TRAFFIC BOUND ROADS AS FOUNDATIONS FOR MORE SUBSTANTIAL PAVEMENTS

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There is ample information to demonstrate the efficiency of traffic bound broken stone, gravel and slag surfaces as subgrade treatments. During the compacting and maintaining of these materials under traffic, soft spots in the subgrade are disclosed and can be eliminated, and the minor variations in the supporting value of the underlying soils are automatically compensated for by the gradual development of an adequate thickness of surface materials when and where required Information which would permit us to obtain so accurately, in any other manner, the proper thickness of road surface for the varying subgrade conditions is not at present available. Recourse to these low type surfaces then can be considered the oldest, and to the present time as concerns the results obtained, the surest, subgrade treatment.

It is true that considered as roads they do not have all of the advantages of more expensive pavements but, as pointed out by Mr Kirk, where funds are limited, they furnish a means of carrying traffic over many locations which during certain seasons would be impassable. And after they have been in service long enough to develop adequate structural resistance to the loads imposed the objectionable surface features can easily be eliminated.

The value of this type of surface as a foundation for more substantial pavement was amply demonstrated to the writer by his experiments in Columbia, Pennsylvania, intermittently between 1912 and 1919 This work had to do chiefly with the resurfacing of street surfaces which consisted of traffic bound crusher run limestone and in some instances blast furnace slag They were dusty in dry weather, muddy in wet and many were rough and uneven. To the casual observer they were extremely undesirable To the engineer, however, they had considerable value because through years of service they had developed a structural resistance adequate for the loads imposed.

The excellent condition of these resurfaced streets which at the time of the writer's last examination in 1925, had been in service from 9 to 13 years, bears ample witness to the fact that if a satisfactory foundation is available, the transformation of that foundation into a high type, serviceable pavement is a simple and inexpensive matter

The traffic accommodated by some of the surfaces is that passing over the Lincoln Highway in eastern Pennsylvania and was maximum during the World War due to the many motor trucks traveling between Gettysburg and Philadelphia.

The experiments included surface treatments of the original traffic bound surfaces, of water-bound and penetration macadam pavements laid on the original surfaces A brief report of certain phases of this work has been published in the Engineering News-Record [1]

For the surface treatments there were used various bituminous materials, applied hot and cold, by brooms and by pressure distributors and covered with stone chips, slag and fine river sand.

For the water-bound macadam layer, the original surface was scarified and regraded to a uniform minimum distance of 2 inches below the final grade A layer of clean 1½ to 3-inch stone was then spread in thickness sufficient to conform to the final grade when compacted While this layer was being rolled, water and stone screenings were added until grout formed a wave before the wheels of the roller. If any soft or spongy spots developed during this operation, the material was removed and clean stone was substituted and thoroughly compacted Surface treatments were applied at different periods ranging from several weeks to a year after construction

For the penetration macadam layer, the original surface was scarified and regraded (using extra material if necessary) to a uniform distance of about 4 inches below the finished grade A layer of clean, dry and uniform 1½-inch stone was then spread, coated with hot bituminous binder (1½ gals per sq. yd.), covered with a layer of trap rock (¾-inch), and rolled slightly. The loose stones were then swept off, and a second coating of hot bituminous binder was then applied (about ½ gal to the sq yd.). This was covered with a layer of ½-inch trap rock and rolled until all movement in the surface ceased Before the first application of hot bituminous material, the stone layer was given a slight rolling, this being less for asphalt than when tar was used. Surface treatments were applied within periods ranging from several weeks to several months (depending on the traffic) after construction.

