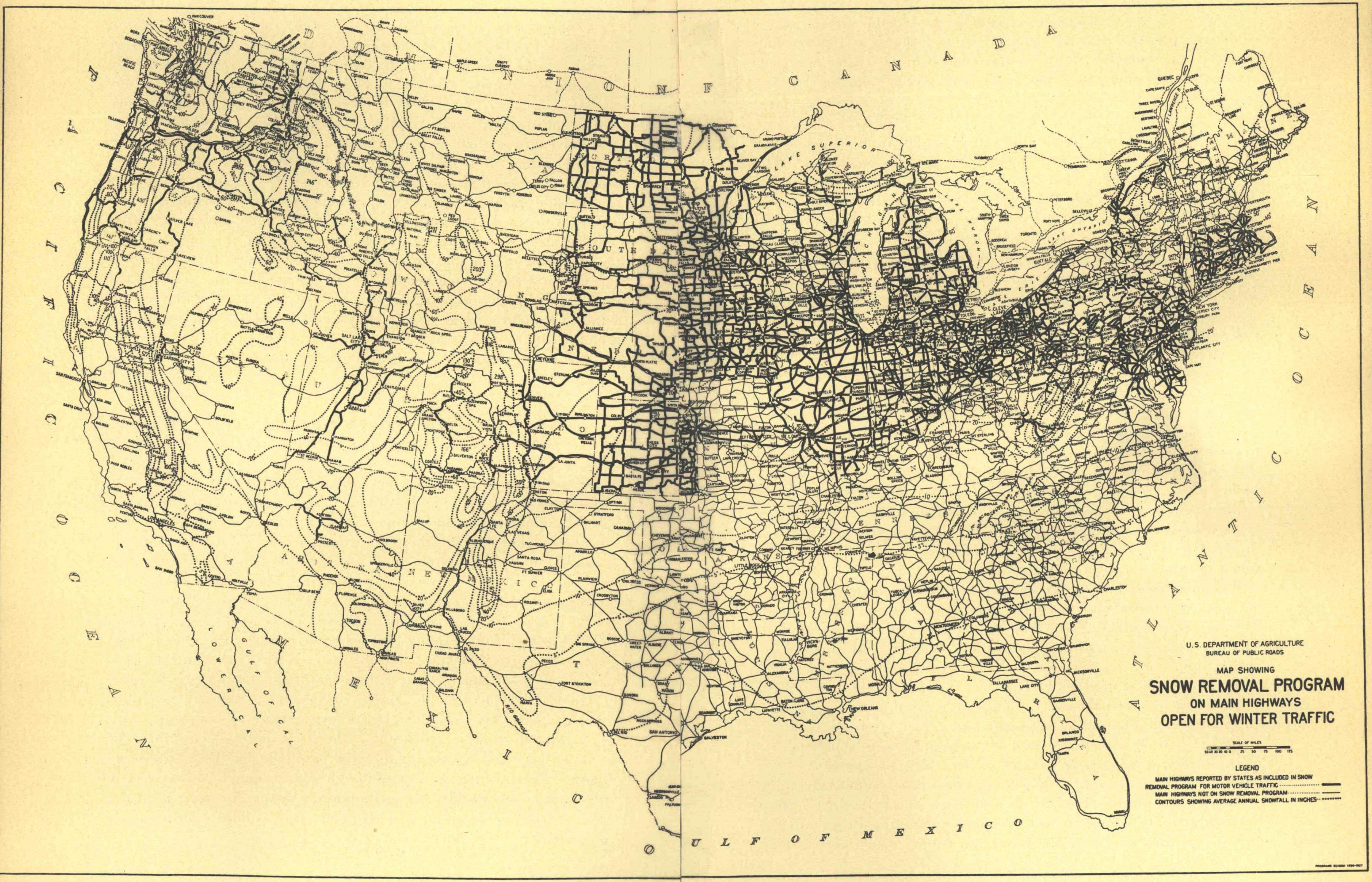
to arrive at relative costs of snow removal per inch mile with varying results In the event, for instance, of snow falling to a depth of seven inches without wind, both during its fall and immediately afterward, and its removal attacked before the snow has become settled, or packed by traffic, its removal would cost comparatively little Provided, however, such a blanket of snow was left on the roadbed until it had become crusted or unevenly packed by traffic, or prevailing winds had caused it to drift badly, the cost for its removal per inch mile would be much greater

Table I gives comparative snow-removal data covering the past four winters with the exception of one The table, along with other information, gives the quantities numerically of the various types of equipment available for use over the snow States during the past winter and the funds expended for snow-removal work, and also the mileage of roads proposed to be kept open for winter traffic during the approaching snow season On pages 348 and 349 is a map of the United States with the main roads indicated which are proposed for all-year traffic through the heavy snow States during the winter of 1926-27.

