PROGRESS REPORT ON LOW-COST IMPROVED ROADS INVESTIGATION

C N Conner

Highway Research Board, Washington, D C

As highway engineers we have often overlooked or have not always realized the possibilities of the use of local materials in roadway surfacing

Professor T R Agg has said "The value of a specific roadway surface depends upon its effect on the cost of transportation The determination of appropriate improvements for a specific highway and the selection of types of surfaces becomes a problem of evaluating the effect of those improvements on the cost of highway transport . . Obviously the cost of transport will depend in part on the type of vehicular equipment, but considering the equipment existing in any locality, comparative values for various types of highways in that location may be estimated"

It is now considered as much of an error to overbuild—that is, construct a highway too expensive for the expected traffic—as it is to build one which is low in first cost, but incapable of carrying the traffic to be expected

The increase in all classes of motor transportation has now reached such a point that we cannot confine our attention to the development of the high-type road surfaces

Traffic must be moved from and to the isolated sections and between objective points, congestion on the heavy traffic highways must be relieved and the safety of our highways increased

When we consider the total mileage of highways of all types with the very high percentage of the lower types of surfacing and then consider further the ever-increasing motor vehicle registration, we are forced to the conclusion that improvement in the lower class roads is immediately necessary

This fact is still further made evident by even a casual study of the results of traffic surveys in various States

These traffic surveys are already of great value in estimating the amount and class of traffic that may be expected, thus making it possible to determine in advance what type of surfacing may be used with economy

The traffic capacities and costs of the various high types have been fairly well established, as have also the limitations of the unsurfaced and lower types of untreated roads

There remains therefore a wide field for investigation and research on surfacings which are intermediate in costs and carrying capacities, between the low and high types

A brief study of the intermediate road situation as a whole comprising experiments, construction and maintenance done by various institutions, States, counties and towns shows that the situation has not been overlooked and that the problem of economically carrying traffic on intermediate type surfaces has been solved in some locations

There are instances also where the construction of an intermediate-type road is entirely justified by local soil and traffic conditions, as well as by the unfortunate but vital fact that funds are not available for the higher and more expensive types of construction

The building of intermediate type surfacing will make possible the building of higher type surfacing, for without a serviceable highway connecting objective points, a comparatively small number of vehicles can be used, whereas, road service for a much larger number may be maintained by the construction of an intermediate type, at a cost within the limits of the funds available Then in the course of time, when traffic conditions warrant and the life of the lighter-type construction has passed, funds will become available for a higher type, due to the fact that the community has prospered and can demand the more permanent construction But without first constructing the lighter type, the period of prosperity might have been indefinitely delayed

In not a few towns, counties, and States, it is now a question of having a medium type of surfacing or no surfacing at all For they must have reasonably good roads generally rather than provision of elaborate facilities in one section and bad facilities in another.

The intelligent combinations of local materials with local or shipped-in admixtures has already given road service to many such communities Others are experimenting on their local situation, while still others are waiting for research and investigation to give them the needed information

It is hoped that the final report of this investigation will indicate the solution to some of their problems

While it is fully understood that this is a very broad subject, including as it does many variables in types, materials, geology and geography, these conditions only serve to make the necessity for the investigation more apparent

The object of the investigation therefore is to collect, correlate and present information in order that conclusions may be drawn and comparisons made on types, costs, traffic capacity and suitability of intermediate type road surfaces under varying conditions of soil and climate

It is not the intention to make it highly technical in character or to delve deeply into the mechanics and chemistry of aggregates and admixtures, but rather to make a wide general survey of conditions as they exist in actual field practice or experimental sections

The technical and theoretical phases of soil and soil treatment will be covered today by Dr Terzaghi, who, as you all know, is a widely recognized authority on the subject of soils

The scope of the survey includes

1 Treatments and surfacing of loam, clay, top soil, sand clay, marl, lime rock, sand, cinders, slag, gravel and stone,

2 The admixtures for these treatments include lime, calcium chloride and other chemicals or by-products, road oils and asphalts, tar and Portland cement,

