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NATIVE ROAD MATERIALS and HIGHWAY MAINTENANCE

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NATIVE ROAD MATERIAL AND HIGHWAY MAINTENANCE

INTRODUCTION

Petroleum products in the form of road oils and asphalts have a distinct place in economic highway maintenance. This report is devoted to a discussion of the various methods of application and utilization of these materials in current highway practice.

Oklahoma, holding first rank among all states of the Union in the production of petroleum and allied products, should be exemplary in the commercialization of this resource. Road builders may well consider the possible economies to be effected through a larger use of road oils and asphalt in the maintenance and reconstruction of many of our highways.

The purpose of this report is to direct attention to the possibilities of extensive secondary road improvement at moderate cost by the utilization of native materials. Only general fundamental principles and representative methods from current practice are herein set forth. Extensive summarization, experimentation and research, in the matter of moderate and low cost road surfacings are being carried on by the U. S. Bureau of Public Roads in conjunction with several state highway departments. Valuable conclusions therefrom should be forthcoming at an early date.

HISTORY

We find reference to the use of asphalt as a road surfacing material as early as the reign of Nebuchadnezzar in the seventh century B. C.[1] Certain streets of Babylon are reputed to have been paved with "asphalt and burnt brick", and also with asphalt blocks. Evidently the asphalt was secured from springs and lake deposits in the Euphrates Valley where it is to be found at present.

The remains of an elaborate system of highways constructed by the Incas in Peru indicate a rather extensive use of asphalt as a road pavement material.

Petroleum is reported by Herodotus to have been found at Kirab, Persia, in the fifth century B. C. Historians and scientific writers make reference to the discovery and various uses of petroleum and asphalt during the middle ages. Asphalt springs were discovered in Cuba early in the 16th century and "Pitch Lake" on the island of Trinidad was discovered by Sir Walter Raleigh in the latter part of the sixteenth century.

1 Abraham, Herbert, Asphalts and allied substances, D. Van Nostrand Co., New York.

Abraham states that the discovery of bituminous matter in Connecticut about 1842 was the first such discovery in the United States. The following year reports were made of similar material occurring in New York, and twenty years later discoveries in West Virginia were reported. In later years native asphalts have been found in the following states, in fairly pure form; California, Kentucky, Oklahoma, Oregon, and Utah.

The use of asphalts in the surfacing of roads and streets, which evidently was considerably practiced by the ancients, completely lapsed during the dark ages. Indeed highway construction and maintenance in any and all forms stopped during this period, marking feudal ascendency and dominance, in which some of the highways were wilfully mutilated and destroyed as protective measures against onslaught of warring and marauding bands.

With the revival of road building activity in France late in the eighteenth century the exploitation of the asphalt deposits at Seyssel on the Rhone, France, was attempted. The first venture failed but was taken over by new management in 1802, under which was marketed a product known as "Rock Asphalt Mastic." This product was used as bridge floor surfacing and for sidewalks. Some thirty years later this mastic was used for surfacing foot paths in England.

A short experimental section of rock asphalt paving was laid in Paris, in 1854. Four years later Palais Royal in Paris was paved with a 6 inch concrete base surfaced with 2 inches of mastic from Val de Travers mine. This is considered the initial construction of modern sheet asphalt pavement. A pavement of like material was laid in London in 1869. Union Square, New York City, was paved with Val de Travers rock asphalt in 1872 and is said to be "the first pavement of any consequence in the United States."[2]

Importation of this rock asphalt mastic from Europe proved rather expensive, yet these initial pavements augured well for the material as a street surfacing medium. Experimentation in the use of native asphalts mixed with local aggregates was begun. In 1776 Trinidad asphalt, with local aggregates, was used in paving Pennsylvania Avenue, Washington, D. C. About five years later asphalt from Bermudez, Venezuela, was introduced in the U. S. for the same purpose. It was found necessary to subject these native asphalts to certain refining processes and to "flux" them with petroleum residual oils in order to produce satisfactory paving materials.

The next major factor affecting the asphalt paving industry was the introduction of asphalts refined from petroleum. Mr. Law[3] writes;—

2 Abraham, Herbert, op. cit., p. 17.
3 Law, LeRoy M., The merits of refined asphalt roads: Better roads and Streets, vol. 6, no. 10, 1916.

> Petroleum doubtless entered the paving industry as a "flux", or softening agency, for the solid native bitumens which were too hard to be used for paving purposes in the condition which they naturally occur. These fluxes were not straight mineral oils but the residues or byproducts of oil distillations, * * * * that they were actually refuse products, with little or no care in regard to their quality, is shown by the fact that the oils were frequently subjected to so-called "cracking" processes for an increase over the normal yield of burning oils, etc., this to the detriment and injury of the residuum. * * *"

After some discussion of the evolution of asphalts from petroleum Mr. Law states,

> This brings us up to about the year 1900, previous to which the oil asphalts were truly artificial materials. They were prepared at best from oils of low asphaltic contents and their solidity and consistency were proportional to the artificial means employed in their manufacture. * * * *.
>
> Asphalts from Texas and California petroleum next deserve our attention, and it is interesting to note that, while they differ widely in characteristics, both are still in use today, though doubtless in modified form * * *.
>
> The ideal raw material for the production of petroleum asphalts, however, became available about five years ago with the entry of Mexican petroleum into the field of raw materials. * * * In 1910, therefore, the opening of several large wells on the east coast of Mexico began a new epoch in the asphalt business, for, with the large supply and the reasonable rates of water transportation prevailing at the time, it soon became possible to place on the market excellent paving and road building materials at prices which have made possible our great highway developments of today * * *.

Native asphalt deposits in Oklahoma have not proved to be of commercial consequence. Rock asphalts, however, have been commercially exploited to considerable extent in some sections of the state.[4]

Oklahoma oils are of mixed base grading. In some sections the base is predominantly paraffin while in other localities asphaltic.

Some years ago, Oklahoma refining companies began the production of large quantities of "road oil" which was shipped to various sections of the country, but strange to repeat, little of this product has been used at home.

The refining of petroleum asphalts, for hard paving purposes, from Oklahoma oils has not been attempted on a commercial scale. Oklahoma may not hope to compete in the field of paving asphalt production. First class road oils however, may be produced and it is believed, should be produced and a considerable quantity of the product utilized in the improvement of our secondary and feeder highways.

4 Hutchinson, L. L., Asphalt and petroleum in Oklahoma: Okla. Geol. Survey, Bull. No. 2, 1911.
Snider, L. C., Preliminary report on the road materials and road conditions of Oklahoma: Okla. Geol. Survey Bull. No. 8, 1911.

SELECTION AND PREPARATION OF ROADS FOR OILING

Oil treatment of road surfaces is essentially a maintenance operation. In fact much heavy surfacing and re-surfacing work is done by the maintenance departments of street and highway organizations.

If satisfactory results are to be expected from the application of oils to earth roads discretion must be exercised in the selection and preparation of the roads to be so treated.

EARTH ROADS

Soil Characteristics

The earth composing the road surface should contain an appreciable percentage of sand or fine gravel. Heavy clays and gumbo, being of high capillarity, are subject to excessive swelling on becoming saturated and of course a corresponding shrinkage is consequent on drying out, hence these soils give an unstable surface and subgrade which never have given satisfactory results when treated with oil. Such soils may be stabilized with an admixture of sand gravel or crushed stone and oiled to advantage. Lime is being used as a stabilizing admixture for heavy soils with varying degrees of success. This treatment has as yet scarcely emerged from the experimental stage and an instance of oiling earth roads so treated has not come to the author's attention. It is reasonable to expect satisfactory results from the oiling of such roads as the addition of lime to heavy earths is said to greatly reduce their shrinkage factor and produce a sort of granular texture in the admixed earth.[5]

Deep sandy roads have been treated successfully by the application of considerable quantities of heavy asphaltic oils, virtually producing a "sand-oil" pavement of 4 in. to 8 in. in thickness.

All earth roads approximating the consistency of metal surfaced roads of the traffic-bound type may be treated with oils economically in most instances. The results to be expected depend on several factors which are, in large degree, under control of the road officials. Proper grading of the surface metal is a prime requisite. In the progress report on investigations now being carried on jointly by the U. S. Bureau of Public Roads and the California Highway Commission[6] we read;

> In general, it has been found that at least 15 per cent of the material passing one-half inch circular opening should pass the 100-mesh sieve, and 8 to 10 per cent should be removed in the washing test to establish satisfactory cementing property. A smaller proportion of fines, except in very soft rock, will usually result in a loose, uncompacted surface.

5 McCaustland, E. J., Dirt roads improved by lime mixed with surface soil: Eng. News. Rec. vol. 94, no. 26,______.
Wood, H. W. Jr., Use of lime in earth roads, Munic, and Co. Eng. vol. 71, No. 2,______.

6 McKesson, C. L. and Frickstad, W. N., Light asphalt oil road surfaces: Pub. Roads, vol. 8, No. 7, ______.

Soil analyses of oiled earth roads on Campus of Oklahoma University
(Mean depth of oiled surface,—2 inches)

SAMPLE NO.	RETAINED ON 10-MESH[3] SCREEN	PERCENTAGES OF MATERIAL PASSING 10-MESH SIEVE										MOIST. EQUIV.[1]	VOLUMETRIC SHRINKAGE	CAPILLARY MOISTURE	PER CENT BITUMEN[2]
		10	20	30	40	50	80	100	200	SILT	CLAY				
1	0.2	100.0	98.0	94.6	91.6	86.5	76.5	70.4	58.4	31.9	26.5	22.2	7.5	37.8	11.50
2	1.2	100.0	99.0	97.2	92.3	86.8	76.0	75.4	60.2	35.8	21.4	22.5	5.5	32.0	
3	6.0	100.0	94.5	89.8	86.0	80.7	69.4	64.5	52.3			22.0		2.8[4]	
4	1.9	100.0	98.5	97.6	96.0	92.3	80.5	80.0	62.8			24.3		38.2	
5	0.1	100.0	99.9	99.8	99.2	97.8	80.0	75.8	53.8			27.4		36.5	
6	0.4	100.0	99.5	96.5	89.3	81.5	66.2	63.2	46.0			22.1		36.4	
7	0.1	100.0	99.6	99.5	97.6	95.2	76.5	74.9	57.4			23.0		23.6	

1 Field method.
2 Reclaimed by Dulin Centrifugal Extractor.
3 All material retained on 10-mesh sieve was foreign, as cinders, crushed stone, and gravel spilled from construction material wagons.
4 Sample No. 3 was very resistive to water. Greatly excessive mixing was necessary to secure saturation in moisture equivalent test. Cinders, ash, and apparently some grease or oil were present.