III COVERING FOR POORLY CONSTRUCTED AND DISINTEGRATED CONCRETE ROADS

There is no denying the fact that the construction of early concrete pavements was haphazard and the workmanship very poor Riding quality was not so important as it now is, because traffic was nearly all horsedrawn, therefore slow moving A surface that was satisfactory under slow-moving wheels became very disagreeable with the advent of the high-speed automobile The quality of the materials used in construction did not receive the consideration deserved, as a matter of fact, pit run gravels were used in the construction of some of our heavily traveled roads Where the sand to stone ratio approached the ideal, and the material was free from clay, good results were obtained Where these conditions did not prevail, steel-tired traffic soon wore the surface down, and disintegration under impact took place rapidly In the early stages of concrete paving construction, it was expected that the wear under steel tires would expose the coarse aggregate after the pavement has been in use one year For this reason a hard tough coarse aggregate, as close to the surface as possible, was an important factor, for the reason that the surface mortar would wear off much more rapidly than the coarse aggregate


U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
MAP SHOWING
SNOW REMOVAL PROGRAM
ON MAIN HIGHWAYS
OPEN FOR WINTER TRAFFIC
SCALE OF MILES
LEGEND
MAIN HIGHWAYS REPORTED BY STATES AS INCLUDED IN SNOW REMOVAL PROGRAM FOR MOTOR VEHICLE TRAFFIC
MAIN HIGHWAYS NOT ON SNOW REMOVAL PROGRAM
CONTOURS SHOWING AVERAGE ANNUAL SNOWFALL IN INCHES
DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE HURON
LAKE ONTARIO
GULF OF CAL
LOWER CAL
RIO GRANDE

In order to get the coarse aggregate as close to the surface as possible, the proportions were changed from 1 2 3½ to 1 2 4 This reduced the thickness of the mortar coat over the coarse aggregate and gave a pavement that stood wear much better than the 1 2 3½

CHANGE IN TRANSPORTATION UNITS

Now that practically all freight and passenger traffic is carried on rubber tires, the wear on our concrete pavements is negligible The marks of the finishing belt are still discernible on concrete pavements laid five years ago that carry very heavy traffic It is universally conceded that modern concrete pavements do not wear out The life of concrete pavement is a direct function of its rate of cracking Deterioration, or cracking up, is brought about by temperature changes causing expansion and contraction, by impact from heavy loads at high speed and from subgrade disturbances In general, the demand for a new surface is not because the sustaining power of the old slab is insufficient but because of the fact that the old surface is so rough as to make it uncomfortable to ride over, and the impact set up by this rough condition causes still further destruction

In covering an old concrete pavement, which in the majority of cases is a matter of necessity due to roughness, some means must be devised that will permit adding enough material to the low places to smooth the old surfaces and bring the surface to a true profile before the finishing course is placed The coarse aggregate in the binder course of asphaltic pavements is too large to permit of feathering to a thin edge For this reason it is not desirable as an equalizer, because too large a quantity is required The varying thickness of material used to even up a surface compresses unevenly under the roller and the result is a rough riding surface

Wisconsin is making an experiment with a cement mortar, mixed one part of cement to two parts of good sharp sand for this purpose The mortar is feathered out, and its cost is not prohibitive as compared to the cost of a bituminous binder The tar and grease is removed from the old pavement, in order to insure a bond, and a wire mesh is used to strengthen the patch Evidence that mortar will bond with a concrete slab can be obtained by noting where workmen have mixed concrete on a pavement and failed to clean it all off

This mortar equalized is opened at cracks and joints, so that movement of individual slabs or sections of slabs will not shatter the thin coating The top course is of a bituminous type, sufficiently thick to have a cushioning effect to prevent heavy loaded vehicles from fracturing the thin mortar coat They are experimenting with the mortar equalized only in a small way, but believe it merits considera-

tion A few old concrete pavements have been covered in Wisconsin as follows A section, built in 1912, was frozen during construction In 1914 a curb was placed on both sides and the surface was paved with vitrified brick Cement grout filler was used This section is in fair condition now

A section was widened and resurfaced with reinforced concrete averaging 3½ inches thick in 1917 The oil and tar was removed from the old slab and the surface was thoroughly scrubbed, using water and stiff brooms Neat cement was sprinkled over the damp surface before the new concrete was placed The reinforcement was triangle mesh and the mix was 1 1 5 2 5 Joints were placed in the new surface directly over those in the old slab This section is giving very good service

A section of 18-foot pavement, built in 1912, was widened to 24 feet in 1916 and resurfaced with asphaltic concrete Curbs were built integral with the widening of the base A 1-inch binder course and a 2-inch top course cost $1 50 per square yard in place Binder was used to even up the old surface This job is rough and has not given particularly good service The maintenance cost has been high