For patching, both hot and cold bituminous materials were used with uniformly sized and graded stone

[1] Light Bituminous Treatments for Macadam Roads, by Chester A Hogentogler Engineering News-Record, V 84, No 1, 1920

For foundations (where the traffic bound surfaces had worn too thin) blast furnace slag or crushed stone was used

From these experiments it was observed that:

1. Compacting a stone course with a roller did not give the stability which resulted from compaction by traffic extending over long periods of time

Many times it was found that the old surfaces which had worn to thickness of as little as three inches, if undisturbed, offered adequate support for the new surface. For new foundations, compacted by roller, thickness of less than 6 or 8 inches did not seem adequate

The effect of traffic and time on the constructed water-bound macadam pavements was evident from the behavior of the surface treatments When these were applied within a short time after thorough compaction by rolling, there was often a tendency to crack off, thus indicating that further compaction was occurring underneath. When, however, the surfaces accommodated traffic throughout the winter before receiving surface treatments, slightly less bituminous material was required for the first coating and no cracking off occurred In this connection it will be remembered that in one of the sections of the Bates experimental road the pressure distributing properties of one of the rolled stone base sections was materially reduced where the traffic runs started This particular section consisted of an 8-inch rolled stone base, a 1½-inch mastic cushion, and a 4-inch bituminous brick top It was reported [2] that before traffic was started the maximum pressure exerted on the subgrade by a 7130 lb. wheel load was about 28 lbs. per square inch. Immediately after the traffic runs were begun (2500 lb. wheel load), the pressure on the subgrade by the 7130 lb wheel load was estimated to be about 50 lbs. per square inch, thus indicating a loss of the bond which had previously existed The writer was present during the construction of the stone base and feels that the original compaction was all that could be secured by a road roller From his previous experience with this type of work, however, he is convinced that if, in addition to this rolling, these base courses had accommodated traffic for a considerable period, the resulting further compaction would have prevented the reduction in distributing value noted above

Therefore, the mere fact that a certain thickness of old stone, gravel or slag road has proved satisfactory as a foundation is not evidence

[2] Distribution of Wheel Loads on Pavement Sections, by H F Clemmer and C A Hogentogler Engineering and Contracting, July 5, 1922

that the same thickness of the same material compacted by roller action and receiving no direct traffic action will be adequate.

2. The most satisfactory surface treatments for the water-bound macadam surfaces under discussion were those obtained by the application of a very thin coat of refined tar, applied cold and covered with a thin layer of fine river sand all of which would pass a 20-mesh sieve.

With regard to surface treatments there naturally arises the question—which is their function or for what purpose are they used? The answer of course is variable depending on the character of the road to be treated. We will consider, however, only the surface at hand, that of a rigid, compacted thickness of stones, with structural resistance sufficient to withstand the loads imposed, whose top layer is composed of stones not less than 1½ inches in size, mechanically interlocked, which are kept in this interlocked condition by having the interstices filled with stone chips and dust. What now is lacking in this pavement that a surface treatment will supply?

Following this line of thought and investigating the behavior of a pavement of this type, under motor vehicle traffic, we find that first the stone dust binder is loosened and forced out from between the top layer of stones Consequently, serious and disastrous results, ranging from the loosening of the stones themselves to the complete destruction of the pavement, can occur It is evident that these troubles would all be avoided if at first the particles of dust could be kept from separating under the stress to which they are subjected. Whether this stress is due to shear, suction or thrust, the point is that the separation results because the stone dust lacks adhesion sufficient to hold its particles together. This then is the sole weakness of the water-bound surface; and the logical remedy is to incorporate into the dust such foreign binder as will prevent the separation of its particles

Since this incorporation into the finished surface can be evidently accomplished only by capillary attractions, the material used must be liquid at ordinary temperatures It should also attain, when set, a hardness and toughness similar to that of hard paint, its object being that of a road paint or skin rather than a wearing mat

The type of treatment which best suited this criterion was that consisting of a thin application of refined tar and covered with a blotting layer of river sand.

For the first application about ¼ of a gallon per square yard was used. The amounts for successive treatments ranged from 1 to .2 of