Location of Samples

1. Asp Avenue west of Engineering building.
2. West of Engineering Building.
3. Asp Ave. west of Engineering Laboratories.
4. Asp Ave. east of Liberal Arts building.
5. Campus drive south of Administration building.
6. South of Administration building.
7. South of Field House.

The following analyses are of materials samples from road surfaces which have been successfully treated with oil.

Sand-asphalt pavement, New Bern-Wilmington road, North Carolina.[7]

	Per cent
Passing No. 10 sieve	100.0
" " 40 "	97.7
" " 60 "	68.2
" " 80 "	53.5
" " 100 "	24.3
" " 150 "	6.8
" " 200 "	4.7

Oil-treated sand road, San Bernardino County, California.[8]

	Per cent
Passing No. 10 sieve	100.0
" " 20 "	71.6
" " 30 "	42.5
" " 40 "	37.0
" " 50 "	31.6
" " 100 "	22.4
" " 200 "	11.0
Bituminous material	8.1

Oiled-sand surface, Las Vegas-Beatty road, Nevada Feder-Aid Project 46.[9]

	Per cent
Passing No. 10 sieve	87.3 to 98.3
" " 14 "	86.2 to 97.9
" " 20 "	85.1 to 97.5
" " 30 "	83.4 to 94.4
" " 40 "	75.4 to 84.3
" " 50 "	63.8 to 67.9
" " 80 "	42.2 to 43.7
" " 100 "	25.0 to 25.4
" " 200 "	6.7 to 7.8
Oil Content	6.73 to 7.27

Oil-treated crushed-rock road surface, Columbia River Highway, Oregon.[10]

Passing ½ in. screen	100.0	per cent
" No. 3 sieve	90.0	" "
" " 10 "	60.0	" "
" " 20 "	42.0	" "
" " 30 "	35.0	" "
" " 50 "	31.0	" "
" " 100 "	27.0	" "
" " 200 "	20.0	" "
Removed by elutriation	18.0	" "
Cementing value lbs. per sq. in.	68.0	" "
Lineal Shrinkage	1.7	" "
Field Moisture equivalent	17.6	" "
Oil (based on material passing No. 10 sieve)	3.2 to 6.7	" "

7 Weathers, H. C., Sand asphalt pavement: Eng. and Contr. (Roads and Streets), vol. 63, No. 1, ____.
8 McKesson, C. L., op. cit., p. 156.
9 McKesson, C. L. op. cit., p. 157.
10 McKesson, C. L., op. cit., p. 133.

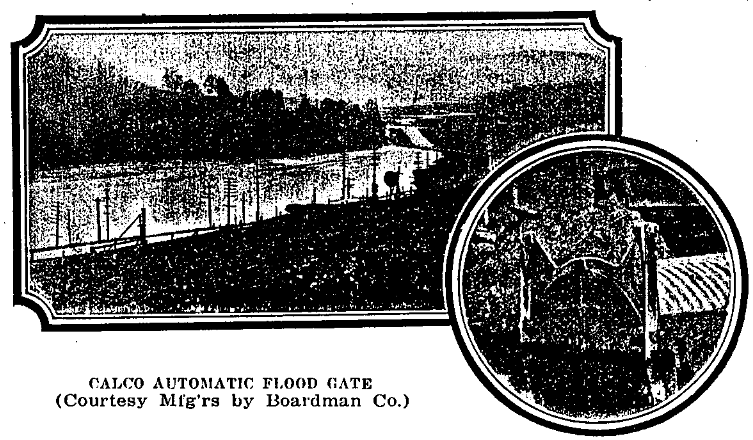
Drainage

Efficient and sufficient provision for both surface and subgrade drainage is axiomatic in roadway construction. If this element is neglected or underestimated during construction it will be maintenance economy to provide supplemental drainage accommodation.

The corrugated culvert, if properly installed, makes a very durable and satisfactory structure and has a definite place in maintenance work as well as in original construction. It is easily and quickly placed by ordinary road labor and is readily adaptable to the relief of numerous vexatious drainage problems.

Side ditches are to be kept open and of sufficient depth and width to care for the water reaching them during an ordinary heavy rainfall. Across river bottoms, satisfactory outlet for the side drains is frequently difficult to secure, especially where the stream bed is relatively high as compared to the flood plain. Cutting the ditches directly into the stream would result in reversal of flow with consequent damage to adjacent lands during flood stages of the river. Installation of a culvert with flap valve or hinged gate will frequently give satisfactory results or as nearly satisfactory as may be obtained. Plate I shows a corrugated culvert type. The same results could be secured by attaching the gate to a concrete culvert. A suitable gate with collar can be purchased on the market.

PLATE I



CALCO AUTOMATIC FLOOD GATE
(Courtesy Mfg'rs by Boardman Co.)

Frequently where the highway skirts a sandy slope the side ditches are constantly being filled with sand and silt. Possibly the simplest and most effective remedy would be to place extra culverts at points where good outlet may be secured and lead the water to these culverts through short surface ditches of sufficient fall to prevent deposition of the sand. In other instances long surface ditches or construction of sand traps where the material could be conveniently disposed of might be the best solution.

An injurious practice, which recently has sprung up in Oklahoma, is that of using road ditches as termini or outfalls for farm terrace waters. Terracing is not to be condemned or discouraged; to the contrary farmers are to be encouraged and assisted in any way reasonably possible, by highway officials and employees, in their efforts to control surface waters to the common good. However, good highways and farm drainage works cannot be economically maintained on a 30 to 50 ft. right of way.

SEEP HOLES

Seep Holes are not infrequently a vexing problem in hill and mountain sections. In cases where they are in evidence at the time of construction, proper drainage should be provided at that time. Because many of these seeps or springs are "alive" only during, and a short time subsequent to, exceptionally wet weather they may not be discernible at the time of construction. Again where heavy cuts are made during construction water-bearing strata may be exposed which later will cause a seep to develop. The maintenance force is thus confronted with remedying these nuisances.

Frequently relief may be gained by placing a small tile drain at the margin of the roadway. It may be necessary to place a branch tile across the roadway through the seep. In certain cases the geologic formation may be such that an impervious stratum of small thickness underlies the subgrade with a porous stratum next below. The simplest solution in such case might be to puncture the impervious stratum and back fill with porous material, allowing the water to escape into the underlying porous stratum. "Blind drains," constructed by digging V-shaped ditches from the mud hole to an outlet and back filling with crushed rock gravel or cinders may be found economical.

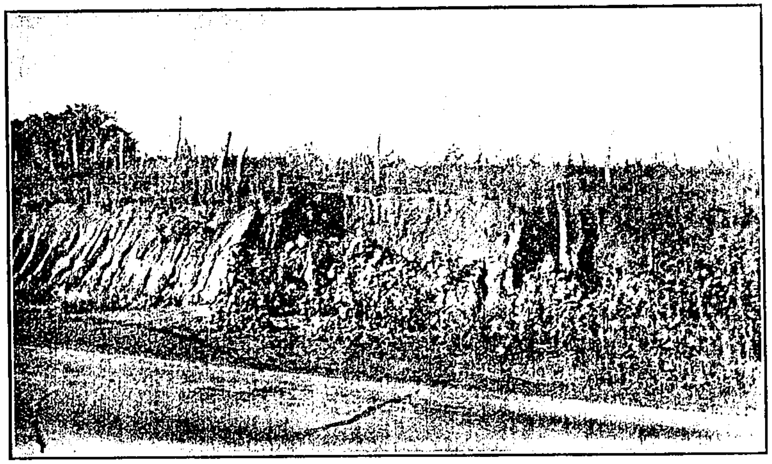
SURFACE DITCHES

Surface ditches as used in highway and railway phraseology, refer to ditches which are constructed for the purpose of intercepting and diverting surface waters before they reach the side ditches.

In some instances surface ditches might be constructed in conjunction with farm terraces for the purpose of alleviating mud-holes or mud-hole possibilities. As stated before, the author believes that it behooves the highway officials and employees to cooperate, in every reasonable way, to the common good, with the owners of abutting farms in the control of surface waters as well as stream waters.

Surface ditches in their most common usage are placed just back of the brow of deep cuts, skirting some considerable slope, for the purpose of protecting the walls of the cuts from erosion. These should be provided for at the time of construction but often are not, with the result that cut walls are eroded and ditches filled. The removal of this dirt is expensive if the cut be a long one. It will be good maintenance to construct the surface ditch. Plate II shows the result of omitting the surface ditch on a main highway in Oklahoma constructed two years ago.

PLATE II



WALLS OF CUT, IN STAGE OF EROSION BY SURFACE WATERS

Here again it may be necessary to seek the adjacent land owner's co-operation in order to lead the water from the crest of the hill to an outlet, on such grade that the ditch will not erode.

EROSION OF SIDE DITCHES

Erosion of side ditches, unless properly provided against, becomes a menace to both the roadway and abutting property on steep slopes.

If the roadway is paved the best method is to pave the side ditches either with concrete or hand placed rip-rap. Loose stones thrown in the side ditches more often aggravate rather than alleviate the scouring. Many engineers advocate a widening of the pavement and construction of curb and gutter on a cross section similar to that of city pavements.