3 The climatic conditions include those of the southern, middle and northern States as well as some of the more arid regions;

4 The types of surfacing will include chemical soil treaments, hot and cold surface treatments with tar, hot and cold surface treatments with asphalts, surface treated and penetration macadams, modified sheet or sand asphalt, using local materials, bituminous concrete, using local materials, natural rock asphalts, Portland cement and local sand mixtures

These types of surfacing will be considered in connection with the different types of base on which they have been used, but will not include standard base courses of Portland cement concrete, plain and reinforced concrete

The procedure is

1 To collect published information and literature on the subject in order to increase their utility by tabulation and classification,

2 To hold conferences and carry on correspondence with institutions, associations, highway officials, road builders, manufacturers and producers of materials so that after learning the results of their experience and experiments, considering their suggestions, and ideas, this information and the consensus of opinions may be assembled and applied

3 To make field inspections of construction, maintenance, renewals and service conditions in order to secure records, obtain photographs and study actual conditions on the ground

The data sheet for recording field studies is shown below

INTERMEDIATE TYPE ROAD INVESTIGATIONS

Report by Date No (*Reverse Side*)

State County Town
Name Length
Type Year built
Built by In charge
Coop by Cost
Ref to Engr Lit.

Photos

Remarks

Natural Soil
Material
Analysis Phys Chem
Preparation

Surfacing
X Sec
Mat Added
Analysis
Proportions
Const Methods

Conclusions

Influencing Factors
Crown Grade Loc
Drainage
Traf Class Amt
Maint Class Freq
Climatic Cond Surf Regu

Cost Const Maint
Remarks Over

CONCLUSIONS

Definite and indicative conclusions will be drawn in the final report on carrying capacities, first costs, approximate yearly costs, comparative surface regularities, thickness of surface, thickness of base courses, how affected by climate drainage and subgrade, typical sections in use, recommended typical sections, principal causes of failures and the remedies, limitations of types on account of crown, grades and curvature

This, of course, will be supplemented by photographs, tabulations, curves, and a bibliography of references and specifications

Field inspections have been made during parts of July, August, September, and October, 1926, in the States of Maine, New Hampshire, Vermont, Rhode Island, in Long Island, New York, New Jersey, North Carolina, and Virginia

It was gratifying to learn and observe the success which has followed the necessity of furnishing highway surfaces at a comparatively low cost This, naturally, has been accomplished to a large extent by using local materials

The types inspected included calcium chloride treatments of gravel, asphaltic oil treatments of gravel, tar treatments of gravel, asphaltic concrete on gravel or stone base, sheet asphalt on gravel or stone base, bituminous macadam on gravel or stone, marl base with tar surface treatment, marl base with sand asphalt top, and sand asphalt

Other types of surfacing have been studied but not investigated in the field, such as the oil-bound surfacing of stone roads, lime and Portland cement treatments of clay and Portland cement mixtures with local sand

LIME TREATMENTS OF EARTH ROADS

The principal tests to determine the effect of treating earth roads with lime were conducted by the Engineering Experiment Station at the University of Missouri beginning in 1924, about the same time field tests were started by the U S Bureau of Public Roads in Iowa and South Dakota Since that time Ohio State University, University of Illinois, and Wisconsin State Highway Department have entered the investigation, each with a particular problem

This investigation has consisted of laboratory work, together with actual field tests, and while the experiments are not yet completed, several things have been discovered which might be of interest here

In making the lime treatment hydrated lime is thoroughly mixed into the road soil to a depth of six inches by plowing and discing To obtain the best results the road should be quite dry when the treatment is made, in order to get an intimate mixture The road is then dragged to the proper cross section and opened to traffic which quickly packs it

It is stated that lime treatment stabilizes heavy clay and silt soils These soils lose their stickiness and plasticity, becoming granular in structure, which renders them capable of sustaining normal traffic loads without failure when wet

The field tests with lime treatment have used various percentages of hydrated lime ranging from 2 to 5 per cent by weight and from 3 to 9 per cent by volume The depths of soil treatment have ranged from 2 to 6 inches with the majority of them at 6 inches

