voids in the aggregate This has been impressed upon me very strongly in some recent laboratory studies where we have taken a satisfactory mixture prepared with asphalt cement and then atempted to substitute liquid asphaltic products of varying viscosity in the same formula with the same aggregate We have found that the percentage of bituminous material must be decreased as the viscosity decreases and I believe that future studies along this line will add much to our knowledge of proper proportions

The other point is that weathering tests have been indicated as being very necessary for development This is particularly true for the class of bituminous products known as slow curing I think all of us who are interested in bituminous materials should devote every effort to developing an accelerated weathering test for this class of product At the present time, however, the necessity for such a test is much more apparent for this class of product than for asphalt cement or asphalt cement which has been cut back with selected distillates, because these have been in use for a long time, have given satisfactory service, and our method of describing them in specifications has in general been found satisfactory

MR R B. GAGE, *New Jersey State Highway Department* The experience in New Jersey with certain oils does not agree with some of the statements made by Mr Allen. It has been our experience that those oils which will produce good ductile residues will give better results than those that form residues having low ductilities. The former naturally are more susceptible to temperature changes and appear to adjust themselves more easily to changes of travel and weather than those of the latter type

These facts are not unknown to the producers of the various grades of bituminous materials, yet the supply of such materials appears to be rather limited compared with those of the non or semi-ductile character Any one who has tried to get a specification adopted that includes a ductility test of any value is well acquainted with the objections that are made by the various producers, and to date the producers have usually been able to have the ductility test so worded and modified that the character of the bitumen is improved very little, if any, by the test.

This argument regarding the ductility test has been going on for over twenty years, and I would like to ask Mr Allen whether the statements made by him are considered to be true under all methods of construction or whether they are limited to certain methods of construction that he happens to use

This test is of vital importance in determining the general character of an asphaltic oil, and we have always considered, in preparing our specifications, that the test should be so worded and drawn as to secure the maximum amount of benefit from it

From the remarks that have been made and from the papers that have been read on the bituminous surface treatment of roads, one might assume that the roads thus treated all turned out to be 100 percent perfect In our own experience many of the roads thus treated could not be worse, regardless of what kind of oil was used on them Their condition in some cases might not all be due to the character of oil used, but in many cases the character of the oil did help to increase the defects However, I do not want to imply that if an oil is used that will produce a good ductile residue, the results will always be 100 percent perfect, for to secure such results the various factors necessary to produce them will have to be coordinated to meet the local conditions However, in certain localities, it appears that the construction conditions are never coordinated or adjusted to meet traffic or local variations in construction, for the roads appear to be equally bad in all cases, and each time I have been compelled to visit such localities I always promise myself that this will be the last trip However, I do not want you to assume that all bituminous treated roads are generally bad, for under certain conditions and methods of construction, very satisfactory pavements can be produced

Mr Allen They are true in so far as we have been able to ascertain. They refer only to the type of construction with which we are familiar

MR GAGE What was that type of surface?

MR ALLEN Bituminous mat surface described in the paper

MR STANTON I want to check Mr Gage's statement in general about some roads that would have given trouble regardless of the nature of the bituminous binder and that is one of the points I attempted to bring out Another reason for our stability tests is to determine the inherent stability of the aggregates and the mixture itself and if that is good we are not so dependent upon the grade of bituminous binder used, but if we have unstable aggregate, then the quality of the bituminous binder is an important characteristic