An alternate method of protection is the construction of masonry or concrete "drops" in the side ditches at intervals of such

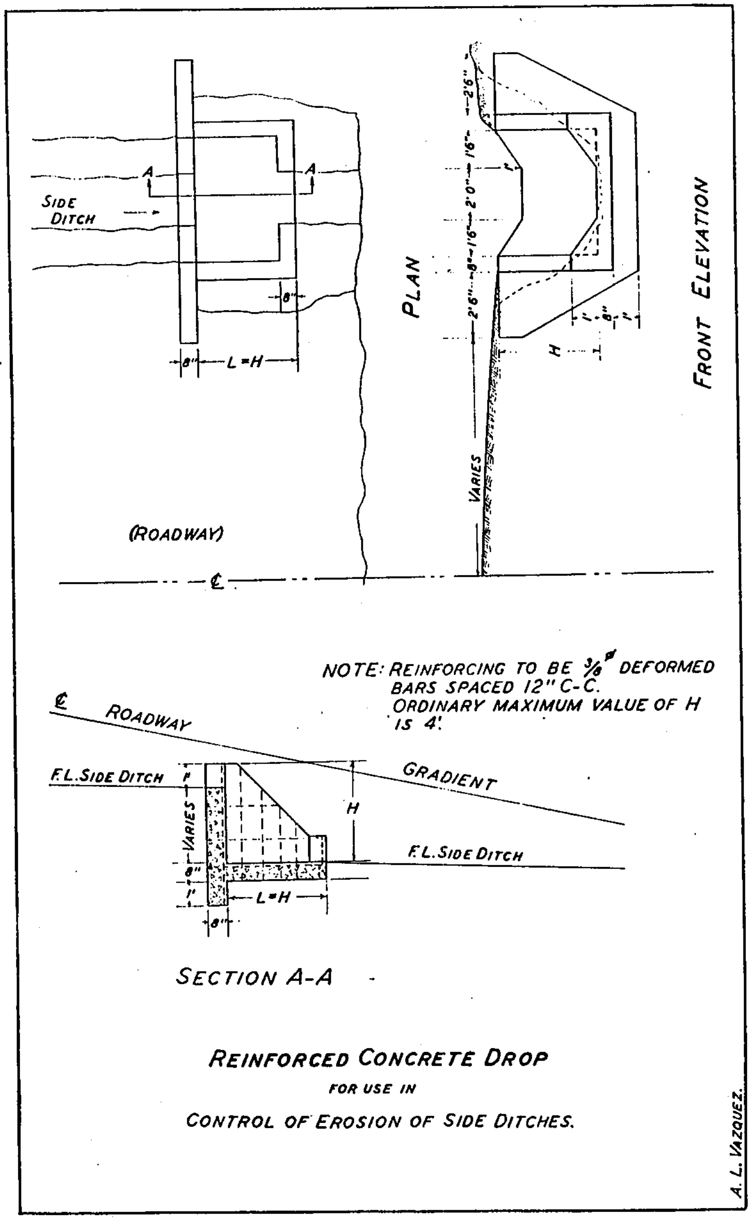


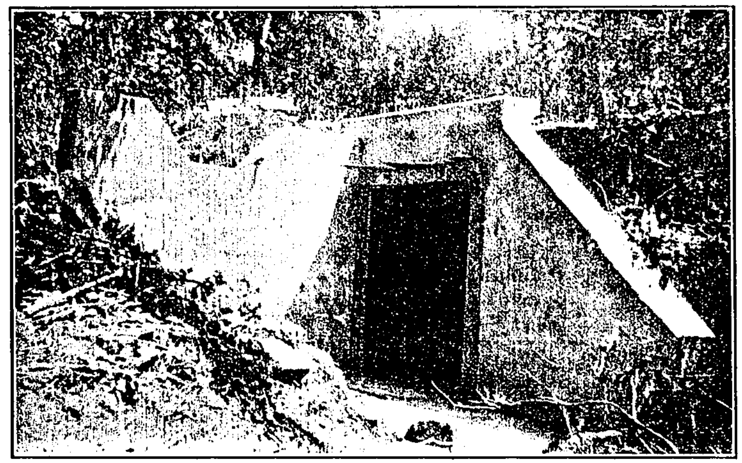
Figure 1

length that the depth and grade of the ditch will be satisfactorily maintained. The maximum depth of ditch should not exceed three and one-half feet while the minimum should not be less than nine inches. The maximum permissible grade will depend on the type of soil and amount of water to be provided for; it will ordinarily range between 0.5 per cent and 3.0 per cent.

Figure 1 shows the details of a typical reinforced concrete drop. Drops of similar type might be constructed of creosoted timber and plank on township roads.

Frequently the entrance of side ditches into the stream or channel outlet develops scouring and caving of banks that are troublesome. The writer has extended the wing walls of culverts, at a slight angle or parallel to the axis of culvert, to act as a check and drop for ditch water. Plate III illustrates such construction, which has proved satisfactory in every instance. This can be most economically provided at the time of construction, but has been placed in several instances as a maintenance measure.

PLATE III



WING OF CULVERT EXTENDED TO SERVE AS CHECK AGAINST SIDE DITCH EROSION

Sometimes recession of a waterfall below a culvert installation will erode a channel bed up to the culvert outlet making necessary the construction of a drop to protect the culvert and embankment. Plate IV illustrates an arrangement provided by the writer to take care of one such condition. Note that the side ditch water is conducted to the drop through a short 2 by 2 feet concrete culvert and flume. A splash box $2\frac{1}{2}$ feet in depth was provided to absorb the shock of the falling water.

Another instance not uncommon is the recession of a fall or drop in a surface water draw or swail. Plate V is a photograph of such a recession which has cut to the shoulder of the traveled way. The posts, wire, and litter in the left foreground are the remains of an unsuccessful attempt to check the erosion by use of a brush and straw barrier. In some instances this method will give temporary relief and if the major portion of the water may be detoured to another course without danger of creating the same

PLATE IV

DROP AND SIDE DITCH TERMINUS AT CULVERT OUTFALL

condition there, such may be the simplest solution. Otherwise the only permanent relief is the construction of either a culvert or paved invert and drop. If the water may be accommodated with a culvert, without excessive cost, it is preferable to the paved invert. In case a large amount of water is to be controlled intermittently, pursuant to heavy storms on the contributing drainage shed, a paved invert of proper design will be the economic structure.

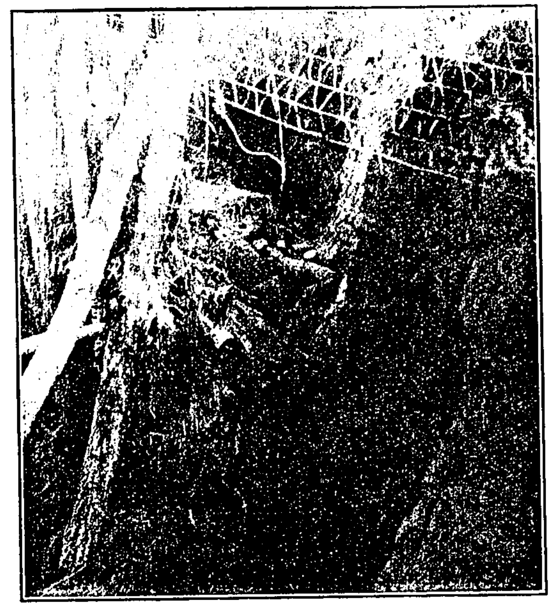
Erosion of shoulders and slopes on high embankments is rather difficult to combat.

Setting the shoulders and slopes to a turf-producing grass is probably the simplest preventive measure. In Oklahoma bermuda grass is used extensively for this purpose, as it is fairly resistant

to long dry spells and moderately cold weather, spreads rapidly, and forms a very tough, resistant sod. Other grasses which have been used with success in various sections are blue grass, timothy, brome, alfalfa, horsetail ferns and bunch grass, fescue grasses, and sweet clover.

In instances where a considerable amount of water passes down the hill and over the slopes of the embankment, as in the case where earth, gravel, and macadam roads are not kept smoothly crowned, it will doubtless prove economical to form gutters on the shoulders and carry the water down the embankment in paved spillways.

PLATE V



AN ATTEMPT TO CHECK WATER-FALL RECESSION IN SURFACE-WATER SWAIL

Where curbs and gutters are provided on a paved slope the water is disposed of through inlets into a culvert or into a paved spillway. This ordinarily is provided for during construction, but omissions occasionally force provision of relief measures by the maintenance crew.

JETTIES AND RIP-RAP

Jetties and rip-rap frequently may be employed to advantage, in the proximity of bridges, to guard against erosion of bridge abutments and approaches when rivers are at flood stage. Jetties are constructed of several different kinds of material and many designs for a like material may be found. Common types are, concrete and masonry walls, rock filled timber cribs, log cribbing, loose rock dumped as a barrier, tree and brush mats weighted with rock, patented steel jetties, "home made" flexible improvisions of angle iron and woven wire fencing, barbed wire, cable, and so on. This subject scarcely warrants general discussion as it has almost universal application, in one form or another, in river bank protection. Economy and efficiency in the use of jetties in the control of large flood flows depends almost entirely on the experience and judgment of the engineers in charge. Much money may be wasted in attempting expensive jetty construction without proper planning and coordination which are really outgrowths of experience and observation.[11]

Conditions of minor erosion control may be effectively and economically handled by anyone conversant with the fundamental laws of hydraulics and who will study and analyze his problem. Small jetties or riprap may be used to advantage. Usually hand-placed is preferable to loose.

The subject of drainage and its companion, erosion, have been discussed at length because of their fundamental importance in good road maintenance and the frequent lack of attention to these details by the smaller administrative road units.

That it is useless and waste of money to oil mudholes has been often written and spoken and is here repeated with emphasis. Unless a road can be and will be properly drained it should not be selected for oiling.

Traffic

The amount and type of traffic is an important factor to be considered in selecting earth roads to be oiled. Only earth roads which will class as secondary or community roads should be included in a program for permanent oil treatment. Several instances are on record where temporary oil treatment has been economically applied to heavy traffic roads pending hard-surfacing, yet it is believed the real economy to be expected from oiling rests with the class of roads carrying traffic up to 500 vehicles per day with a small percentage of motor trucks.

