REPORT OF COMMITTEE ON MAINTENANCE

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Your Maintenance Committee has not undertaken the study of any new subjects during 1928 It was thought desirable to review all of the subjects which had been previously investigated by the committee and to present a summary of this review in the 1928 Annual Report

At a meeting of the Committee held in Chicago in November 1928, it was decided that better results might perhaps be obtained in the future work of the Committee if the number of subjects under investigation at any one time should be reduced to not more than two The subjects which were considered tentatively for investigation in 1929 were·

1 Maintenance equipment (To consist of a history of the development of various types of maintenance equipment, the specifications for such equipment, and methods of purchasing equipment)

2 Bituminous surface treatments and toppings (Under this subject the Committee contemplates the correlating of all of the various methods of surface treatment, retreads, light oil treatments, and various types of asphalt mixtures)

The Maintenance Committee calls attention to two developments during the past year in connection with maintenance equipment They are noted as follows

First there is the question of the standardization of cutting edges for graders As the matter now stands, there are several hundred styles and types of cutting edges The Missouri State Highway Department first called attention to this matter at the 1927 meeting of the Mississippi Valley Highway Association It was discussed and endorsed by the Maintenance Committee of that association As a result of this endorsement, a committee was appointed by the Mississippi Valley Association to confer with manufacturers of graders and blades to see what might be done toward standardization This Committee met in St Louis in September, 1928, with representatives of all of the leading graders and blade manufacturers and the following standards were unanimously approved

Standard blades to be six, seven, eight and nine feet long There may also possibly be a five foot standard and for a time some will be made that end in six inch multiples to take care of some old equipment that is still in use For a twelve foot mold board, we will use two six foot blades, for a fourteen foot mold board, two seven foot blades, and so on The punching is very simple Beginning at the end there is a

three inch space from the end of the blade to the first hole, then three inches to the next hole, then a twelve inch spacing The sizes of the holes are specified for different thicknesses of blades No attempt was made to standardize the chemical composition or the curvature of the blades

This report of the Mississippi Valley Association was referred to the Maintenance Committee of the American Association of State Highway Officials which met in Chicago late in 1928 It was endorsed by that Committee and has been referred to the Executive Committee with the recommendation that it be sent to the States for letter ballot This letter ballot will be taken this winter and the proposition will undoubtedly be favored by a majority of States This standardization will be highly desirable to both manufacturers and users of blades It will mean that the mold boards of many graders now in use will have to be redrilled to fit the standardized punchings of blades

The second development referred to in connection with maintenance equipment has been the appointment of a Committee by the American Association of State Highway Officials to act jointly with a similar committee of the American Road Builders Association for the purpose of devising, if possible, standard methods for the purchase of equipment It is believed that work done along this line will be of great advantage to many Highway Departments in the purchase of their equipment

A Summary of previous investigations of the Maintenance Committee is given herewith as follows

CRACK FILLERS FOR CONCRETE PAVEMENTS

The reports of the Maintenance Committee of the Highway Research Board have included a number of reports on crack filling researches The 1922 report contained information concerning the experiments of L G Carmick of the Bureau of Public Roads in the development of a concrete colored crack filler Mr Carmick developed a crack filling compound of rubber, petroleum oil and rosin with a mineral filler The proportions used were about one part of rubber to twelve parts of rosin and the cost approximated ten cents per pound This material has never become popular, probably on account of its cost and the difficulty of its application

The 1923 report contained a summary by Thomas E Stanton of California, including a preliminary report of the Iowa experiment

The 1924 report contained a final summary of the Iowa experiment in which fourteen materials were used three tars, five oil asphalts, three blown oils, one white compound, one mixture and one whose composition was unknown This report indicated that the tars used gave satisfactory results and that the high penetration asphalts gave partially satisfactory results The other materials were all unsatisfactory

In 1925 J T Donaghey of the Wisconsin Highway Department presented a summary of a survey of the crack filling practice in the various states This summary showed that there was no standard practice either in the materials used or the method of application. Different states were using asphalt and tar with about equal satisfaction In some places the material was being put on cold, in others hot, and in some places sand was used and in others no sand was used

The Committee believes that a thorough study of crack maintenance by the maintenance organizations of the various states would result in data which would be of great value in the design of pavements Filling cracks with bituminous material contemplates accomplishing the following three results

1. To water proof the crack
2 To prevent abrasion of the edges of the concrete at the crack
3 To prevent spalling

It is considered that the most important of these three results is the prevention of spalling In the work of filling the cracks, the following points are emphasized

Thorough cleaning of all foreign matter or spalled concrete from the crack with brooms or compressed air prior to filling

Cracks should be filled just to overflowing with hot bitumen and the use of an excessive amount of bitumen is undesirable Bitumen should be covered with sand as a protection to traffic unless it hardens so quickly that it is not affected by traffic

Tar should be applied within a temperature range of 200°F to 250°F. and asphalt within a temperature range of 300°F to 350°F Thermometers should be used in controlling temperatures of bitumen

ANNUAL REDUCTION IN THICKNESS OF GRAVEL ROADS UNDER DIFFERENT TRAFFIC AND EFFECT OF DUST LAYERS

The 1926 report of the Maintenance Committee contained an interesting article by A H Hinkle of Indiana, on the loss of gravel on graveled roads This report covered a considerable number of test roads in Indiana and the average figures evolved from this experiment are probably applicable to other states They showed that the loss of gravel is 289 cu yds per mile per year per average daily vehicle. This is not as great an amount as is usually supposed

No data has been made available to show the reduction in loss of gravel due to the use of dust palliatives It is thought that the use of dust palliatives is justified from the standpoint of dust elimination alone.