Among the possibilities looked for in these tests are

Where traffic is heavy enough to warrant a better road, the subgrade may be treated with lime and the surface covered with a thin layer of crushed stone or gravel Without the lime this thin layer of surfacing material would soon sink into the clay and disappear, but with the increase in stability and loss of plasticity due to the

effect of the lime, the thin layer of gravel or crushed stone is expected to remain on top

It is claimed that maintenance on a lime treated road is simplified in several ways The soil loses its stickiness and is not picked up by the wheels of vehicles This keeps the road from becoming rough The increased stability of the soil prevents the wheels of vehicles from cutting ruts after the surface begins to dry The lime treated road dries out faster and can be dragged many hours sooner than the road without lime The treated soil mulches more easily under the drag, making it easier to obtain a smooth riding surface

But whether or not these treatments are to become an economic success in competition with local sand and gravel as surface stabilizers has not been proved from the results so far obtained

CALCIUM CHLORIDE TREATMENTS

In many States and localities where local gravel, sand clay, or top soil are available a large mileage of surfacing has been constructed, but due to the intensity of traffic in summer and dry weather the dust nuisance has become a serious menace

As is well known, when traffic reaches 300 to 500 vehicles per day the surface often becomes corrugated and an appreciable amount of surfacing material is lost

Insufficient funds to lay a hard surface highway or even oil or tar treatments have forced these localities to find a palliative in order to carry their summer traffic

In New England both Vermont and Maine have used this material with a reasonable amount of success for the purpose intended

During 1925 Vermont treated over 2200 miles of gravel road and Maine has about 500 miles

The amount of calcium chloride applied per year varies between ½ and 1½ pounds per square yard in these States and is applied from a lime spreader hauled by a truck Other trucks are put in use to bring up additional supplies as the work progresses

It has been found that dust and corrugations are reduced but that pot holes will occur, which may be remedied by patching with fresh gravel

The calcium penetrates as deep as 1 inch in places, in others scarcely at all This variation is due to the porosity of the surface material and amount of calcium chloride applied.

The opinion in Vermont is that the gravel should contain a fair amount of binder, say up to about 25 per cent

These treatments do not effectively carry through the winter, however, there is a slight evidence that some benefit exists in the following spring from the previous season's treatment

The total costs per mile per year seem to vary between $100 and $300, the variation being due to the porosity of the soil, intensity of traffic and amount of applied chloride The cost of application in Vermont is 17 per cent of the cost of the delivered material

One of the principal objections to this type of treatment is a slick or slippery condition of the road surface which sometimes occurs during and immediately after a rain

The final report will contain data from other States including Michigan and Minnesota where it is understood these roads are carrying 1,000 to 3,000 vehicles per day.

SAND-OIL SURFACING OR SAND ASPHALT LAYER METHOD

Although this type of surfacing has been satisfactorily used in Long Island, New York, for at least ten years, it is only within the past few that its possibilities for similar soil conditions in other localities have become apparent

We now find this or a similar surfacing being tried out in actual service in several of the southern, middle, and far western States

Its economy and success depend largely upon the proper selection and manipulation of the local materials, as well as performing the construction and maintenance under suitable weather conditions

The surfacing in Long Island consists of a mixture of road oil, (Texas 55) mixed in place by dragging and traffic with local sand or sand loam, after successive applications of the oil and aggregate

As a result of a field survey on some 400 miles of this work in Long Island a few observations will be made in this report:

The subgrades were in general sandy loam over sand or fine gravel.

Local materials as aggregates were used entirely

The surfacing widths varied from 9 to 75 feet.

The thickness of mixed surfacing varied from ½ inch to nearly 6 inches

Crown ranged between ¼ and 1 inch to the foot

Wider sections showed less fatigue than the narrow ones.

Two treatments are necessary the first year for satisfactory results.

One treatment each succeeding year is in general sufficient.