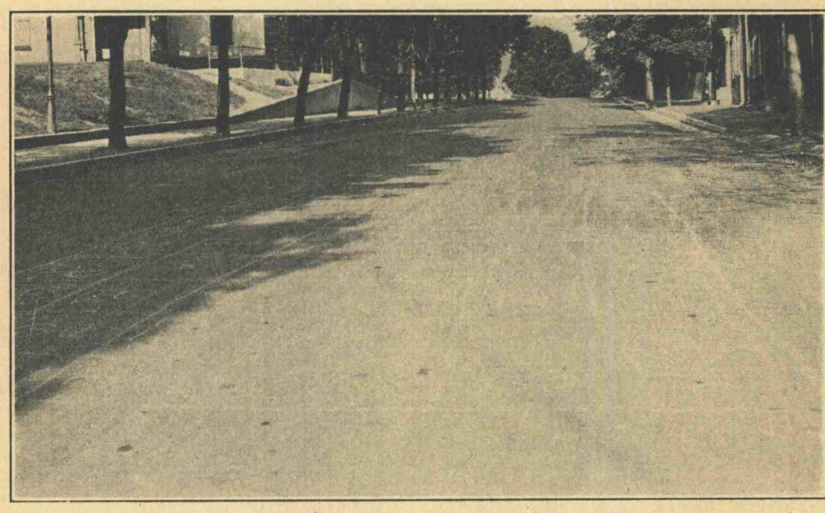


Figure 90. Water Bound Macadam Surface Maintained 4 Years with Tar and Sand Surface Treatments

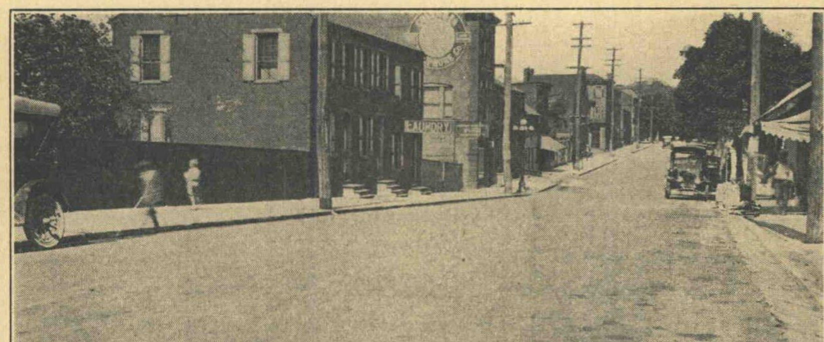


Figure 91. Water Bound Macadam Surface Maintained 7 Years with Tar and Sand Treatments

a gallon per square yard These were completely covered immediately by a layer of river sand about 1/8 of an inch thick. There resulted a hard, tough, wear-resisting, non-skid preserving coat at an extremely low cost They did not crack off, did not bunch or push, and retained their smoothness with successive applications.

The fine sand covering had several advantages First, it completely eliminated tracking of the tar by pedestrians and vehicles During seven years not a complaint was made from this source Second, it gave a very compact and tough coating which to the eye was smooth and uniform. Third, contrary to its smooth appearance, it gave a non-skid surface This was due to the fact that instead of wearing smooth, the tiny sand grains would break out, always having a sand paper finish which prevented slipping and skidding.

Figures 90 and 91 show the character of pavement resulting from these treatments The smoothness is demonstrated in Figure 90 which shows usage for the game of "hop-scotch" after four years of service. This street is on a 7 per cent grade. On one occasion, fire apparatus passed up this grade at a high rate of speed six hours after the application of tar and sand, and an examination did not show any trace of tar on the bodies of the vehicles Figure 91 shows the first surface treated It is now 15 years old and had been in service 7 years (on the Lincoln Highway) when the photograph was taken.

3 The difference in cost and behavior of these treatments on the traffic bound graded stone surfaces and the constructed water-bound macadam surfaces was such as to make it more economic to construct the water-bound macadam surface of uniform 1½ to 3-inch stones before the treatment than to maintain the original graded stone surface with treatments

There are several reasons for this On the traffic bound surfaces considerably more tar was required per application than was required for the water-bound surfaces Also, breaking out of portions of the top frequently occurred on the traffic bound surfaces This necessitated extensive patching and in several years resulted in an uneven top In the water-bound surfaces composed of uniform and larger stones this breaking out did not occur and consequently patching was not required.