MAINTENANCE COSTS AS AFFECTED BY THE LIFE OF THE ROAD

This subject is covered on pages 256–257 of the 1925 annual report of the Highway Research Board

Conclusions of the Committee are summarized as follows·

Marked improvements have been made recently in the use of certain road materials and in the design of pavements

Maintenance data to be fully informative should extend over a period of not less than twenty years

Deductions from long-term data, at the present time, must necessarily pertain to pavement design of an inferior type and, therefore, would be misleading with respect to modern uses of paving materials

In the earlier periods of highway construction, records were seldom kept in such detail as to be of service in the present investigation, segregating slab maintenance from the cost of shoulders, drainage, culvert repair, snow removal and items of improvement

Traffic conditions have changed markedly and maintenance costs ten or fifteen years ago do not reflect the conditions which now exist

Traffic records concurrent with cost data for any extended period are incomplete

Maintenance costs to be reasonably informative should be on a ton-yard basis

MAINTENANCE OF CONCRETE PAVEMENTS

A full discussion of this subject will be found on pages 322–326 of the 1926 annual report of the Highway Research Board This discussion covers the following features of the maintenance of concrete pavements·

Maintenance of contraction or other construction joints
Treatment of cracks
Treatment of small holes and spalled surfaces
Treatment of scaling
Removal of inequalities in concrete surfaces

The following general principles are generally recognized in the maintenance of concrete pavements

1 Repairs should be made so far as practicable with concrete.

2 Temporary repairs may be made with bituminous material.

3 The cause of cracking and breaking of the concrete slab should be removed if possible and the subgrade strengthened prior to repair of the slab

4. Inequalities should be corrected after construction when necessary to provide good riding qualities.

COVERINGS FOR POORLY CONSTRUCTED AND DISINTEGRATING CONCRETE PAVEMENTS

Experience has proven that where concrete is badly cracked, but not disintegrated badly, a 1 inch compacted asphaltic wearing surface can be laid thereon with reasonable assurance of success Care must be taken to thoroughly clean out all cracks and fill with heavy hot tar or asphalt before laying the wearing surface While not absolutely necessary it is good practice to give the surface of the old concrete a light paint coat of light tar or asphalt The paint coat should be as light an application as possible to apply Good results have been obtained with both the "hot mix" and "cold laid" type of asphaltic mixtures

All depressions should be filled in advance, using the same material contemplated for the wearing surface and well compacted before laying the 1 inch wearing surface

Where the old concrete is both badly cracked and disintegrated the asphaltic wearing surface must be not less than two inches compacted depth when finished and should be laid in two courses in order to secure a good riding surface

All loose sections of concrete should be replaced and especially along the edges of the pavements The cracks cleaned and filled and if thought necessary a paint coat applied A paint coat is more necessary when a dense "hot mix" wearing surface is specified than when the more "open mix cold laid" types, are used

The 2 inch asphaltic wearing course should be laid in two courses, the lower or binder course about $1\frac{1}{4}$ inch compacted and the top or wearing surface about $\frac{3}{4}$ inch compacted There is less danger of creeping and buckling if the lower or binder course is composed of aggregate from 1 inch down to $\frac{1}{4}$ inch and uniformly graded

There is a large field for research work on this subject

A full discussion of this subject will be found on pages 347–355 of the 1926 annual report of the Highway Research Board.

BRIDGE MAINTENANCE INCLUDING PAINTING AND REFLOORING

This subject is covered on pages 274–276 of the 1927 annual report of the Highway Research Board The following points are discussed:

Regular maintenance inspection of projects
Proper painting and reflooring
Foundation maintenance
Design of bridges with reference to subsequent maintenance.

MAINTENANCE ACCOUNTING

The Committee in their report for the Fourth Annual Meeting of the Highway Research Board held at Washington, D C , December 4 and 5, 1924, covered Maintenance Accounting This report will be found on page 150 of the Proceedings of the Fourth Annual Meeting of the Highway Research Board

This report covered the work done by the sub-committee of the American Association of State Highway Officials, giving their recommendation as to the classification of accounts on maintenance work. The committee also gave a summary of the recommendations made by the Mississippi Valley Association on the same subject

The classifications recommended by the committees of both the American Association of State Highway Officials and the Mississippi Valley Association are intended to furnish uniform headings to which the various maintenance expenditures occurring each year can be distributed.

Since the committee made its report for 1924 the committees of the American State Highway Officials Association have been revised The association now has a sub-committee on Uniform Accounting, acting under the direction of the Committee on Administration The work of this committee covers the entire field of highway accounting, including maintenance.

A tentative report was submitted to the association at Chicago at its recent meeting in November, 1928. This report has been submitted to the State Highway Departments for comment and criticism, with the request of a report from them to be in the hands of the committee not later than May 1, 1929 It is the intention of the sub-committee on Uniform Accounting, of which Mr G G Clark of the Bureau of Public Roads is Chairman, to redraft this report on the receipt of the comments and criticisms of the State Highway Departments and submit a final report to the association at its next meeting, with a view of having the States adopt a uniform system of accounting

We quote from the report of the committee the following relative to the classification of accounts:

"Cost Analysis

(31) Ordinary Maintenance
- (1) By types and mileage
- (2) By design or cross-section
- (3) By year of original construction
- (4) By location (county, district, division, section, patrol, route or project)
- (5) By statutory class (Federal-aid, State-aid, etc)
- (6) By whom constructed (State, counties, townships or other political subdivisions)

Costs under these heads should be collected under the following accounts

(1) Subgrade
(2) Base
(3) Surface
} Roadway

(4) Drainage structures
  (1) Bridge and culverts
  (2) Ditches and drains
(5) Roadside and grade
  (1) Cutting and clearing vegetation
  (2) Cleaning and clearing right-of-way
  (3) Upkeep of earth shoulders
  (4) Upkeep of metal shoulders
(6) Structures
  (1) Retaining walls
  (2) Riprapping
  (3) Et cetera
  (4) Grade separations
(7) Traffic service
  (1) Upkeep of markers and safety signs
  (2) Upkeep of guard fence
  (3) Snow removal

Further subdivisions may be made as required.

Costs under the above heads to be further detailed as follows

(1) Direct labor (detail according to operations).