Some of these roads it is estimated are carrying as high as 5,000 and 6,000 vehicles per day in the summer season

These surfacings are said to cost from $800 to $1,500 per mile for the first year using an 18-foot width and from $300 to $800 for each succeeding year.

In many cases the surfacing is protected during the winter months by pulling in sand and loam from the ditches to a depth of about

one-half inch over the entire surface This is done at the beginning of cold weather, usually in October

It must be borne in mind that the local material as found in Long Island is well adapted to this type of construction

Beginning in 1924 oil treatments of gravel roads were started in New Jersey

The same grade of oil is being used and similar methods of construction and maintenance are being employed as in Long Island

Good aggregates for cover material are easily procurable locally.

Inasmuch as skill in construction and maintenance are not as highly developed on this particular type in New Jersey the results at present are not as gratifying as in Long Island

There is every reason to believe that this sand-oil type will be satisfactorily developed as the local materials are excellent

The costs in New Jersey are about the same as in Long Island

This same type of construction was started in North Carolina in 1925 after some experimenting in 1924

The oil treatments were applied to sand clay, top soil, and gravel roads

At first oil was used for the prime coat and following treatments This was later changed to a prime treatment of tar followed by a quick curing asphaltic oil

Something over 400 miles of this work have been constructed in that State

The results in general have been very satisfactory especially as to improvement in smoothness of riding surface, increase in traffic-carrying capacity at all seasons and abolishment of dust

Some of this work cost as high as $2,500 per mile for a treated width of surface of between 18 and 21 feet for the first year

It is very probable that the cost can and will be reduced for succeeding years to about $700 per mile on surfaces previously treated

These treatments were not entirely satisfactory on certain sand clays, on worn-out fine gravels and in places where the cover sand contained undesirable foreign elements

It is probable that these roads will satisfactorily carry from 1,000 to 1,500 vehicles per day and possibly more

The sand-oil or gravel-oil road has been tried out in other States and in Mexico with varying degrees of success and there is great probability that, with careful study and intelligent selection of local materials as well as proper construction and maintenance, the sand-oil road will become much improved in the next few years

TAR TREATMENTS OF GRAVEL

In Maine, New Hampshire, Maryland, Virginia, Wisconsin, Michigan, and several other States, the use of tar on gravel roads has met with considerable success

As in the case of the oils, the most successful results have been achieved when great care was taken in the selection and preparation of the surfaces to be treated, as well as care and pains in the construction and maintenance

Forced by the necessity of carrying its own traffic and that of a large tourist traffic in the summer months, Maine was probably the first State to make a success of tar-treated gravel surfaces After many of the details and methods had become established, other States took up this method of tar treatments of gravel

There are about 550 miles of tar-treated gravel roads in Maine whose climatic conditions are probably as severe as any State in the Union

Depending on weather and traffic these roads at times break up in the fall or winter of each year This breaking occurs at a period of thawing on warm days following a period of freezing weather

In Maine, it is the policy to scarify and reshape these surfaces each year The old tar mat, however, is not wasted but is broken up and spread again over the gravel surface, compacted by traffic or rolled and then retreated with tar

On account of the heavy freezing and poor subgrades, a sub-base of from 2 inches to 12 inches of gravel or stone is laid before the standard gravel surfacing is placed Gravel sub-base is quite generally and satisfactorily used in New England under all types of surfacing, including Portland cement concrete

The gravel surfacing proper has a compacted thickness of from 8 to 11 inches The tar mat has a trickness of from ¼ to 1 inch

The tar surfacing complete costs in Maine, for an average of 17-foot width of surface, from $800 to $1,500 per mile per year, the average being about $1,100

This includes considerable patching, which is done by mixing coarse sand or fine gravel with tar either by hand or in a small power concrete mixer, hauling and placing as required

The annual scarifying and reshaping process results in a comfortable and smooth-riding surface

The methods in New Hampshire are similar to those in Maine except for the annual scarifying While this is done to some extent it is not followed as extensively as in Maine

The annual cost per mile in New Hampshire is about the same as in Maine on the same type of construction

New Hampshire has about 1,000 miles of this type of surfacing

Virginia has and is constructing tar-treated gravel roads The surface treatments are costing from $1,100 to $1,500 per year for the first year.