A very rough section of concrete was given a brush coat of hot asphalt, followed by stone chips A second application of hot asphalt, covered with torpedo sand, completed the work While this covering did not entirely eliminate the bumps, it served as a cushion and made the pavement ride much better This work was done in 1915 The only maintenance this section has had was a light seal coat in 1918 Results are as good as could be expected, considering the cost This is evidence that an asphalt mat will adhere to a concrete surface

In order to determine the tenacity with which a mat coat will cling to a smooth concrete pavement, about 2,000 linear feet of new 18-foot concrete in good condition was treated with an application of one-third of a gallon of tar, on which gravel ranging from one-fourth to 1½ inches was distributed with shovels The gravel was too coarse and the work was very poorly done However, this mat coat is still in place It has crowded to the side slightly, nevertheless, the slabs are still completely covered The average thickness is about three-eighths of an inch A surface treatment of one-sixth of a gallon of tar in 1922 is all the maintenance we have given it This experiment proves to our satisfaction that a tar mat will adhere to smooth concrete

A defective section of new concrete pavement was covered with asphaltic macadam in 1921 The holes in the old pavement were

filled with concrete When the concrete had set sufficiently, the surface received a paint coat of cold tar Granite chips ranging in size from one-fourth inch to three-fourths inch were spread over the surface and raked down smooth Tar heated to 250 degrees was then poured on with pouring pots, care being used not to fill the voids entirely One-half-inch stone chips, sufficient to fill the voids, were then applied and a seal coat poured A dusting of fine stone chips completed the work No roller was available, so rolling was omitted A seal coat was applied in 1924 That is all the maintenance this section has required It is in good condition at the present time

A section of 16-foot concrete pavement 4,000 feet long, built in 1914, was widened to 20 feet and resurfaced with 5 inches of concrete in 1924 The oil and tar was removed from the old surface and the slab was thoroughly scrubbed with brooms and water. Concrete was mixed 1 2 4 and 42-pound welded mesh reinforcement was used to hold the material in place Although the old pavement was jointed, no joints were placed in the new top The result was a badly cracked surface, however, this piece rides well and is giving very good service

An old 14-foot concrete pavement, built in 1912, was widened to 20 feet and covered with 7 inches of concrete in 1923 The old slabs were badly worn and nearly every slab was cracked longitudinally One-half inch square bar reinforcement was used, and a parting strip on the center line They believe it advisable to use parting strip where concrete is used as resurfacing The flexibility of the slab split down the center allows the slab below to warp and heave to a certain degree without rupturing the surface This work is in good condition and bids fair to be a lasting improvement

A one-mile section of poorly constructed pavement, built in 1920, has been covered with a 2-inch top of amiesite this season This surface has been in service only a short time and they are not prepared to make any statement relative to its durability as a covering The experiments of the eastern States would indicate that it has considerable merit for resurfacing purposes It is our opinion that the essential thing to do prior to laying Amiesite is to even up the old surface before placing the binder course and try to place the work to a true profile, and this holds true of any of the bituminous types of surfacing

Rock asphalt is being used by some of our cities as a covering for worn concrete It is easy to lay and presents a nice surface

SUMMARY

The riding quality of a rough concrete road can be materially improved at small cost by a thin mat of tar. This mat will also reduce the wear

If an old concrete pavement is not strong enough to bear the traffic, its life can be materially lengthened by resurfacing with a bituminous top, or such a slab can be strengthened and made to serve for many years by resurfacing with concrete

It is considerably cheaper to cover the old slab than it is to remove the old slab and replace entirely It costs from 50 to 75 cents per square yard to remove old concrete, and when it is removed, the next thing is to find a place to put it. If left in place, it certainly serves to support the new slab

If an old pavement has sufficient stability to withstand the traffic and an asphalt concrete is used to even it up, it is nearly as cheap to widen the base 2 feet on each side and build the curb integral with the widening as it is to build vertical curbs alongside the old slab

If bituminous tops are to be used on our rough concrete roads, some kind of an equalizer that can be used in the shallow depressions must be devised This material must be of such a nature that it can be feathered out and it must be unyielding when in place.

It is realized that as traffic increases in density, weight and speed, older pavements will require replacing or covering that will prolong their usefulness and better the riding quality In other words, it is apparent that present concrete surfaces will eventually become concrete bases to sustain some future type of surfacing material that can be replaced from time to time quickly and cheaply without delay to traffic. Good riding quality is a better sales argument than extreme lasting quality ever will be.