(2) Direct material and supplies
(3) Direct equipment charges
(4) Indirect expense or overhead

(32) Extraordinary Maintenance
(1) By types and mileage
(2) By design or cross-section
(3) By year of original construction
(4) By location
(5) By statutory class
(6) By whom constructed
(7) By reasons for extraordinary maintenance

Costs under these heads should be divided as follows

(1) Subgrade
(2) Base
(3) Surface
} Roadway

(4) Drainage structures
  (1) Bridges and culverts
  (2) Ditches and drains
  (3) Curb and gutter
(5) Roadside
  (1) Cleaning and clearing right-of-way
  (2) Upkeep of earth shoulders
  (3) Upkeep of metal shoulders

(6) Other structures
  (1) Retaining walls
  (2) Riprapping
  (3) Et cetera.
(7) Traffic service
  (1) Upkeep of markers and safety signs
  (2) Upkeep of guard fence

Further subdivisions may be made as required

Costs under the above heads to be further detailed as follows

(1) Direct labor (detail according to operations).
(2) Direct material and supplies
(3) Direct equipment charges
(4) Indirect expense or overhead "

RHYTHMIC CORRUGATIONS IN GRAVEL ROADS

This subject first appears in Bulletin No 32, issued by the Board in relation to the November 23, 1922, meeting The report, so to speak, starts with a description of most extensive studies pursued by Dr. George E Ladd, Economic Geologist for the U S Bureau of Public Roads and written report by him compiled from investigations made throughout some few New England and Midwestern States (Report by Dr Ladd is carried by "Public Roads" issue of September, 1924) From the observations it was found that usually the distance from crest to crest of the corrugations averages about 31 inches and that the maximum height from the bottom of the trough to the top of the crest is 1½ inches. Deductions regarding causes of the corrugations are:

a. The kick-back of surface materials arising from the spin of the rear wheels of automobiles as they descend after a bounce over some obstacle or depression

b. From impact of both the front and rear wheels of automobiles

The class of corrugations under consideration appears to be more prevalent when the clay content of the gravel is high, and especially where the gravel particles are well rounded Concerning the corrugations first noted (a) the location of the ridges remain fixed, but in the second class (b) they seem to swing on an axis located near the center of the road In some instances the swinging movement was so great that corrugations which were originally perpendicular to the road, took a position only a few degrees from its axis Gravel roads subject to traffic of not more than 200 or 300 cars per day remain practically free from corrugations when occasionally dragged As soon, however, as traffic reaches 400 or 500 cars per day, corrugations develop very rapidly. The corrugations develop at the surface of all types of gravel roads and in all sections of the United States where sufficient traffic is experienced It is claimed, however, that the menace is reduced and more easily controlled where the road is constructed of gravel more uniform in size

than pit run, and especially where everything over one inch is excluded. The report concludes: "The problem remains for future solution and must be worked out by a combination of field observations and laboratory tests"

Bulletin No 43, Proceedings of the November, 1923, meeting of the Board, continued discussions of the subject involved, which terminate as follows:

"The committee does not believe that this subject should be continued as a major research problem We feel that cause and remedy of corrugations is definitely agreed upon As it is generally conceded that corrugations form with little regard to construction or maintenance methods, it would seem, then, that their prevention is a matter of traffic restriction or regulation We do not believe that this is feasible"

EARTH ROAD OILING

Bulletin No 32, Proceedings of November, 1922, states in effect that the University of Illinois had sponsored experiments on earth road oiling under the direction of Prof W. M. Wilson, but that his report was not as yet ready for publication. The experiments were conducted along a well-graded road with separate sections considered averaging 1200 feet in length using four different types of oil and from one-fourth to one gallon of the material per application

The Illinois Department of Public Work has also made similar studies on oiled earth roads, but with no data relative to the subject available at the time the bulletin was printed, expecting, however, that a paper on same would be issued during the next winter

SNOW REMOVAL—EQUIPMENT AND DRIFT PREVENTION

Six consecutive issues of Proceedings of the Highway Research Board carry discussions on this branch of winter maintenance, beginning with the meeting of November, 1922 These various bulletins appear to cover all features pertinent to snow removal from rural highways ranging from economic considerations of the subject to studies of snowfall, drift prevention and comparisons and descriptions of the various equipment employed in the work

The first mention of this important subject is found in Bulletin No 32, where experiments of the Wyoming State Highway Department are briefly described relative to the elevation of grade lines to eliminate snow hazards and in this connection, Mr Z E Sevison, State Highway Engineer, states. "It is our practice to lay the grade line 12 to 18 inches above the natural surface of the contiguous ground The cuts are eliminated except in cases where it is unavoidable in order to secure satisfactory grade. We do not hesitate to deviate from tangents or section lines in order to secure the proper locations on account of snow conditions

"This has practically eliminated the snow hazard on all of our constructed projects There is no question in my mind but what this is the proper construction in a windy county subject to drifted snow There would probably be nothing gained by adopting this plan in those sections where there is very little wind to sweep the snow off the surface of the road"

The Proceedings of November, 1923, refer to a study of the subject of snow removal proposed to be undertaken at that time by the U S. Bureau of Public Roads, and also carries the statement that "the committee believes that further research is necessary on this subject, particularly with the end in view of developing snow-removal equipment for highway work"

The Proceedings of the Fourth Annual Meeting (1924) includes a general tabulated summary of snow removal data and discussion of the subject by Mr W A Van Duzer, of the Pennsylvania State Highway Department The table of data carries the average cost per mile of snow removal work for several States which range in cost from $2 00 per mile for the State of South Dakota, to $400 00 per mile for Nevada, but inasmuch as climatic and working conditions, experiences and methods, are not described in relation to the various costs they should not be used for comparable purposes