Details from other localities are not available for this report, the final report, however, will include them

It is somewhat difficult at times to classify the various low-cost roads by name, but at the risk of being misunderstood the next type to be considered will be the Veneer Bituminous Macadam

This type of surfacing consists of a layer of crushed stone placed upon and keyed by rolling into the surface of a sand clay, top soil, or gravel roadway.

It is then penetrated with bituminous material and completed in practically the same manner as a penetration macadam surface

An experimental stretch of this was laid near Raleigh, North Carolina, more than three years ago and is still rendering good service with a traffic of about 1,400 vehicles per day

Another road of practically the same type was laid near Richmond, Virginia.

The first cost is about the same as for a bituminous macadam surface; the annual costs have been about the same as for bituminous macadam under equal traffic

A similar type of construction was completed in Oregon The roads to be surfaced consisted of old water bound and also traffic bound gravel or crushed stone It was found that the ordinary methods of maintenance were not sufficient to hold the surface intact and free from corrugations

After experimenting for a number of years with clay binders the Oregon engineers developed the method of incorporating the binder with the surfacing material of crushed stone or crushed gravel by the process of thoroughly mixing the proper proportion of carefully selected binder with the stone or gravel by means of heavy blade road machines which mixed the material thoroughly

In most cases water was applied by means of sprinkling trucks so that the resulting surface was really a stone clay or gravel clay roadway veneer

The blading and traffic made this into a dense hard surface After this surface had been maintained under traffic it was wet down with water trucks and the moistened surface shaved smooth and regular with a road machine

It was then thoroughly cleaned of dust and oiled in two or more applications About 0 3 gallon per square yard for the first and 0 2 gallon for the second

It is stated that the total cost per mile 18 feet wide for preparing and oiling these roads when in actual condition to receive the oil should not exceed $500 per mile

With a normal amount of maintenance this road would probably carry 1,000 to 1,500 vehicles per day

In line with this retreatment of old surfaces is the Retread treatment as it has been called

This consists of shaping and patching up the old-road surface, placing on it a two-inch layer of three-fourths-inch stone, smoothed out with a blader and treated with a half gallon per square yard of bitumen, then rolled if a roller is available Traffic may be let over it, but if this is done the road should be bladed and dragged for from 3 to 5 days This keeps the ruts filled and maintains a smooth and regular surface

At the end of the fifth day, or when the surface begins to set up, blading is stopped

The surface is again treated, this time with 0 3 gallon of the same material and covered with chips or corase sand

This method has not been investigated in the field, but if it is as satisfactory as claimed it should be of service in many communities

In West Virginia the graded earth and shale surfaces are first surface treated with either road oil or tar, and then it is proposed to cover with stone passing the 1½-inch screen

It is expected there will be some heaving and breaking during the winter when frost is coming out of the ground, where surfacing is thin and clay is abundant

After the first year they propose to scarify the surface to the depth of the stone and then blade it to each side of the road in windrows. Between the windrows a new 2-inch layer of stone will be spread and penetrated as before The two windrows will then be bladed back on this new layer and the same process of machining repeated as in the first year

It is expected that the annual cost for a 16-foot width of roadway will be between $2,000 and $3,000 and that by the end of the fourth year a good bituminous surface will have been built

This and similar experimental construction on low-cost improved roads are attracting deserved attention

In Pennsylvania the oil bound broken stone surface on stoned road consists of a surface course 2 inches thick after compression

It is composed of ¾-inch stone which passes a 1¼-inch screen and is retained on a ⅜-inch screen

The stone is dumped and spread, in accordance with standard specifications for macadam, into a smooth and regular surface on the old stone roadway

It is then rolled with a ten-ton 3-wheel power roller

Bitumen ranging from 0 3 to 0 4 gallon per square yard is applied and the surface rolled again to a uniform cross section and allowed to dry from 24 to 36 hours

The second application of bitumen material is then applied at the rate of from 0 2 to 0 35 gallon per square yard

Where a dull-brown color exists it is necessary to apply a larger amount of bituminous material than where an excess amount of bituminous material shows on the surface from the first application.