On page 259 of Part I of the Proceedings of the Fifth Annual Meeting of the Highway Research Board, a number of Ohio resurfacing jobs were noted for future study An inspection of these roads this year showed them to be in the following conditions

Ohio, Ashtabula County, State Road 151, Section E, just west of Andover —The old concrete road was built in 1912 of plain concrete 6 inches thick, 16 feet wide, and 1 22 miles long It was resurfaced in 1921 with a 3-inch brick top Good condition

Ohio, Geauga County, State Road 15, Section G, just west of Scottland —The old concrete road was built in 1915, 6 inches deep to a width of 14 feet and a length of 1 52 miles In 1921 it was widened with concrete to a width of 16 feet, and resurfaced with 4-inch brick surface with tarmastic filler There are many depres-

sions in the surface due evidently to base failure This section has become much worse during 1926

Ohio, Huron County, State Road 290, Section G-2, west of East Townshend —The old concrete road was built in 1914, 6 inches thick and 14 feet wide and 0 85 mile long, of plain concrete In 1924 it was widened to 20 feet with concrete and resurfaced with a 4-inch brick top with asphalt filler. Present condition good

Ohio, Huron County, State Road 290, Section G-1, length 1 75 miles —The old concrete constructed is the same as G-2 above It was widened in 1922 with concrete 18 feet, and resurfaced with brick 3½ inches thick with asphalt filler and 12-inch concrete curb built on either side The present condition is good.

Ohio, Licking County, State Road 47, Section F, 3 92 miles long, just east of Granville —The old road was built in 1914 of plain concrete 5 inches thick on the sides and 7 inches in the center. In 1925 it was widened to 20 feet with concrete and resurfaced with reinforced concrete 5 inches thick in center and 5½ inches on the sides Recently completed

Ohio, Lorain County, State Road 3, 5 62 miles, Section J, west of Oakpoint —The old road was built in 1915 of plain concrete, of Oakpoint; 6 to 7½ inches It was not so badly broken but narrow and dangerous for the heavy traffic, hence it was widened in 1923 to 18 feet with concrete and resurfaced with bituminous concrete hot mix top Cracks are not on the increase and are showing tendency toward healing

Ohio, Muskingum County, State Road 344, Section E, 1 07 miles long, north of Dresden —The old road was built in 1912 of plain concrete 6 inches thick It was badly broken and disintegrated, when in 1921 it was resurfaced with 4 inches of concrete, part of it plain and part of it reinforced with wire mesh The surface at present is cracked quite badly

Ohio, Trumbull County, State Road 150, Section G, 2 86 miles long —The old concrete road was built in 1915 of plain concrete 6 inches thick and to a width of 10 feet It was badly broken and disintegrated and was widened in 1924 to 16 feet with concrete and resurfaced with rock asphalt A few additional pot-holes have developed Rock asphalt has shoved over the curb in a few places

Ohio, Huron County, State Road 290, Section N, 1 32 miles long —The old road was built of plain concrete 6 inches thick and 12 feet wide In 1915 it was widened to 16 feet with waterbound macadam strips along each side In 1919 it was resurfaced with brick to a 16-foot width using alphalt filler In 1922 a 24-inch

wide concrete gutter was built on each side, making a total width of pavement of 20 feet. Condition of entire section is excellent.

The same report listed some experimental sections in Indiana which have been inspected this year and the following conditions noted

Indiana near South Bend on the Lincoln Highway, the six samples referred to in this report went through the winter in splendid condition except No. 1 which disintegrated slightly. It was patched this spring and looks to be in very good condition at this time. No. 5 which was a bituminous macadam disintegrated quite extensively.

It is not believed, however, that the disintegration of either of these two types necessarily condemns them We would be more inclined to ascribe their partial failures to poor work, as will be demonstrated by the next paragraph

Indiana near Indianapolis, State Road 37 The section of road described here went through the winter in good condition None of it is breaking up even though it was only 1-inch deep On the other hand, the old concrete surface which has not been coated, broke up quite badly and is just at this time being resurfaced with six different types of surface

It was originally planned to use eight different types of surface about one-quarter mile long each as follows

One-inch bituminous concrete (Cold mix made with emulsified asphalt)

One-inch bituminous concrete standard hot mix

One and one-half-inch bituminous concrete (Amiesite hot mix, laid cold)

Three-inch bituminous macadam

One-half-inch rock asphalt on a 3-inch bituminous macadam base using only one application of bituminous material on the base

One-inch rock asphalt

Four-inch reinforced concrete

Five-inch reinforced concrete

It was finally decided to omit the two concrete sections and substitute in their stead the 1-inch emulsified asphalt

IV REDUCTION IN THICKNESS OF GRAVEL ROADS UNDER DIFFERENT TRAFFIC AND EFFECT OF DUST PALLIATIVES

It is a well-known fact that the amount of gravel disintegration, or that which is worn out and blown away from a gravel road surface under traffic, varies with the kind and amount of traffic on the road