Mr Van Duzer discusses snow removal equipment as follows: "It would seem that it is generally agreed that heavy equipment, i e. caterpillar tractors with "V" plow, is most practical for moving heavy accumulations of snow, say in excess of 24 inch depth Lighter equipment, typically 3 to 5 ton motor truck equipped with straight blade of moldboard pattern, is most economical and efficient for moving lighter accumulations of snow

"In estimating the limitations of equipment as above, 24 inches is assumed as the maximum occasional limit for the truck plow, that is, the truck plow is recommended for light work and for occasional drifts up to 24 inches, but the truck and straight blade is not considered adequate for long distances of 24 inch depth"

In connection with heavy types of equipment, we again quote· "The criticism of this type of equipment is that it leaves piled up along the side of a road a bank of snow which constantly increases the likelihood and seriousness of drifting"

And referring to the rotary type of plow, Mr Van Duzer says. "A more effective type of machine for heavy work is the rotary plow which removes the snow to a sufficient distance so that subsequent drifting is not increasingly cumulative This type of equipment, however, is a great deal more costly and I believe its maintenance and depreciation would be heavier, and that the purchases of equipment of this character would not be justified except in particular localities where extremely heavy snow and traffic conditions warrant the increased expenditure."

The report goes on in effect that the avoidance of drifting conditions is considered of greater importance than snow removal In many cases the proper study of the snow problem lies in the location or relocation of the road, frequently in determination of the grade line and the planting of hedge and other roadside growths Investigations appear to have proved that the use of snow fence greatly reduces the snow problem, and that the lighter type is preferable over the heavy or so-called "railroad" type

Proceedings (Part I) of the 1925 meeting of the Board, includes a Report on Snow Removal and Snow Removal Equipment, compiled by Mr H K Bishop, Chief, Division of Construction, from research work carried on by the U S. Bureau of Public Roads, with the report making mention of similar investigations undertaken by the Michigan State Highway Department

This report, like the preceding one, is confined to the 36 so-called snow States and to rural roads For these States it is set forth that for the three winters ending with 1924–25, the amounts expended for snow removal work increased from $760,000 to $1,380,000 and as each season shows a material increase over the last, the statement was ventured that snow removal and control was gaining in popularity at that period

With snowfall averaging 20 seasonal inches in some sections of the snow area, to 392 seasonal inches in others, it was apparent that no particular class of equipment or method of work could be recommended for the 36 States, but in order that studies could be made relative to the more efficient and economic work, the different types of plow were discussed and for convenience segregated as noted below.

1 Straight blade plows attached to trucks
2 V-shaped plows attached to trucks.
3 V-shaped plows attached to tractors
4 The rotary type of snow agitator

The report, under these captions and with suitable illustrations, attempts to describe the different plows and estimate their accomplishments

This report notes the absence of any reliable comparable cost data figures as follows.

"The average cost of snow removal per mile is a very indefinite figure It varies so widely between one State and another and even between counties in the same State that little information can be given on the subject The cost of snow removal varies with the density of the snow, depth and length of drifts, and width of traveled way provided One mid-western State with considerable snow to contend with, reports that 2,580 miles of road was maintained for wheeled traffic during the winter of 1924 and 1925 at an average seasonal cost of $22 52 per mile The average width to which the snow was removed on this system of highways

was probably 24 feet and the average seasonal snowfall was 46 inches This average cost per mile was considered by the State as remarkably low as compared with the average cost per mile of $59 12 for the winter of 1923 and 1924, and was attributed partly to the fact that a great many units of new modern equipment were placed in operation last winter which decreased the amount of hand shoveling that had been necessary

"A northeastern State with considerable snow cleared 406 miles of road last winter at an average seasonal cost of $44 00 per mile The width cleared averaged 24 feet

"One of the north-central States reports 400 miles of road cleared at a seasonal average cost of $44 96 per mile In this area the snowfall ranged from 53 to 70 inches deep and the width of roadway cleared was 24 feet where possible.

"In order to illustrate the variable cost of snow removal, the following is quoted from an eastern State

" 'The number of miles in the 1924–25 program was 816, the total cost of snow work was $223,117 and the average cost was $273 per mile, but the average cost does not have much significance as the cost on the minimum section was $8 70 per mile and on the maximum section $2,033 Snow is removed to a uniform width of 20 feet except in a very few instances where it is removed up to 30 feet ' "

The report closes with a discussion of drift prevention in its various phases.

Proceedings 1926 The report considered by this meeting was also written by Mr H K Bishop, sub-committee member, contemporaneous member with Mr G C Dillman, Deputy Commissioner and Chief Engineer of the Michigan State Highway Department The winter of 1925–26 is considered with numerous illustrations included in the report along with a table of comparative snow removal data, and also a map of the county showing snow removal programs for the next snow season

In these proceedings it was set forth that "Open roads for winter traffic" had grown considerably in popularity and activity since the last report on snow removal from rural highways and snow removal equipment was presented by the sub-committee Enthusiasm for winter maintenance had augmented to the stage, as judged from extended observations, where the taxpayers demanded open roads the year round regardless of the cost, and would have snow removed from their main highways even if the funds required for that purpose curtailed their summer road construction program Highway officials of the thirty-six snow States had reported to the Bureau of Public Roads that 62,165 miles of highways were kept clear of snow during the winter 1924–25 by their maintenance departments, with $1,826,800 expended for the work, and also that for the winter 1925–26 the roads cleared were increased to 93,000 miles with $3,757,660 expended This made a tangible increase in terms of miles cleared of approximately 50 per cent

With further economic consideration of the subject, the report continues.