Having selected the roads to be oiled proper provision should be made for drainage, as has been suggested. The surface should be brought to permanent gradient, if possible, so that the road bed and surface, which will improve with age, need not be torn up for grade reduction at a later date.

In the light of observations and investigations of subgrade soils it would appear to be good practice to treat heavy soils, hav-

11 Chamberlain, John R., Retards in stream control: Public Roads, vol 7, No. 3, ———

ing a clay content of over 30 per cent, with sand, gravel, crushed stone or possibly with lime to a depth of 3 to 8 inches, regardless of whether the road is to be permanently oiled or is to be paved within two or more years.

The amount of granular admixture to be applied should be such as would reduce the clay content of the mixed surface below 30 per cent and preferably below 20 per cent.

The roadway should be allowed to compact under traffic sufficiently that practically no settlement will take place after treatment. To insure uniform compaction and even surface, dragging and possibly occasional blading should be frequent during the period between final shaping and application of the oil.

GRAVEL ROADS

The gravel road surface should be brought to uniform cross section and gradient contour. Modern practice dictates a medium or low crown in most instances for the reason that a better distribution of traffic over the metal surface will result thereby. A crown of 3/8- to 1/2-inch per foot width is common practice.

There may or may not be a covering of loose material on the surface. The particular method of application of the oil will be governed somewhat by this condition.

CRUSHED STONE ROADS

Water-bound Macadam and crushed stone roads may be economically treated with bituminous materials. The surface should be put to a true, uniform gradient with about the same crown as given for gravel roads. Bituminous cold patch material might be used to advantage in filling deep holes in the surface. If the surface is extremely rough it should be scarified to the depth of the majority of holes and ruts, reshaped and compacted, either by roller or by traffic. During the period of compaction, if by traffic, close attention should be given to secure a uniformly smooth surface.

BITUMINOUS PAVEMENTS

Bituminous pavements of artificial mixtures or of natural rock asphalt occasionally become brittle and "lifeless." These have been successfully treated with asphaltic oils or tar. All holes in the pavement should be patched before treatment.

ROAD OILS AND METHODS OF APPLICATION

Only asphaltic or mixed base oils are suitable for road treatment purposes. To obtain best results the percentage and consistency of the asphaltic content should vary with the kind of road materials, type of construction and somewhat with temperature and climatic conditions.

Oils marketed as "fuel oils," undoubtedly, have been used more frequently than have specified "road oils" in surface treatments to date. The reasons for this are; first, that "fuel oil" is usually cheaper than "road oil" due to more exacting specification in the preparation of the latter; second, "fuel oil" being a residual oil of no definite specification is more easily obtainable; third, "fuel oil" is more easily applied than is "road oil" as it can frequently be applied without heating and is more easily applied to mixed with the road surface without heating.

From the standpoint of ultimate economy and service undoubtedly "road oils", prepared according to definite specification,[12] will prove superior to "fuel oils" in most instances.

Oiling operations should be carried on in warm weather and better results will be obtained if the surface be fairly moist than if it be bone dry. Also the treatment of any given section should be timed so as to cause least inconvenience to traffic in case the section may not conveniently be closed to traffic during oiling operations. The methods and procedure of treatment will be largely determined from traffic considerations. Oiled roads have lost favor with the traveling public largely because of the inconvenience and nuisance from splattering oil at the time of treatment. This nuisance can and should be almost if not entirely eliminated by using proper methods and discretion in treatment operations. Motor speeds should be kept below 8 miles per hour until the oils have penetrated the surface.

Various methods have been and are being used in applying oil to and mixing it with road surfaces. Quoting one writer;[13]

> The earliest oil treatment in California consisted of the application of crude asphaltic oil, approximately a gallon per square yard to the surface of a dirt road. The oil was allowed to penetrate at will or dirt was thrown on top. This was virtually a surface treatment and generally proved inadequate except for very light traffic or where the subgrade was unusually firm. The next development was the reworking of the thin mat, adding more oil and stirring to a greater depth. This was the crude beginning of the mixing treatment. The process was repeated in later years until some of the roads first treated had a surface of 6 in. or more in thickness * * *.
>
> The success or failure of these oiled earth roads depends largely upon the character of the material. Sandy, gravelly, or even silty soils have produced serviceable roads in most instances where properly treated and maintained. Heavy clays or alkali soils have been similarly treated but the results have been almost universally unsatisfactory * * *.

Within the past two years Minnesota has been experimenting in the oil treatment of heavy gumbo soils carrying a floating gravel surface of 350 to 450 cubic yards of gravel per mile. This is a

12 McKessan, C. L., and Frickstad, W. N., op. cit., p. 154.
13 Idem.

rather extraordinary treatment, being essentially a method of subgrade insulation against water and gravel penetration.

The prevalent method of treatment today is the mixing method, variously executed, on all types of road surfaces having a loose or floating surface.

EARTH ROADS

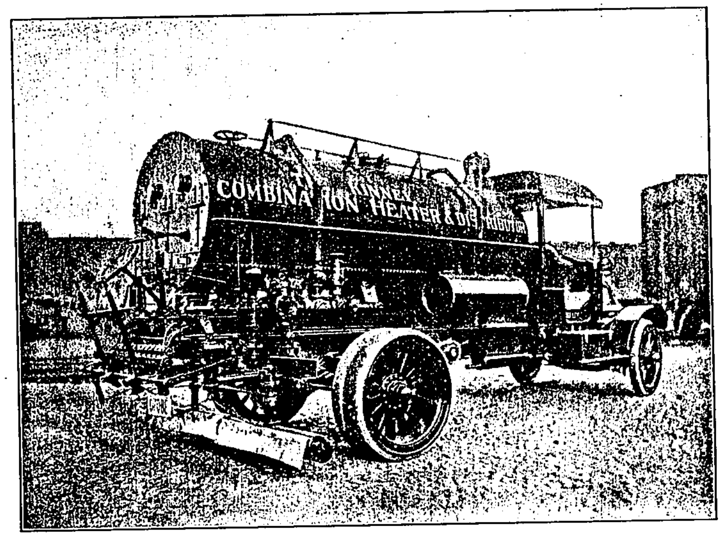
Earth roads having a clay content ample for binder and not of sufficient amount to cause instability, ranging between 15 and 30 per cent, an oiled surfacing of 1 to 4 inches, the depth depending mainly on traffic conditions, should give good service.

It is difficult to arrive at the proper amount of oil to use on earth roads for two reasons. First, the grading and clay and silt content of the road surface is not constant for any considerable section of road; second, it is nearly impossible to secure a depth of mixing sufficiently constant to maintain a true bituminous percentage of mixture. Experienced oiling foremen, however, will secure surprisingly satisfactory results by modifying the rate of application of oil based on their judgement of material being treated.

The following formula has been proposed for estimating the amount of oil required:

$$P=0.015\ a+0.03 \times b+0.17\ c$$

PLATE VI



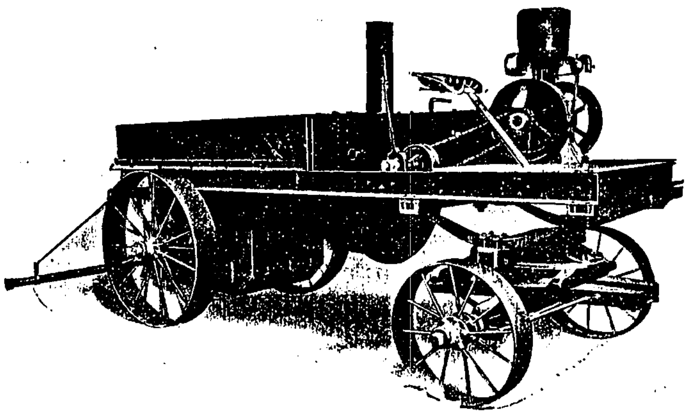
INTEGRAL-POWER-DRIVEN HEATER-DISTRIBUTOR FOR BITUMINOUS ROAD MATERIALS
(COURTESY KINNEY MFG. CO.)

in which P is the percentage of oil required, a is the percentage of metal retained on a 10-mesh sieve, b is the percentage of metal passing the 10-mesh and retained on the 200-mesh sieve, and c is the percentage passing the 200-mesh sieve.[12]

A stain test, comparable to the pat test for sheet asphalt mixtures, has also been proposed.

In shallow treatment ¼ to ½ gallon per square yard is a common application and is applied with either a gravity or pressure distributor of a type similar to those shown in Plates VI and VII.

PLATE VII



HORSE-DRAWN HEATER-DISTRIBUTOR FOR BITUMINOUS ROAD MATERIALS; MAY BE TRAILED BY TRUCK OR TRACTOR ALSO (COURTESY KINNEY MFG. CO.)

If dust has accumulated to any appreciable degree on the road surface, treatment should be delayed until the surface has been moistened by rain to the depth of the firm material. As soon as the surface is sufficiently dry it should be dragged or bladed if necessary; in the latter instance using care not to cut deeply, thereby causing an oversupply of loose material on the surface. The oil should be applied immediately and the surface harrowed and dragged. The dragging should be continued daily until the surface becomes compacted. In case lean spots show up additional local applications of oil should be made. Rich spots should be treated with sand or gravel.

In case the oiling operation has been unavoidably delayed until the dry season when no rain may be anticipated soon, the dust should be pushed to the side of the roadway, the oil applied and the dust re-spread over the road way as a covering. This procedure will require 50 to 75 per cent more oil than the preceding

method for an equally satisfactory job. Dust has not proved as satisfactory as coarse sand or gravel for covering of the oiled surface, yet it has been used with reasonably good results in several instances.

Sandy surfaces will require larger quantities of oil and deeper treatment than above set forth.

Oklahoma has not, to date, utilized oil, to any great extent, in earth road treatment. This would appear to be an inconsistency of policy in a state of first rank in oil production in the United States and in view of the fact that A-1 road oils may be refined from Oklahoma crude products.