After the last application, the rolling is continued until the surface is thoroughly compacted

Costs and further data on this type are not available for this report

"RAWHIDE" SURFACING

Among the patented types of surfacing is the "Rawhide road"

The general principles of the type are similar in effect to the sand-oil roads

The main difference is the employment of a special 10-ton tamping roller to mix and compact the soil and asphalt in a short period of time rather than waiting for traffic to do the compacting

The wearing surface is built up in successive layers by mixing the existing soil road surface with the applied asphalt until a compacted thickness of from 4 to 6 inches is obtained

In principle this type of road should be successful

It is probable, however, that the promoters have been over-optimistic and have promised good road surfaces on local materials which were not in suitable condition and which did not contain suitable aggregates for an oil road-layer method, and further that sufficient care in the construction was lacking

It is claimed that this road for an 18-foot width can be built for from $5,000 to $10,000 per mile

MARL AND LIME ROCK BASE WITH BITUMINOUS SURFACE

When local material of marl or lime rock are available a base course of 6 to 8 inches thick and covered with a bituminous surface has provided a low-cost improved road

In some South Atlantic States deposits of these materials are found in close proximity to the road locations and can be more economically used as a base course than shipped in materials

In southeastern North Carolina there is quite a large mileage of marl base

This material is hauled from the pit, and the larger pieces screened out and crushed, all of the materials from some pits requires crushing

It is then hauled to the road, suitably dumped, spread, machined with a blader, and firmly compacted by rolling

Timber side forms on edge and equal in depth to base course, if set to line and grade, will aid in securing a better job

Timber forms left in place where lumber is cheap have resulted in excellent work

When the base has dried out the surface is finally trued up and cleaned It is then ready for the bituminous surfacing

In Florida there are three principal classes of local material used in this type of base course—Florida lime rock, ojus rock, and coquina rock

Ninety per cent of the material is required to pass a 3½-inch screen and not less than 30 per cent retained on a ¾-inch

The specifications require temporary side forms, sprinkling, rolling, harrowing, and machining until the entire depth of crushed stone is bonded and compacted into a dense and unyielding surface true to grade and cross section

These surfaces, after traffic has searched out the weak spots, are prepared and treated with various types of bituminous surfacing

For lighter traffic a surface treatment of bituminous material and a coarse chip or coarse sand is used

Another type is bituminous macadam, using hard crushed stone

Asphaltic concrete using local materials has been satisfactorily employed, as has also sheet asphalt with a binder course

Costs and traffic estimates for these types of construction will be available for the final report

SAND ASPHALT AND BITUMINOUS CONCRETE, USING LOCAL MATERIALS

The coastal plain of the Atlantic seaboard does not have an appreciable amount of local hard rock but in many instances it does have large areas of fine or coarse sand

Massachusetts, in what is known as the Cape Cod section, took advantage of this fact some 15 years ago and started building bituminous concrete roads, using the local sands

On account of the excellent drainage of the sand subgrades many of these older roadways are still entirely serviceable

The earlier surfaces were laid 4 inches compacted thickness but this method has now been changed to two courses of 2 inches each

In the earlier pavements no side forms were used, in recent years temporary side forms of 2 x 4 lumber are used for the top course

The bituminous concrete is rather open and carries a low percentage of asphalt It is considered necessary at times to ship in stone and filler dust

After the first year these surfaces are treated with a light seal coat of road oil and sand

At the present time these pavements are costing about $10,000 per mile for an 18-foot width

Some of these roads in Massachusetts are carrying as high as 2,500 vehicles per day

The first sand asphalt pavement in North Carolina was constructed nearly five years ago

It is similar in some features to the Massachusetts work on Cape Cod, the principal difference is the use of a much finer sand