This difference is shown in Figures 92 and 93 Figure 92 shows the condition which developed under heavy truck traffic in a treated surface whose stones ranged in size from 1½ inches down. Figure 93 shows the condition of a tar treated surface after having been in

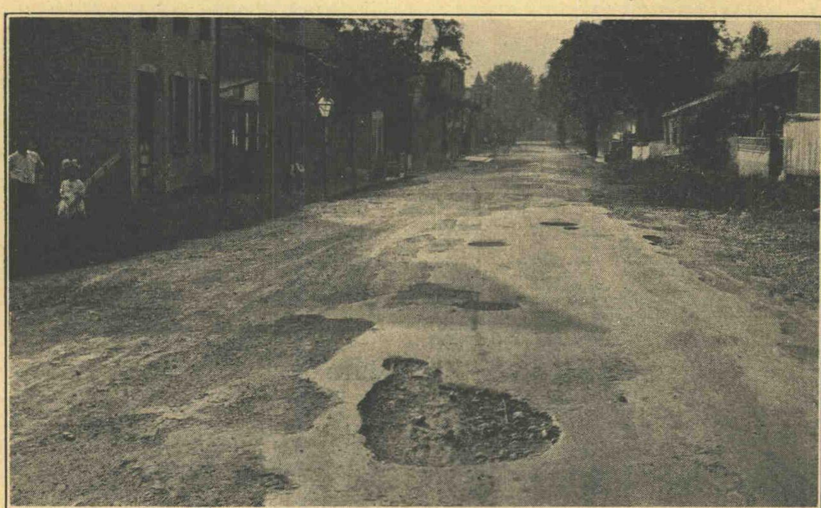


Figure 92. Traffic Bound Pavement (Graded Stones) After 2 Years Maintenance with Light Tar Treatments

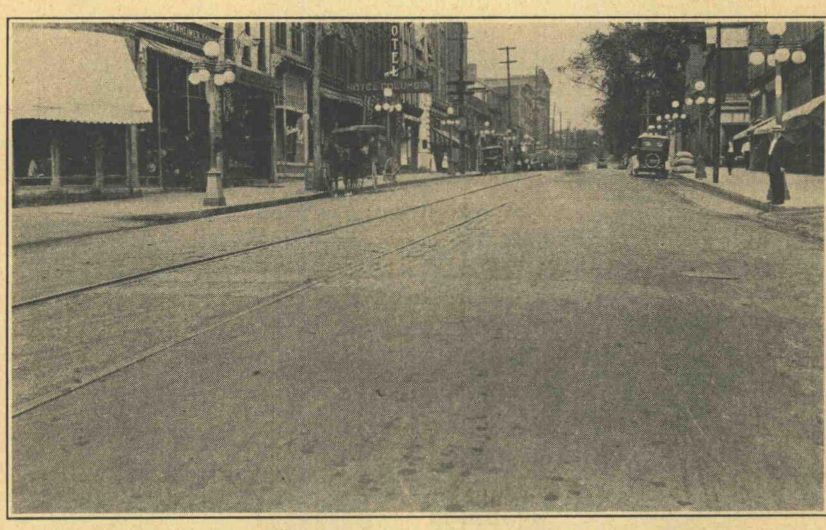
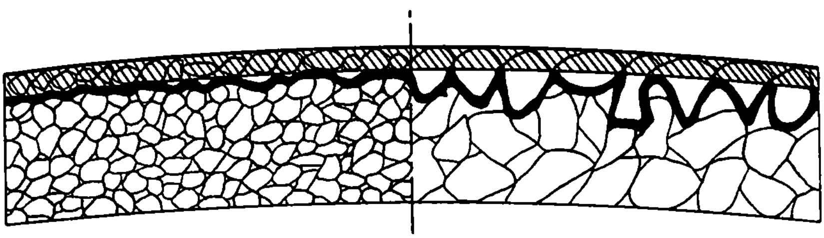


Figure 93. Waterbound Macadam Pavement—Having Same Traffic and Treatments As Surface Shown in Figure 92, After Six Years Maintenance

service six years and having same character of stone, the same kind of tar and the same traffic as that for the purpose referred to in Figure 92. The difference lies in the fact that the pavement shown in Figure 93 received a water-bound layer of 2-inch stone before treatments were begun in 1913.