I am advised that in years past certain sections of earth and gravel roads in Oklahoma were treated with oil. The treatment was abandoned because it proved too expensive. Further inquiry did not reveal full details regarding the operations but this significant fact was revealed that *constant and continuous maintenance* was not provided which without doubt was responsible for expensive failure instead of an economic success.

The State Highway Department recently began to use "tank bottoms" in treatment of certain sections of State Roads in Seminole County. This treatment has not been in use long enough to yield definite conclusions.

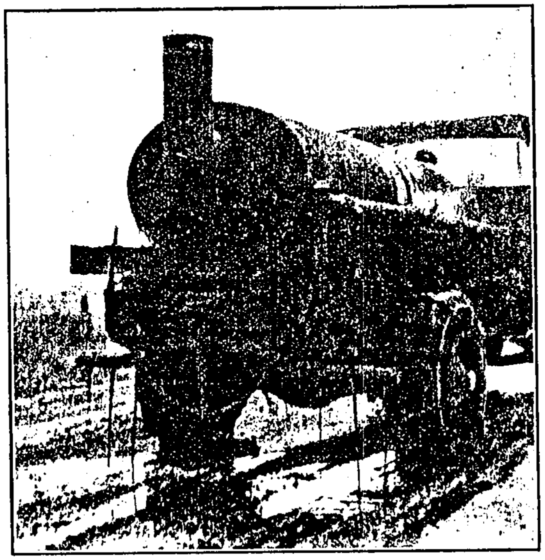
It has been demonstrated in Tulsa County that oiling of earth roads is a practical maintenance measure. During the past biennium approximately 80 miles of earth roads have been oiled to a width of 24 feet and considerable additional mileage is being shaped preparatory to oiling. After being brought to a good grade and cross section the roads are allowed to compact under traffic until reasonably firm and uniform of surface. In most instances the dust is not removed prior to oiling.

The oil used is a road oil having viscosity of approximately 86 (210 Sabolt Universal) manufactured from Oklahoma crude. Application to the road surface is made by a pressure distributor of a type similar to that shown in Plate I. Two successive and approximately equal applications are made at intervals varying from one to ten days. The surface is harrowed and dragged after each application. Sanding of the surface is not practiced. The total amount of oil applied averages about 12,000 gallons per mile of 24 feet width, at an average cost of approximately $500.

It has been repeated that excessively sandy roads such as could not be traversed by the distributor under its own power have been treated by the pouring can method until the distributor could be driven over them, after which oil was applied periodically until a fairly stable surface resulted. The exact amount of oil applied per square yard could not be determined.

The writer recently rode over several miles of these oiled earth roads with Mr. Steiger, maintenance superintendent, who reported that considerable of the mileage has not been oiled for a period of 18 months and had received no maintenance. Considering the heavy traffic service reported for this road and the excessive and extended wet weather of the preceding year, the roads were in remarkably good condition. As to the "all-weather" claims for the oiled road Mr. Steiger said that on occasion he had worried for hours through the mud of ordinary earth roads, being forced to drive in "low" and "intermediate" most of the time, and that, when coming upon one of these oiled roads, he went into "high" and travelled with ease. He believes such experiences will make "believers" of the most skeptical.

PLATE VIII



IMPROVISED DISTRIBUTOR APPLYING "TANK-BOTTOMS" TO EARTH ROAD SURFACE, OKMULGEE COUNTY, OKLA.

Okmulgee County, for the past two years, has been using "tank bottoms" or residue from oil storage tanks for treatment of earth roads with fair success. Approximately 25 miles have been thus treated. The roads are graded up in good shape and allowed to compact under traffic. Dust is not removed prior to oiling. The residue is secured by pumping directly from wooden or steel storage tanks or from on open slush pit. At the time of the writer's visit the material was being pumped from an open pit with a Blackmer

Rotary pump, mounted on the chasis of an old Dodge motor car and driven by the car motor and drive shaft. This "hook-up" gave easy and positive control of pumping operations. Mr. Hale, who rigged the equipment, said they had endeavored, at first, to use a duplex plunger pump driven by a small gasoline engine but trouble and expensive delay were experienced due to clogging of the pump.

The residue is of such consistency that it must be heated before it can be pumped and applied to the roadway. This was being accomplished by forcing steam jets from a small boiler into the slush in proximity to the pump intake pipe.

The material was being applied to the roadway through variously improvised nozzles attached to truck tanks. Plate VIII shows one of the trucks on the job. The impurities and foreign matter in the residue precluded the use of standard type distributors.

The residue is applied at the rate of approximately 10,000 gals. per mile on a width of 18 feet, at a cost ranging between $200 and $300. The surface is harrowed and bladed after the residue is applied.

This residue has been applied in large quantity to excessively sandy stretches of road and is said to produce a fairly stable surface.

While the roads treated with the tank residue do not present the quality evidenced by the treatment with higher grade road oils, a surface much superior to the untreated earth road is thus secured. It is a question, somewhat debatable at this time, whether or not the added expense of using the higher grade road oil will be evidenced in a proportionately more durable and serviceable road. Careful observation of road conditions and probable variation in vehicle operation costs and accurate detail records of maintenance costs will answer the question.

The University of Oklahoma began the oiling of certain campus drives and bordering streets in 1922. The soils in the surfaces treated range from clay to sandy loam, analyses of which will be found on page 9. The sections contemplated for treatment were shaped to a proper cross section and gradient and allowed to compact under traffic. During the interval of compaction the sections were frequently bladed to insure a uniform surface after settlement. The period selected for treatment operations being about mid-summer, traffic on the drives was at a minimum, also weather conditions were ideal for the work. No great quantity of dust had collected on the surfaces which were not swept prior to oiling.

The oil used was a heavy residue from the distillation of Oklahoma mixed base crude oil, having viscosity of 300 at 122° F. (Furol), specific gravity 15.5°C. (60°F) of 0.937 and the 100 penetration residue was 68-70 per cent.

The oil was received in a tank car and heated by direct steam. Application to the road surface was accomplished by gravity through an 8 ft. section of 4-inch gas pipe perforated with ⅛-inch holes attached to an ordinary truck tank. The amount of oil applied was 0.75 gallons per square yard in one application. The surface was harrowed and bladed after the application of the oil. The treated sections were blocked to traffic for 72 hours when no pooled oil or slush was in evidence.

This work was under direct supervision of Prof. Fred W. Padgett of the Chemical Engineering Department, who is now in the Petroleum Engineering Department.

The results of this initial oiling program were very satisfactory producing good serviceable drives throughout the following wet and cold seasons.

These roads were given a second treatment, using a lighter oil in the late autumn of 1923. The surfaces were reshaped by light blading and the oil applied hot in the amount of 0.5 gallon per square yard. The road was closed to traffic for 48 hours.

Due to cooler temperatures and wet weather before the surface had thoroughly cured, this second treatment was not as satisfactory as was the first. However, the drives gave good service throughout the following winter and spring.

In August, 1924, certain portions of these drives, on which the surface had "shoved" and corrugated somewhat, were plowed up, pulverized, harrowed, and reshaped together with the other sections which had not been plowed.

A light oil containing 40 to 60 per cent 100 penetration residue, was used at the rate of approximately one-half gallon per square yard, on the unbroken sections while from double to treble this amount was used on the scarified sections, which were thoroughly harrowed and then sanded and rolled with a 15 ton roller.

No subsequent treatments and very slight maintenance had been given these roads until the spring of 1927 when considerable patching was done with natural rock asphalt. It will be interesting to note the results of this method of patching. It is predicted that the patches will eventually develop into bumps due to their greater stability as compared to the original oiled earth surface.

Certain sections of the drives are again becoming rough due to corrugations and "shoving", although better than 50 per cent of the treated surface is in good shape after the lapse of three years since treatment.

Some samples were cut from the oiled surface of Asp avenue in front of the Engineering building, care being used to remove the sample without fracture, for the purpose of making a punching

shear test. The samples were carefully pared to a roughly circular form so as to be easily placed inside a collar 5½ inches in diameter where they reposed in inverted position on an annular ring having a concentric circular orifice 3 inches in diameter. Clean dry sand was compacted around the margin of the sample and a sufficient amount was spread on top to form an even bearing for the clamp ring and shear plug. The clamp ring had a 3 1/16 inch circular orifice for insertion of the shear plug and was screwed down snugly onto the sample. The shear plug was a cast iron slug 3 inches in diameter and 3 inches high, the entire apparatus being a copy of that described by J. T. L. McNew in his study of Texas limestone rock asphalt.[14]

The apparatus containing the sample was placed on the block of a testing machine and pressure applied, through low gear, until the beam dropped, the resulting pressure being recorded.

Data Obtained From Punching Shear Test.

TEST NO.	THICKNESS INCHES	TEMP. °F.	FAILURE LOAD LBS.
1a	1.5	65°	2,320
1b	2.0	65°	3,610
1c	0.9	68°	1,060
1d	0.9	68°	1,015

Note: The material for this test was taken from the same location as Sample No. 1 in the analysis on page 9.

The samples were then heated to a temperature of about 160 F. crushed but not pulverized so that the maximum lumps would pass a ¾-inch ring and new test specimens formed under a pressure of 3,000 lbs. per square inch. The data from these tests follow on page 28.

While a sufficient number of tests, on specimens of uniform thickness were not made to warrant conclusions, yet when the results above set forth are compared with results given below, similarly secured on sand asphalt mixtures, indicative values of oiled earth surfaces may be conjectured. It is the writer's intention to extend investigations of oiled earths in the manner above set forth maintaining more exacting control of specimen thickness, temperature, and density.

The importance of good drainage in the manner of cross-section slope and ample road ditches has been evidenced by our small campus oiling program.

14 McNew, J. T. L., A study of the fluxing of the bitumen contained in Texas limestone rock asphalt: Texas Eng. Exp. Sta. Bull. 31.

Data From Test Specimens.