"At the close of the calendar year 1925, or during the winter under discussion, approximately 376,575 miles of paved rural roads were in place, both on and off the State systems, extending over the thirty-six snow States, and 16,139,859 motor vehicles were under registration in the same territory This motor vehicle registration for the snow States represents 66 per cent of all motor vehicles registered over the surface of the globe The cost of the improved road mileage is not available, but it is known that over the snow States during the past five years—1921 to 1925, inclusive—three and one-quarter billion dollars were expended on highway improvement and maintenance, and it has been estimated that on January 1, 1926, there were nearly three-quarters of a billion dollars available for construction and maintenance of rural roads over the snow territory for the calendar year 1926 It is also known that the motor vehicles registered over the snow area carry a purchase cost of fourteen and one-half billion dollars and require for their upkeep, tires, garage and fuel, an amount aggregating four billion dollars annually With the vast sum expended on paved roads and the staggering cost of their motor vehicles, the taxpayers and traveling public definitely realize that the interest on the investment for highway improvement and on the purchase cost of motor vehicles is going on during the entire year, and are demanding greater mileage of open roads during each successive winter to the extent that it is apparent that snow removal from rural highways is with us to remain; it is not a passing fad, but a well-established business along with the improvement of highways and manufacture of motor vehicles"

Some of the benefits derived from open roads during the winter are enumerated With open roads maintained during the snow season, protection from fire in rural communities is afforded to some extent throughout the year, the physician can visit his patient with necessary frequency and the country merchant can keep his store stocked with merchandise at a minimum carrying expense The U. S. Post Office Department supplied the information that 31,600 rural free delivery vehicles used 869,390 miles of road yearly over the 36 snow States, and served 21,296,400 patrons All year open roads prevent more or less interruption in the flow of mail and benefit beyond calculation millions of our citizens An official of the U. S. Bureau of Education stated, through a printed publication, that during the school year 1925–26 more than 585,000 pupils were transported over rural roads to 4,300 consolidated schools located in eight of the snow States, at an expense of $15,800,000, and it was estimated that proportionate figures might be considered for the remaining States in the heavy snowfall area Open roads during the winter months tend to make uninterrupted attendance at these schools possible, and provide the opportunity for suitable education of all children living in the snow area with equal ease of those living elsewhere

The report continues with estimates of the depth of prevailing snowfalls, the efficiency of artificial and natural drift prevention and the possibilities of different types of snow removal equipment. Without paying any attention to snow precipitations of less than 2 inches in depth, it was learned from a study of the U S Weather Bureau records

throughout a period of four seasons and over scattered areas that by far the greater number of storms deposit snow between two and three inches deep or between three and five inches deep, with those falling between five and seven inches deep materially few in number, and storms with resultant snowfalls of seven to nine inches or greater than nine inches deep, comparatively infrequent Or, in terms of percentage, 33 per cent of the storms during the four seasons studied deposited snow two to three inches deep, 29 per cent deposited snow three to five inches deep, 22 per cent deposited snow five to seven inches deep, 8 per cent seven to nine inches deep, and 8 per cent greater than nine inches deep The cause and cure of snow drifting conditions are discussed to some length as is the higher efficiency of fast-moving truck plows over the slow-moving tractor plows with the high cost of operating a tractor These items were carried by the text to bring out the point as exemplified, thus

"Nearly all of the State officials in the heavy snowfall area of the country report that newly fallen snow to a depth of nine inches, and recently drifted but not packed or crusted snow to a depth of 36 inches over short sections, can be efficiently moved with truck plows, and the records of the United States Weather Bureau supply the information that snow falling to a depth greater than nine inches is of rare occurrence, and of those that do fall greater than that depth, but very few of them occur within separate 24-hour periods From the above facts it appears that the problem of 'open roads for winter traffic' at the minimum expense may be solved to a greater or less extent by the effectual use of snow fences and other methods of drift prevention at locations determined after careful surveys, and the employment of as numerous a fleet of the lighter type of plows as the trucks available will permit"

The report closes with a description of a very heavy forward type rotary snow plow used at least in one county of northern Michigan

Meeting of December, 1927 . These proceedings, as before, carry a report on snow removal by Mr Bishop, which report is liberally illustrated and like the others includes the table of data and a reproduction of the Government map This report contends that snow removal work needs no further promotion for the reason that open roads for winter traffic have been sold to the taxpayers and users of the highways because they view cleared highways as a matter of fact and expect open roads to exist during the snow season the same as they are provided with well-maintained surfaces during the remainder of the year In respect to the different types of plow, the text states that with the exception of such progressive improvements in snow plows as might be expected, this type of equipment remains essentially the same as formerly reported, those engaged in the work appear to be giving their attention chiefly to the motive power employed in order that wider roads may be opened and maintained with the greatest possible speed. The mold board snow plow, the lighter and heavier types of "V" plows and the rotary

plows, all continue popular, but the engineers in charge of their use have, through careful study and experiments, become able to specify fairly accurately the types most suitable for use under various conditions and with different types of motive power.

The report then continues with the thought that while the heavier types of tractor plows are highly useful and expedient during and after very heavy storms and for widening work, it has been found that fast moving truck plows are more efficient and economical for ordinary conditions Various high speed trucks are then illustrated which are considered suitable for straight blade, V-shaped and rotary plow mounts The report closes with a description of an auger type rotary plow suitable for truck mount, and a bank sloper attachment used with rotary plows for attacking high banks, employed in the State of Michigan

GUIDE, CAUTION AND DANGER SIGNS

This subject is covered in the published reports of the maintenance committee to be found in both 1924 and 1925 annual reports of the Highway Reaearch Board

Details relative to the standardization of shape, color and size of Guide, Caution and Warning signs are discussed Reference is made to activities of the American Association of State Highway Officials in this matter and to the action of a joint committee and from the United States Bureau of Public Roads and the various State Highway Departments, which committee was appointed by the Secretary of Agriculture.