The 3-inch base course is composed entirely of local sand and asphalt

The top course contains local sand, asphalt, and filler

Side forms of cypress or pine are set on edge to line and grade, firmly staked and left in place

The pavement as originally laid had a 3-inch base course and a 1½ top

On account of some difficulties in cracking of top coarse and lack of band between top and base, some experimental sections were laid in 1925 and satisfactory results were obtained by making the following changes

The surface of the 3-inch base was treated with a squeegee coat of hot asphalt immediately before placing the top and the top was increased in thickness from 1½ to 2 inches

Sand asphalt is now being laid in Delaware in the southern part of the State where large quantities of sand are available locally and where subgrade conditions are suitable

Contract prices in North Carolina on this work have varied from about $1 40 to $1 90 per square yard, including side forms

It is probable that this surface can be built for about $18,000 or less per mile for an 18-foot width

It will easily carry 1,500 to 2,000 vehicles per day

GRAVEL BASE AND STONE BASE WITH BITUMINOUS CONCRETE AND SHEET ASPHALT SURFACE COURSES

These all-year surfacings have given good service in widely separated sections of the United States

From the field investigations so far it is evident that their traffic capacity has been exceeded near some of the larger centers of population

This is more noticeable in the bituminous concrete than in the sheet asphalt

The sheet asphalt is generally laid to a greater thickness and the binder course gives it greater stability by keying the top more securely to the gravel surface

While these surfacings have been laid on newly constructed rolled gravel and stone surfaces, the better results have been obtained on surfaces which have been under traffic and maintenance for a considerable length of time

In Rhode Island, bituminous concrete on gravel has been in service for six or seven years and possibly longer

Like most of the other New England States, Rhode Island uses a sub-base or foundation course of pit-run gravel under nearly all of its surfacing This varies in depth from a few inches up to 10 or 12 inches

On this sub-base course a 6-inch rolled gravel surface course is built, which in turn is covered with a 2-inch surface of hot-mix bituminous concrete This bituminous top is made up largely of local sand and gravel Two by four-inch temporary side forms are used during the construction of the top

The surface regularity is about the same as that of a good penetration macadam

Average traffic on some of these roads is estimated at between 2,000 and 4,000 vehicles per day, with an estimated maximum of from 8,000 to 10,000

The roads carrying the heaviest traffic, though still serviceable, show signs of fatigue as indicated by longitudinal, diagonal, and transverse cracks, also a continued depression or wide shallow rut near the edge of the pavement, caused by concentrated traffic

A thickened edge of bituminous concrete would probably be advantageous

Greater edge stability of this type of pavement has been secured by making the base course wider than the top course This has been done on a large contract in California, in Massachusetts, and in other States

In Michigan asphaltic concrete on gravel base is being built under careful inspection, workmanship, and selection of materials

They are using a base course extending 6 inches beyond each edge of the surface course, but without the thickened edge

An extensive test on 12 different types of asphaltic concrete and rock asphalt surfaces on gravel will be conducted in Louisiana Each test section will be 2,500 feet long This test will be watched with much interest and it is fully expected that definite conclusions can be made from the observations and results

The investigation of low-cost improved roads has not progressed so far that conclusions can be drawn at this time between the relative merits of bituminous surfaces on gravel and on stone bases

Some localities are getting good service with rock asphalts on gravel and stone base and at a reasonable cost

BITUMINOUS MACADAM

It is very evident from inspections in New England that this type of surfacing cannot be overlooked

We must recognize that with good materials and fulfillment of specifications that bituminous macadam has and is still giving excellent service

Its cost is sometimes higher in parts of New England than bituminous concrete, due to the fact that only the best trap rock is accepted Results, however, seem to justify this, as we find many miles of bituminous macadam carrying heavy traffic with no more than a normal amount of maintenance cost

The investigation as conducted so far makes evident the possibilities of classifying between limits the many types, by cost, traffic capacities, soil and climatic conditions, as well as drawing other useful conclusions which will assist the engineer, the producer of materials and equipment, and the contractor in selecting, building, and maintaining low-cost improved roads