TEST NO.	THICKNESS INCHES	TEMP. °F. WHEN COM-PRESSED	TEMP. °F. WHEN TESTED	FAILURE LOAD LBS.
1_3	2.5	100	100	2,850
1_4	2.25	160	150	2,500
1_7	1.6	160	68	2,020
1_8	2.0	140	68	2,710
1_9	2.0	160	68	3,170
1_{10}	2.1	160	68	2,900
1_{11}	2.1	160	68	3,030
1_{12}	2.2	160	68	3,610

Complete data of Prof. Padgett's investigations and conclusions in connection with this work have not been published and it is to him that I am indebted for much of the detail herein given. He has concluded that no better oil for the oiling of earth roads may be secured than can be produced from Oklahoma mixed base crude. The viscosity test (Furol viscosimeter) is, by him, recommended as the best criterion test for road oil quality along with the determination of 100 Pen. residue. The Furol viscosity at 122°F. should be above 100 seconds; the percentage of 100 penetration residue should be 60 to 70 per cent and in the case of residual oils, the per cent of bitumen insoluble in 86-88° naphtha should be less than 10 per cent, preferably below 5 per cent.

Prof. Padgett is enthusiastic over the possibilities to build and maintain really serviceable roads in Oklahoma at low to moderate cost through the intelligent use of this great natural resource combined with the exploiting of other state resources in the nature of gravels and stone suitable for road metal. However, he would call attention to the fact that oiled earth roads, at best, may not be classed higher than secondary improvement and will never be comparable in service economy to metalled and paved surfaces.

Having investigated oiled roads in many sections of the country, Prof. Padgett is convinced that the failures are more often to be attributed to improper preparation of the roadway, or to the application of oil when the roadway was not in proper condition, rather than to other causes. Often the proper quantity of oil is not used per square yard. The best results in oiling roads have been obtained where the operators have studied local soil conditions, and learned by experience the proper type of oil, and quantity to be used per square yard.

GRAVEL SURFACES

In most instances, economy may be shown in oil treatment of gravel roads from the following standpoints; conservation of the road metal, reduction of maintenance cost, smoother riding qualities and a saving in fuels, reduction of tire wear and dust nuisance to motorists.

It is not possible to attain a high degree of precision in balancing the expense of oiling against these latter costs incident to untreated gravel roads. However, a little careful estimating will reveal almost conclusive evidence as to where the balance of economy is to be found.

The annual loss of road metal from untreated gravel roads has been variously estimated from ½ to 1½ inches depending on several factors. On an 18 feet width of metalled roadway this loss would amount to 150 to 450 cubic yards of material and at an average value of $3.00 per cubic yard (placed) the annual cost of replacement would be $450 to $1,350.

The saving in maintenance cost is estimated from $100 to $500 per mile per annum. It is difficult to place a monetary value on improved riding qualities effected by oil treatment, yet none will dispute that real value is represented therein. It is likewise difficult to place definite values on the saving in fuel, tire wear and mechanical life increment of motor vehicles due to the improved tractive qualities and elimination of dust through surface oiling of the roadway. The experiments carried on at Iowa State College and Washington State College indicate that a relative saving of from 100 to 500 per cent may be expected.

A few years ago Wisconsin introduced a special mixing method for oil treatment of roads which is being used by several states today. This method, well described in the literature, as below set forth, is modified in some instances to suit conditions.[15] Treatment of gravel roads which carry no loose material on the surface will approximately parallel the method given below for Macadam road treatment.

WATERBOUND MACADAM SURFACING

The claims for economy effected through bituminous treatment of gravel roads will apply with almost equal force to similar treatment of waterbound Macadam and crushed stone roads. Sepecifications and methods of application, found in "Oklahoma State Standard Specifications" are typical of current practice.[16]

15 Highway Maintenance: Wisconsin Highway Commission, Bull. No. 16.

16 Standard Specifications—road and bridge construction: Oklahoma State Highway Commission.

BITUMINOUS SURFACES

All types of bituminous surfaces may be rejuvinated by treatment with medium asphaltic oil or tar at the rate of approximately ⅛-gallon per square yard. A covering of coarse sand, fine gravel, or stone chips should then be applied and the surface rolled with a roller sufficiently heavy to all but crush the covering particles.

This treatment should be executed in hot weather and of course the old surface will be thoroughly cleaned and all holes patched prior to treatment.

RECAPITULATION

A few facts and high lights will here be singled out for review.

Bituminous road surfaces antedate history.

Asphaltic oil and tar have been used for twenty-five years as dust palliatives and water proofing for earth and metalled road surfaces.

These years of experience have proved:

First, heavy clays and gumbos will not respond satisfactorily to oil treatments without granular admixtures.

Second, proper roadway drainage must be provided if satisfactory results are to be obtained from oil treatment.

Third, The roadway must be put to good gradient and cross section well in advance of oiling so that proper compaction will result.

Fourth, the grade and quantity of oil applied have an important bearing on the service qualities of the road and must be varied according to the characteristics of the surface being treated.

Fifth, the oiling should be done in warm weather when the road surface is moist but not wet.

Sixth, every precaution should be exercised to prevent the bespattering of vehicles during oiling operations.

Seventh, oil storage facilities should be provided in order that oil may be had when needed, and conversely, that it will not be placed on roadways at an improper time in order to save demurrage on tank cars.

Eighth, if continuous and proper maintenance of the oiled road be not provided, oil treatment will not be economical.

ROCK ASPHALT

Rock asphalt exists in undetermined quantities at various location in the southern portion of Oklahoma. The map, figure 2, shows the locations of the main known deposits.

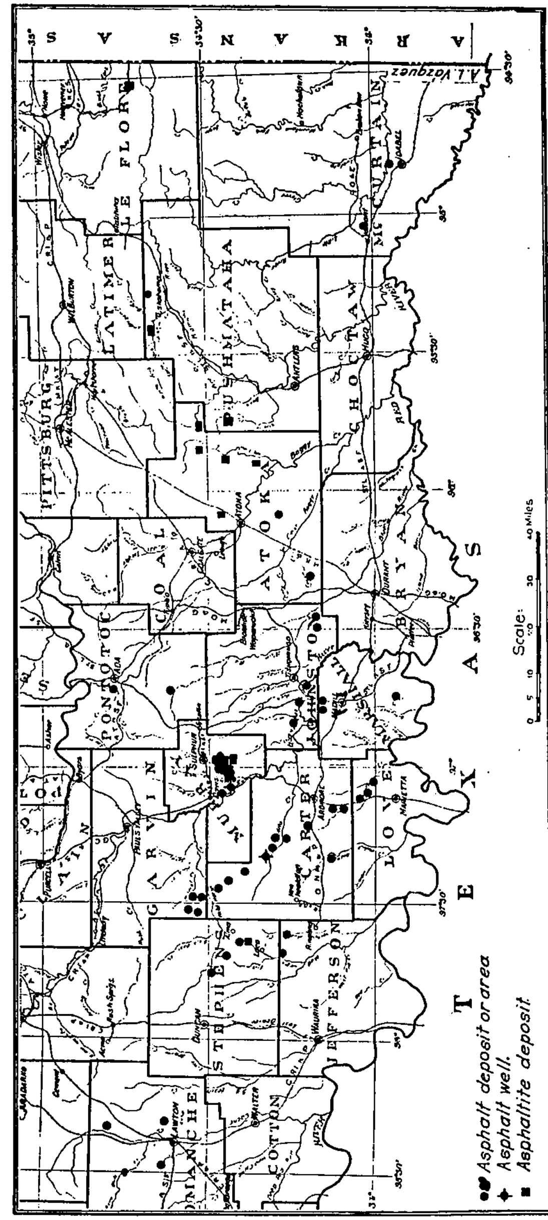


Figure 2.—Map of a portion of southern Oklahoma showing principal asphalt deposits. (After Hutchison)

The nature of the asphalt deposits and characteristics of the material together with the extent of development and exploitation are well set forth by Hutchison.[17] Since the publication of this bulletin a few of the deposits have been more extensively developed.

L. C. Snider[18] gives a brief discussion of Oklahoma rock asphalt deposits and their suitability as road paving materials.

The deposits in the vicinity of Dougherty, in Murray County, have been developed more extensively to date than in any other section, due to promotional activity and advantageous location commercially, rather than to any superiority of materials. However, both the asphaltic and mineral constituents of the rock asphalt in this district rank with the best in the State. Also the bituminous content is fairly uniform throughout the deposits and of about correct proportion and consistency to produce good paving material, averaging about 5 per cent in the limestone deposits and about 9 per cent in the sandstone deposits.

Following are analyses of several samples of lime rock asphalt base and of 20-80 lime-rock—sand-rock asphalt wearing surface recently placed by the Oklahoma Department of Highways.

Analyses of materials used in constuction of Oklahoma State Aid Project No. 321 A.

TYPE "C"

Section 33+94 to Station 50+54.67, 1½" cold rock asphalt top, 4" cold rock asphalt base, 2" compacted gravel sub-base.

The 2-inch gravel sub-base consisted of 2-inch limestone rock, rolled into place. The 4-inch cold limestone rock asphalt base was then spread into place and a mortar consisting of sand rock asphalt was harrowed into this. After traffic had compacted this for a few weeks, the surface consisting of 80 per cent sandstone rock asphalt, mixed with 20 per cent limestone rock asphalt was then spread into place cold. An Ord concrete finishing machine was used in spreading the surface material to obtain a smooth riding surface.

The following are grading analyses of the 4-inch limestone rock asphalt. This material is a limestone containing approximately 4 per cent bitumen and showing a French coefficient of wear of about 7.5, before the bitumen is extracted.

Each of the analyses in the second table p. 33, represents one car of approximately 50 tons, of the cold rock asphalt surfacing used on this section.

17 Op. cit.
18 Snider, L. C., Rock asphalts of Oklahoma and their use in paving: Oklahoma Geol. Survey Cir. 5, 1913.

Grading Analyses of 4-inch Limestone Rock Asphalt.