CAUSE AND CURE OF FROST BOILS

The term "frost boils" is given to the heaving of soil caused by an addition of water to this soil after the ground is already frozen The difference in the expansibilities of frozen soils amounts to not over $2\frac{1}{2}$ inches in 5 feet of frost under the freezing of the saturated soil Since the rise in elevation caused by frost boils is much more than this, it is quite evident that the cause must be something more than a simple difference in expansion between two soils of different characteristics adjacent to each other The frost boil, then, must come from an actual moisture transfer through the frozen soil which may be partly by capillarity and partly by a transfer of moisture vapor Still another type of frost heave exhibited beneath pavement, but which is not a true frost boil, is caused by the flow of free water beneath the pavement to some point where further flow is obstructed and freezing takes place

The remedy for frost boils is, of course, drainage as soon as possible This may be affected by cutting a hole through the ice in the shoulder and placing porous material in the cut through which the water can drain After they have formed, if the soil beneath is porous, drainage is sometimes accomplished by use of a steam jet forced down through

the frozen soil and opening up drainage to the porous soil beneath If the soil is heavier in texture, drainage may be affected by thawing a hole through the shoulder at as low an elevation as possible and permitting the water to drain out of this hole laterally If porous materials are used in an attempt to cure frost boils, they must be thick and connected to tile system in order to secure free and rapid underdrainage Points at which these frost boils will occur cannot now be predicted before construction, although they occur at the same place after the road is built, year after year A more thorough knowledge of soils and the method of moisture transfer through them may at some future time enable us to remedy this situation before it occurs

MAINTENANCE MACHINERY FOR GRAVEL ROADS

Previous reference is made to this subject on page 71 of the 1923 report of proceedings of the Highway Research Board

A sand distributer design by the Idaho Department of Public Works is described

The Committee feels that the matter of maintenance equipment in general is important and that this should be made the subject of future investigation.

BITUMINOUS TREATMENT OF EARTH SAND-CLAY AND TOP SOIL ROADS

The treatments of earth, sand-clay and top-soil roads with bituminous material is practiced in some places and *under certain conditions* this work seems to justify itself This class of work is done for two purposes, First, to lay the dust, and second, to form a bituminous mat which not only serves as a dust layer but also provides a more solid surface for traffic

Earth Roads

The bituminous treatment of earth roads is done only to a very limited extent by one of two methods

First Method Where such treatment is applied as a dust palliative only, a light grade of non-asphaltic oil (Sp Vis Engler 50 cc. at 25°C.—5 to 15) is used in two applications of 0 2 to 0 3 gallon each, the first being applied at the beginning of the dry season and the second 4 to 6 weeks later It is desirable to level the surface before the second treatment by filling all holes. This treatment serves only as a temporary dust allayer. (The Pennsylvania State Highway Department has used light oil for allaying dust on earth roads)

Second Method To the properly shaped and compacted earth surface is applied, at the beginning of the dry season, about ½ gallon per square yard of an asphaltic oil ranging in specific viscosity of from 8 to 42 (Engler 50 cc at 60°C) which is followed within a couple of months

with a second treatment of $\frac{1}{4}$ to $\frac{1}{2}$ gallon per square yard The lower viscosity oil is used on the first treatments The purpose of this treatment consists in saturating a top layer of earth with the Asphaltic Oil so as to make a sufficiently strong road crust to withstand the wheel traffic This surface breaks up under any amount of farm traffic or heavy trucking and costs from $500 00 to $800 00 per mile per year It can only be justified where no gravel or stone is available at a reasonable price Such treatments have been practiced quite extensively in the State of Illinois

Sand-Clay and Top-Soils

Bituminous Surface Treatment of Top-Soil and Sand-Clay Roads The treatment of top-soil roads is practiced fairly satisfactorily in some of the southern States and the treatments are very similar to the practice of treating gravel roads

Treatments on top-soil which are giving results are where the top soil is composed largely of gravel and where perfect sub-soil drainage prevails Such treatments consist primarily in treating the smooth and compacted surface which has been previously swept clean of dust and loose material, with a light tar (Sp Vis at 40°C of 8 to 13) or a 60 to 70 per cent Asphaltic Oil (Sp Vis Engler 122°F 25 to 45) to the amount of about $\frac{1}{3}$ gallon per square yard After this first treatment is properly hardened a second coat of hot tar of Asphaltic Oil is applied at the rate of about $\frac{1}{4}$ gallon per square yard This second coat is covered with stone or gravel 1 to $\frac{1}{2}$ inch size The bituminous surface thus formed is maintained by patching from time to time with a suitable bituminous material and aggregate, and by the successive treatments of tar or Asphalt covered with a suitable covering material. Such treatments would only be satisfactory in climates not susceptible to frost action or in a semi-arid climate and only when perfect sub-drainage exists However, when suitable conditions prevail, this class of road maintenance is warranted Perhaps the best details of this class of work may be secured from the State Highway Departments of California and the Carolinas.

The light treatments on sand clay roads are not very satisfactory. The tightly bonded surface does not permit of proper penetration of the oil and furthermore when the clay becomes wet it loses its stability, causing the surface to break

DUST PREVENTION AND SURFACE TREATMENT ON GRAVEL ROADS INCLUDING SIZE OF MULCH GRAVEL

This subject is covered on pages 270–273 of the 1927 annual report of the Highway Research Board

With the large variety of dust laying materials and especially grades of bituminous materials, a great variety of methods have been used to

lay the dust on gravel roads and furnish a bituminous mat to carry the traffic However, this work may be standardized into certain classes, the two principal sub-divisions of which are

(1) *Dust Palliatives* consisting of the use of Calcium Chloride or a light grade of oil, without the formation of a mat and wherein the dragging operations are continued as routine maintenance and small amounts of gravel or stone added from time to time.