SCREEN	LAB. NO. 6740	LAB. NO. 6739	LAB. NO. 6599	LAB. NO. 6741	LAB. NO. 6738	LAB. NO. 6600
RET. 2"	0.0	0.0	0.0	2.5	2.5	0.0
" 1½"	14.5	17.1	2.1	16.8	8.3	7.2
" 1"	43.0	33.3	15.8	47.4	34.8	21.5
" ¾"	25.8	29.4	22.4	26.9	34.2	24.5
" ½"	15.0	18.4	35.1	4.7	17.5	29.7
" ¼"	0.8	1.5	23.3	0.6	2.4	16.3
PASS ¼"	0.9	0.3	1.3	0.4	0.3	0.8
	100.0	100.0	100.0	100.0	100.0	100.0

The limestone and sandstone rock asphalts are crushed and mixed in the process of crushing in the required proportions to produce the commercial paving material.

The average mixture for wearing surfaces is 20 to 30 per cent lime rock asphalt and 70 to 80 per cent sandstone ashpalt.

The rock asphalt matrix is placed on the road either cold or hot. There seems to be little difference in the service given by the pavement due to the method of placing where proper discretion is exercised in the construction. Of course, to secure good results, the cold application must be carried on in warm weather. Following are typical specifications for rock asphalt surfacings.

Analyses of Cold Rock Asphalt.

	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO. 6	NO. 7
BITUMEN	7.0	9.0	8.7	8.4	8.2	7.5	6.5
200 MESH	6.5	4.8	4.4	4.3	4.5	4.1	3.3
80 MESH	47.7	51.5	48.5	50.0	53.6	46.3	41.4
40 MESH	18.2	17.1	15.6	18.2	16.7	15.7	25.8
10 MESH	6.5	4.7	6.2	5.9	5.7	6.6	5.4
¼-INCH	7.3	5.6	9.4	7.9	4.7	8.7	6.9
½-INCH	6.8	7.3	7.2	5.3	3.4	11.1	10.7

Oklahoma Department of Highways

SPECIFICATIONS

Type "C"

For Cold Rolled Oklahoma Natural Rock Asphalt Paving

Gravel Course

Upon the sub-grade, after same is prepared and rolled, there shall be spread a layer of coarse gravel, approximately all of which shall pass the 2½-inch ring, and be retained on a 1-inch ring. This shall be evenly spread and rolled.

Rock Asphalt Base

Upon the gravel course there shall be spread 4 inches of Oklahoma Natural Lime Rock Asphalt approximately all of which shall pass a 2½-inch ring and be retained on a ¾-inch ring. This shall be carefully spread and raked to an even surface. Upon this there shall be spread a mixture of 60 per cent lime rock asphalt and 40 per cent sandstone asphalt, all passing a ⅜-ring This shall be spread to an approximate depth of ¾-inch and shall be thoroughly raked and harrowed into the base course. During the raking sufficient fine mixture shall be added so that after being thoroughly rolled and compacted, the base shall have a thickness of 4½ inches and the surface of the same shall be true to cross-section and grade.

Wearing Surface

Upon the base course, as above specified, there shall be laid a wearing surface composed of 80 per cent sandstone asphalt and 20 per cent lime rock asphalt, all to pass a ⅜-inch ring. This shall be evenly spread, harrowed, raked, and rolled. The wearing surface shall have a depth of 1½ inches after final compression. After the initial rolling, there shall be swept upon the surface, a thin coating of Portland Cement. The wearing surface shall then be rolled and the street opened for traffic. No wearing surface shall be laid during rainy weather or when the temperature is below 40 degrees Farenheit.

The use of conglomerates will not be permitted in either the base or wearing surface, and all lime rock asphalt which does not show a French coefficient of 5 will be rejected.

All mixtures of sandstone asphalt and lime rock asphalt must be mixed while being crushed, at the source of supply.

Basis of Payment

This work will be paid for at the contract unit price per square yard for completed pavement in place, measured from outside to outside of curb, which price will include all materials, equipment, tools, labor, and work incidental thereto.

Bituminous Sandstones

It is customary to specify the minimum amount of bitumen which must be present and the size to which the rock asphalt must be reduced by crushing and pulverizing. The following requirements are specified by the Louisiana Highway Commission. (1925)

	Per Cent
Bitumen	6.0 to 7.5
Crushing silicia and lime	92.5 to 94.0
Passing 1-inch screen, not less than	90
Passing ¾-inch screen, not less than	80
Passing ½-inch screen, not less than	70

Bituminous Limestones

The bituminous limestone from Alabama is generally placed hot. An asphalt paving cement, having a penetration of 60 to 70 at 77° F., is used in the approximate proportion of 4.0 to 5.5 per cent. by weight. The Louisiana (1926) specifications for this type of rock asphalt are as follows:

Bitumen content, per cent	4 to 8
Maximum size of crushed particles, inch	0.25

In original construction work rock asphalt surfacing may be laid on any type of base suitable for any of the standard bituminous surfacings.

As a maintenance material it has been used successfully for patching all types of bituminous surfacing and should prove a convenient and economic patch material for Portland cement concrete pavements. It has proved to be a successful surfacing when placed on gravel, macadam, or crushed stone base which attests its value in reconstruction work.

It would appear that cold rolled rock asphalt should prove to be of distinct value in stage development of our highway system. There is a considerable mileage of gravel roads in Oklahoma on both state and county highway systems. When traffic increases to a point where maintenance of the untreated gravel surface becomes excessive, bituminous treatment should be initiated. Later when traffic would appear to warrant a still further improvement of surface a 2-inch topping of cold rolled rock asphalt should yield an approximate high type of roadway at a moderate cost with very slight, if any, loss in salvaging early stage development.

The margins of the old metalled surface should be given due attention as here are the cruxes of this type of pavement. The margins should be extended, if widening is necessary, and in any event dressed and remetalled to a depth effecting a thickened edge pavement cross-section.

Prior to the placing of the rock asphalt wearing surface it might prove an economy to treat the old surface with a heavy asphaltic oil which, in effect, would add depth to the bituminous surfacing. Indeed the rock asphalt topping course might be reduced to 1½ or 1¼-inches on a firm, substantial, treated subsurface.

With our vast and widely distributed quarries of natural rock asphalt as well as gravel and stone deposits, and oils of major asphaltic base, well directed experimentation on this type of construction is justifiable.

Last year the main street of Crescent and a section of highway extending five miles south of that town was paved with a 4½-inch black base and 1½-inch wearing surface of rock asphalt. The subgrade of the highway is composed largely of wind-blown sand. The road carries a great deal of heavy traffic to and from the oil field north of Crescent. In view of these conditions this will be an excellent observation section in which to study the merits of this type of construction. Plate IX shows a section of this road at the Cimarron River crossing.

The value of Oklahoma rock asphalts as paving material is attested by the service yield of streets and highways paved with this material twenty years ago, in and near various cities and towns in Oklahoma and neighboring states.

Below are listed the major rock asphalt paving projects in Oklahoma City since 1910.

Oklahoma Natural Rock Asphalt Paving in Oklahoma City

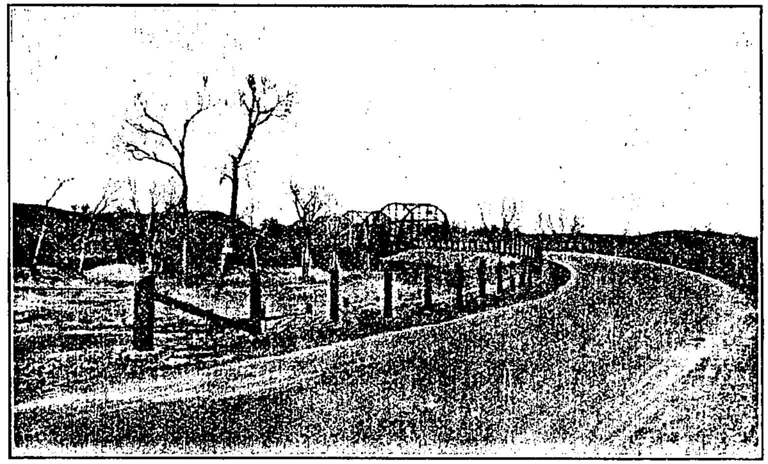
STREET	EXTENT	YEAR PAVED
Lee Ave.	19 to 22nd sts.	1910
Park Place	Western Ave. to Ollie Ave.	1910
Twelfth St.	Broadway to Robinson	1910
Dewey Ave.	Grand Ave. to Reno Ave.	1911
Seventh St.	Walker Ave. to Lee Ave.	1911
Seventh St.	Stonewall Ave. to Lottie Ave.	1911
Francis Ave.	Main St. to Reno Ave.	1911
Noble Ave.	Robinson Ave. to Santa Fe Ave.	1911
Shartel Ave.	Main St. to Reno Ave.	1911
Sixteenth St.	Young's Blvd. to Linwood Blvd.	1911
Hudson Ave.	15th St. to 19th St.	1912
Ave. "E"	Robinson Ave. to Lee Ave.	1923
Ave. "A"	Robinson Ave. to Central Ave.	1924
Seventeenth St.	Young's Blvd. to May Ave. (Willite)	1924
Randolph Ave.	16th St. to 19th St. (Willite)	1925
Western Ave.	34th St. to 36th St.	1926
Blackwelder Ave.	16th St. to 19th St.	1927
Gatewood Ave.	16th St. to 18th St.	1927
Douglas Ave.	25th St. to 26th St. { 6½ R.A. base / 1½ R.A. top }	1927
Shartel Ave.	Classen Blvd. to 16th St.	1928
Twenty-Seventh St.	Military Ave. to Western Ave.	1928
Paseo	28th St. to 30th St.	1928

Except as noted the R. A. wearing surface, 1½ to 2 inches thick, was placed on Portland Cement concrete base.

Approximately 200,000 sq. yds. of rock asphalt surfacing has been laid in Oklahoma City up to March 1, 1928.

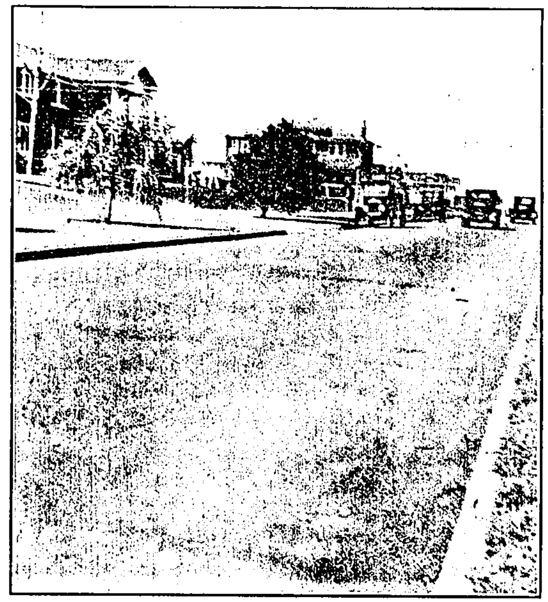
Plate X shows a section of Hudson Avenue as listed above. This is one of the heavy traffic streets of Oklahoma City.

PLATE IX



ROCK ASPHALT SURFACE ON "BLACK BASE" OKLAHOMA STATE HIGHWAY 44

PLATE X



HUDSON AVENUE, OKLAHOMA CITY, SURFACED WITH ROCK ASPHALT ON CONCRETE BASE IN 1912

Plate XI shows the placing of rock asphalt surface on a base of the same material. The base was placed and allowed to compact under traffic before the placing of the wearing surface.

PLATE XI

ORD CONCRETE FINISHING MACHINE, FINISHING COLD ROCK ASPHALT SURFACING, U. S. HIGHWAY 66

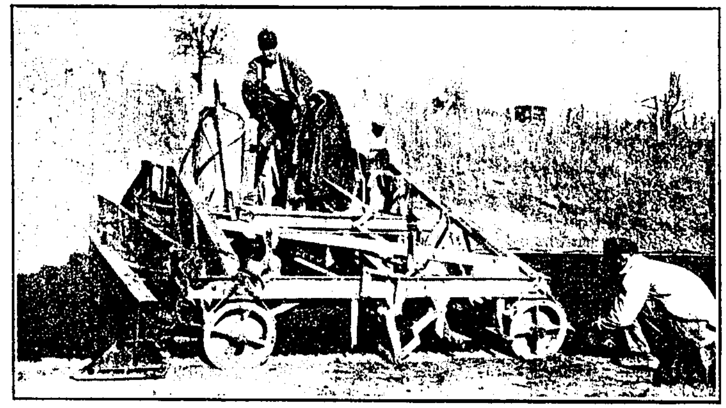
The subgrade, being a fill of 3 feet to 10 feet in depth, was stabilized by the application of river gravel spread to a depth of 2 inches and rolled. On this was placed 4 inches of crushed Oklahoma lime rock asphalt, graded between the 2½- and ¾-inch screen, which was spread and raked to a uniform surface. Upon this was spread "a mixture of 60 per cent lime rock asphalt and 40 per cent sandstone asphalt, all passing a ⅜-inch ring," to a depth of ¾-inch. This mixture was thoroughly raked and harrowed into the base course. Where necessary, additional fine mixture was added to produce a base course of 4½-inch after rolling. The pavement is retained between Portland cement concrete curbs of 12 by 10 inch section. The wearing surface is composed of 20 per cent lime rock asphalt and 80 per cent sandstone asphalt all passing a ⅜-inch ring.

This is possibly the first job on which a mechanical spreader template has been used for cold materials work. Satisfactory results were secured with the machine, in fact a firmer and more uniform surface was secured than is possible by raking and of course greater speed and economy is bound to result from use of the machine in this field.

The surface was double rolled with an 8 ton roller and sealed with a sweeping of Portland cement.

The employment of a concrete finishing machine to supplant "rakers" in asphalt surface construction was initiated by H. L. Cannady Construction company last autumn. Plate 12 shows the machine at work. It will be noted that a gasoline pressure tank was installed on the machine for the purpose of supplying fuel to burners placed back of the template in order to heat it when operating at cold temperatures. It is believed that this or a machine of similar type will become standard equipment in asphalt paving work.

PLATE XII



LAKEWOOD CONCRETE FINISHING MACHINE OPERATING ON HOT TOP ROCK ASPHALT SURFACING

RECONSTRUCTION AND BETTERMENTS

Maintenance merges almost imperceptably into reconstruction and betterment. With earth roads and the lower type surfacings no line of demarcation may be drawn. With the higher types of pavement differentiation is more easily effected.

However, we are not especially interested in nomenclature as much work that may be classed as strictly reconstruction and betterment is performed by the maintenance organization.

It is highly desirable that every dollar invested in highways whether it is for right-of-way, construction, maintenance, beautification, or what not, should yield the greatest possible return in service. At no stage of highway development does "unit-service-cost", however it may be defined, demand more attention and analyses than at the juncture of reconstruction.

No doubt, in many instances during the last decade, in our enthusiasm for high-type pavements, values in macadam and gravel surfacings have been sacrificed through misdirected reconstruction programs. On the other hand, possibly an equal or greater loss has been sustained through attempting to maintain the lower type roads in service at excessive maintenance costs.

It is impossible at present to compute, with precision, the economic service limit for any type of surfacing or pavement. If a uniform system of maintenance cost accounting were practiced by all the states, counties, towns, and townships, precision in computations could be much more nearly approached.

Fuel and repair costs for vehicles operating over the various types of road and over a given type in varying state of repair, are important considerations in this connection. This cost factor is as elusive as it is important. Many commercial organizations are keeping rather detailed account of motor vehicle operation costs. Analytic co-ordination of these costs with road conditions and corresponding maintenance costs are being attempted.[19]

Studies of this problem have not been extensive enough to supply data which may be intelligently incorporated in a formula for computing the "economic life" of pavements.

Granting that a given type of surfacing or pavement were maintained to the perfection and smoothness of new construction, the factor of operational costs would remain constant and hence would not enter into the computation of "economic life." This factor, however, would enter into the determination of the stage of traffic increase at which it would be economical to replace a lower with a higher grade type of paving. Investigations to date indicate, as would be expected, an increase of operational costs similarly proportionate to maintenance costs for the various types of surfacings and pavements, so the use of maintenance costs as a criterion of service cost is sound practice.

Various theoretical and empirical formulae, more or less arbitrary annual maintenance cost limits, and mechanical roughness determination constants, all based on correlation of maintenance, reconstruction, and operational cost approximations, are proposed as criteria for initiating reconstruction measures.[20] It will be remembered that "annual maintenance cost," as applied in these formulae, should comprise only the cost of maintaining the paved way and not include the expense of general maintenance of shoulders, bridges, sign boards, and right of way.

Oftentimes, the inconveniences and interferences with traffic flow, incurred by maintenance operations, will prove of more important consideration than will the actual cost of operations.

19 Agg, T. R., and Crater, H. S.,—Highway transportation costs; Eng. Exp. Sta., Iowa State College, Bull. 69, ______.

20 Harger, Wilson G., Rural Highway Pavements—Maintenance and Reconstruction. McGraw-Hill Book Co., N. Y.

An instrument for the measurement of relative road roughness: Public Roads, vol. 7, no. 7, ______.

Dunbar, Harley, Vialog operation and graphs: Eng. News Rec., vol. 92, no. 2,——.

Again, financial extremity, popular and commercial demands, and political expedient are ever present factors which must be reckoned with by the highway engineer and administrator. A given section of road, after serving its ten, score, score-and-ten, or two score years, may be easily adjudged to have reached its limit of "economic life", yet funds may not be available for reconstruction or replacement, or other consideration above mentioned may decree that available funds should be spent in new work in another section rather than on reconstruction of the given section. So it is here, as in practically all public enterprises, that rules and formulae, calculated to give optimum results, cannot always be applied. The degree to which they may be applied will depend upon the knowledge, acumen, experience, and freedom from political restraint of the administrator, and the sufficiency of public finances at his disposal.

The Oklahoma State Department of Highways is now wrestling with the problem of reconstruction vs. new construction. Some sections of our main highways bear surfacing of a type commonly adjudged as non-commensurate with the amount and type of traffic now using the road. Due to lack of finances, and possibly other causes, maintenance has not been at par. Other sections are carrying equally heavy traffic on the dirt and through the dust. Yet others have had a maintenance treatment of gravel in the amount of 10 to 12 cubic yards per station.

New construction will doubtless be given preference in the apportioning of Federal and State moneys as county bond issues, for the purpose of participation in state road construction, as well as county road and bridge construction, are being voted from time to time by counties traversed by the inferior sections of state road.

Other states are maintaining gravel and macadam roads under traffic of from 500 to 5,000 vehicles per day so there is precedent for maintaining much of Oklahoma's graveled road system as such for some years to come. To properly maintain them will require more funds than have been made available for maintenance in years past.

In the first instance construction has largely been financed through township and county bond issues in conjunction with Federal aid. As these bond issues were voted the bodies politic demanded their prorata of Federal money as is now the case and will evidently obtain for some time, hence the available funds for reconstruction will be necessarily restricted. Also a portion of the revenues from motor vehicle license fees was used for construction and the balance for maintenance.

In the second instance the accelerated industrial and commercial development of the State has demanded roads, then more roads, and then better roads and is now demanding yet better roads; consequently the maintenance fund has been kept at, if not a little below, the irreducible minimum necessary to keep the Federal Aid Projects at "status quo" and the balance of the system passably passable.

During the past few years State road maintenance has been receiving decidedly increased attention and, with continued due consideration of maintenance, extensive reconstruction may be held in abeyance for some years yet.

Reconstruction is as yet scarcely a problem with most of the counties and townships of the State. The main task here is grading and drainage operations and earth road surface improvement with the attendant maintenance. Bituminous materials unquestionably have a distinct place in many reconstruction projects. Wisdom in their selection and use must certainly result in economies for our highway program.