(2) *The building up of a bituminous* mat by the use of an Asphalt or Tar product made by either (a) the addition of covering material to applications of tar or asphalt intended to penetrate the solid clean gravel surface, or (b), treating a layer of loose material on the surface

1 Dust Palliatives

Cold Oil Treatments Method (a) At the beginning of the dry season a light grade of cold oil is applied to the gravel surface in the amount of about 0 3 gallons per square yard This is followed by one or more treatments in the amount of about 0 2 gallon each at intervals of 4 to 6 weeks When the oil is applied there should be on the surface $\frac{1}{2}$ to $\frac{3}{4}$ inch of *loose clean gravel* Small amounts of clean gravel are added between applications and the surface maintained by routine dragging as on an untreated gravel road This method of treatment contemplates the avoiding of the formation of a mat in order that the routine maintenance by dragging can be continued, thus preventing "pot" holes from forming When a soft surface results from wet weather or frost action maintenance of the road continues the same as on an untreated road The grade of oil used for this surface usually has a specific viscosity at 60°C of from 8 to 28 and must be of such a nature as to have the least tendency to form a mat

Method (b) A second method of cold oil treatment which seems to be giving results in some places, consists in first scraping the loose gravel on the surface to the side of the road with a road grader and then applying about $\frac{1}{2}$ gallon of the light cold oil per square yard and immediately thereafter scraping the loose material from the side of the road back onto the fresh oil This system necessitates that the loose material be on the side of the road before the application begins as the system requires that the loose material be applied on the *fresh* oil before it all penetrates in the road surface or reaches the tacky, sticky stage which would seriously interfere with the spreading of the covering material in the fresh oil The surface is maintained in a smooth condition by ordinary dragging as in (a)

If a rough surface or pot holes develop at any spot, the surface may be lightly scarified or a small amount of new gravel may be added, and the surface given another oil treatment as in the first instance, using,

however, only such quantity of the oil as will be required to barely saturate the loose gravel Method (b) ordinarily contemplates but one treatment a year Wisconsin has done this class of work to some extent

In either Method (a) or (b), it is necessary to have gravel *comparatively free from clay or soft calcareous material* to prevent the formation of a mat Disintegrated granite or other hard stone is as suitable as gravel in this method of treatment

Calcium Chloride ($CaCl_2$) Treatments Calcium chloride treatments consist in the application of 1 to $1\frac{1}{4}$ pounds of calcium chloride per square yard of road surface at the beginning of the dry season followed in about 6 weeks with a subsequent application of about 1 pound per square yard, or followed by two $\frac{1}{2}$ to $\frac{3}{4}$ pound treatments about 4 weeks apart When the treatment is applied it is desired to have about $\frac{1}{2}$ to $\frac{3}{4}$ inch thickness of loose, properly sized gravel upon the surface Clean, coarse gravel without any binder is not desirable for this purpose The surface is maintained in a smooth condition and free from pot holes by routine dragging as in maintaining an ordinary gravel road Small amounts of gravel are added from time to time as may be necessary to prevent pot holes from forming Gravel having a *small amount of clay or other soft filler retains the effect of the calcium chloride better than does perfectly clean gravel* Calcium chloride is much more effective in shaded than on exposed surfaces, hence, it is desirable to slightly vary the quantity of the treatment to fit the conditions of the surface being treated

The States of Michigan and Vermont have used $CaCl_2$ quite extensively as a dust layer on their State Highway Systems

Both the Cold Oil and the Calcium Chloride treatments produce a small cumulative effect as the gravel becomes more or less saturated with the treatments Hence, treatments in following years may require slightly less material

It should be observed that *cold oil* treatments give best results on gravel or disintegrated rock *comparatively free from clay or a high* cementing binder while the *$CaCl_2$ gives best results when there is a reasonable amount of such* binder present

Not all Dust eliminated by Cold Oil and Calcium Chloride Treatment It must be kept in mind that all the dust is not eliminated by either the Cold Oil or the Calcium Chloride treatment described above However, the reduction is such as to justify their use under certain conditions

2 The Building up of a Bituminous Mat by the Use of an Asphalt or Tar Product

The construction of this bituminous mat may be accomplished in one of two ways

Method (a) By the *penetration* of light grade of tar or asphalt into

the hard compacted gravel surface By this process the old road is properly shaped and permitted to compact either under traffic or by rolling The surface is swept clean of all dust and loose material and treated with about $\frac{1}{3}$ gallon per square yard of light tar (Sp Vis at 40°C of 8 to 13), a 60 to 70 per cent asphaltic oil; or a cut back asphalt, (the latter two materials having a specific viscosity Engler 112°F, 25 to 45) After this first treatment is dry a second application of the same grade of bituminous material or preferably a slightly heavier grade is applied at the rate of about $\frac{1}{4}$ gallon per square yard The second application is covered with stone or gravel 1 to $\frac{1}{2}$ inch size The bituminous surface thus formed is maintained by patching the small holes that break in the surface with a mixture of the bituminous material and a properly graded aggregate Future treatments are applied to the amount of about $\frac{1}{4}$ gallon per square yard and covering material, as the traffic and condition of the road surface require Following the treatments on which covering material is used, the surface may be dragged so as to level same

The amount of traffic and the kind of traffic that such a surface will carry is proportionate to the stiffness of the gravel crust before treating This will vary with the depth of gravel, sub-soil and climatic conditions and it is found that the coarser the gravel in the crust usually the stronger it will be The coarse size of this gravel will be limited only by the roughness of the surface which it will produce

The prevention of waving and shoving in the surface of such treatments will be governed by the grading of aggregate covering and the amount of bituminous material used The least amount of bituminous material on successive treatments and the greatest amount of comparatively coarse covering material used thus producing the leanest mixture that will just prevent raveling, will give the least trouble from this source

Method (b), Mulch System This system consists in spreading a layer of gravel or disintegrated rock over the old gravel surface one or two inches in thickness and treating same with the first grade of tar or asphalt mentioned under "a" above This method more properly belongs in the next general class where a description of same will be found

BITUMINOUS WEARING SURFACES FOR GRAVEL ROADS

This subject is covered on pages 270–273 of the 1927 annual report of the Highway Research Board

There has come into practice in recent years the treating of a layer of loose gravel or stone with a light or medium grade of tar or an asphalt with very promising results This method contemplates the making of a bituminous mixture of from 1 to 3 inches deep on the old gravel road by applying the bituminous material to the loose gravel or stone in

several applications The bituminous mixture is generally made by one of two processes known as (1) The Mulch System, or (2) The Bituminous Retread

1. The Mulch System

This method consists in treating a 1 to 3 inch layer of loose gravel or stone containing a comparatively large amount of sand and fine material In *one process* the bituminous material is applied to the layer of loose gravel which is afterwards scraped to one side of the road and the clean road surface thus produced given another application after which the previously treated gravel is scraped back over this second treatment and thoroughly mixed by dragging and scraping with graders and maintainers, until it hardens under traffic or the roller These two treatments may consist of about $\frac{1}{3}$ gallon each, the exact amount varying with the thickness of loose material. A third treatment of about $\frac{1}{6}$ to $\frac{1}{4}$ gallon of bitumen is applied if necessary after the mixture has hardened, to prevent raveling of the surface

Practically the same results are secured by first scraping the untreated loose gravel to one side of the road and applying the first treatment to the clean, hard surface After this first treatment has hardened a second treatment is applied, after which the ridge of loose material previously removed is scraped back over the second application of bituminous material The mixture of bitumen and gravel is dragged and bladed until thoroughly mixed and finally made smooth and compacted by traffic or rolling.

The total amount of bitumen required will vary with the grade of bitumen and aggregate being used as well as the quantity of aggregate. It will usually be close to $\frac{1}{2}$ gallon per inch of depth of loose material Experience has shown that best results are secured if the mixture is made so lean of bitumen that it shows signs of raveling and then a light coat of about $\frac{1}{6}$ gallon applied a little later to prevent the raveling

The bitumen for this work may be a Tar of 10 to 40 viscosity (Engler 40°C), a Cut Back Asphalt of 20 to 180 viscosity at 122°F , or a 60 to 70 per cent fuel oil of 25 to 45 viscosity as used in California The first application should be of the lighter grade of material if the aggregate contains much fine material The coarser the aggregate the heavier the bituminous material that may be used. The heavier materials require heating before they are applied.

Experience *in places* seems to indicate that the more durable surfaces produced by this process contain a small percentage of fine material and relatively large proportion of aggregate $\frac{1}{2}$ to $1\frac{1}{2}$ inches in size When the aggregate is *increased in size* the process of mixing in place on the road is done by a slightly different method described below under "Bituminous Retread "

2 Bituminous Retread Top

This process may be briefly described as follows

Two to 3½ inches of aggregate (concrete aggregate size or coarser) is spread upon the road surface and leveled by heavy graders and drags, lining up the edges by hand work While concrete aggregate size is used, it is found that best results are secured by using stone from 1 to 2½ inches in size, where the stone is not of very hard quality This size aggregate can be leveled with a grader or maintainer and if the work is properly performed, a smoother riding surface can be produced than by hand methods of leveling

To this layer of coarse aggregate is applied three successive applications of the bituminous material After the first application of bituminous material the aggregate is leveled with a grader or planer if necessary and after the bituminous material has become stiff and tacky in process of curing, the aggregate is thoroughly rolled with a 10 ton 3 wheel roller After the mixture has become fairly solid and firm, a second application of bituminous material is applied and the surface again well rolled Just before the third application of bituminous material the voids between the coarse aggregate in the surface are well filled with loose ¾ inch size aggregate and the third application of bituminous material applied and the surface dragged and planed to produce a level riding surface and again rolled No rolling is done on the covering material before the third coat of bitumen is applied and dragged, the process resulting in well filling the voids in the surface with bituminous coated stone

The grade of bituminous material apparently giving best results for this purpose is a cut back asphalt from 50 to 200 viscosity at 220°F or tar from 20 to 40 viscosity at 40°C The lighter grades of tar or asphalt should be used on the first application if there is much sand or fine material in the aggregate, where-upon if the aggregate is comparatively coarse and open, the heavier grades of tar or asphalt may be used in all applications

The secret of success with either method (1) or (2) above, lies in the producing of a smooth riding surface resulting from the mechanical spreading of the aggregate and in the application of just the right amount of bituminous material to prevent raveling of the surface The use of any excess of bituminous material will always be the source of shoving and pushing later on under heavy traffic

The exact amount of bitumen required will vary with the grading and quality of the aggregate as well as its thickness. Ordinarily the three treatments for a 2½ inch loose layer of aggregate may be given as 0 4, 0 3, and 0 3 gallon per square yard respectively

The heavier the traffic the leaner the mixture can be While the proper amount of bituminous material will generally be less than ½

gallon per inch of depth of loose aggregate on the road surface to be treated, the exact amount will vary with the grading and kind of aggregate and with the quality of bitumen and can not be definitely told except by actual experience

One should always be conservative in the amount of bitumen applied, permitting the road to be used by traffic and adding a small additional amount of bitumen where necessary in order to avoid raveling, rather than add too much in the beginning It is frequently best to permit a small amount of raveling rather than put on an excess of bitumen as the raveling can always be taken care of by patching or applying a small additional amount of bituminous material Such a surface is maintained by successive treatments as in maintaining a bituminous macadam or surface treated road

These cheaper types of road surface do not produce a surface which will remain ideal without attention from time to time It must be recognized when starting this class of work that attention to the maintenance of up-keep of the surface will be required and unless the work is undertaken with this requirement contemplated, it will not be a success With proper attention given these cheaper types of surface they are frequently justified on the lighter traveled roads

BERM MAINTENANCE

This subject is covered on pages 295–298 of the 1927 annual report of the Highway Research Board

Grassed and ungrassed berms are discussed Also, maintenance methods, maintenance costs and special features

MAINTENANCE COSTS AS AFFECTED BY TYPE OF PAVEMENT AND AMOUNT OF TRAFFIC

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The general belief is that the higher types of pavement are the most economical in maintenance costs and the maintenance records of the Pennsylvania Department of Highways appear to substantiate this belief

The records of 1924 to 1927 inclusive show the following types, mileage, average annual cost of maintenance, and order in economy The maintenance costs, as used here, include the items of grading, base, surface, drainage structures, roadside, traffic service, betterments,