The reason for this breaking out is illustrated in Figure 5 and as stated in the discussion previously referred to was as follows:

The untreated macadam is a one-layer surface, and breaking begins at the top, where the stress is greatest An application of bituminous binder transforms this single layer into a surface composed of two distinct layers, the top one of which is composed of bitumen, screenings and stone Providing that a proper penetrating and binding material has been used, the weakest part of the original surface is along the plane between the two layers (shown on the diagram by the heavy black, irregular line), and it is along this plane that the top breaks away from the bottom, causing pot-holes, as noted above The position of this plane



A—Small Stones B—Large Stones

Figure 94

of breaking is entirely dependent upon the size of the stones used In order to overcome this, it is necessary that this plane of division be so far beneath the surface that the distributed unit stress at that point will be less than the adhesion

Section A of the diagram (Figure 94) shows that, in a surface composed of 1-in stone and ¾-in penetration, the position of this breaking plane is about 1 in from the top With 1½ to 3-in stone and ¾-in penetration this plane is shown by Section B of the diagram to vary from 1½ to 3 in from the top Thus for the same thrust at the surface the unit stresses resulting along the division plane in the small stone surface will probably be somewhat greater than along the plane in the large stone surface Also the mechanical bond furnished by the larger stone offers greater resistance to separation than that of the smaller

It has been observed that traction engine lugs will break out sections of treated small stone surfaces, while no impression is made on those composed of large stones While small stone surfaces one year after treatment are often full of holes, adjoining surfaces composed of larger stone, from the same quarry, treated at the same time with similar material, are practically free from such breaks

4. Cold applications of bituminous materials covered with fine river sand was the cheapest method of supplying to bituminous macadam pavements all that was needed in the way of surface coating.

Here again it is pertinent to inquire—what is the purpose of surface treatments on bituminous macadam pavements? Certainly not that advocated for the water-bound, for here there is no dust binder to force out One of the troubles, however, which developed in the early untreated bituminous macadam pavements was ravelling at the top

This ravelling which can be the beginning of many kinds of failures must be preceded by a rocking of the individual stones This rocking, which is caused by direct contact of the stones with traffic, apparently cannot be prevented by the bituminous binder alone, because of the latter's ability to flow under certain conditions of temperature and compression Rocking can be reduced, however, by wedging stones of smaller size firmly into the crevices between the tops of the larger stones, thus securely locking the latter in their positions

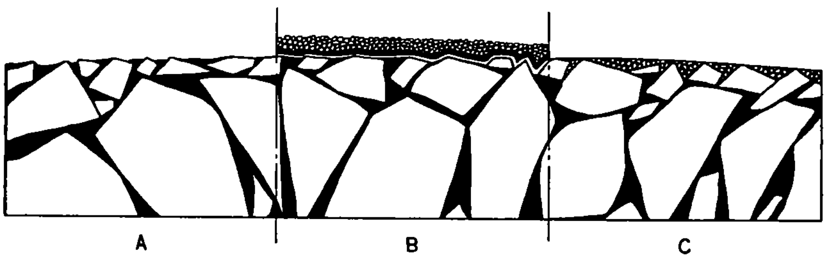


Figure 95

In surfaces of this type, whether constructed with one or with two coats of bituminous material, the evident purpose of the small stones of the top course or courses is to accomplish the locking together of the larger stones of the base course This result is effected in part by rolling during the construction of the surface and is completed afterward by the action of the traffic.

If, in addition to this wedging, small grains of sand could be forced into the crevices between the smaller stones, and the particles of stone and sand were bound in place by a proper bituminous material, the resulting top would be one of ideal compactness and hardness, answering the requirements of bond and stability

Therefore, the purpose of the surface treatment becomes that of affording a means for getting sand into the bituminous materials between the small stones in the top of the pavement, thus furnishing a stability that was not there before

This effect was accomplished in a very simple manner After the pavement had been in service for a short period, it was swept clean, given an application of light asphaltic oil or tar (cold, about 1/5 gallon to the square yard), and covered with a layer of river sand The light oil or tar softened up the bituminous binder underneath and allowed the sand to be forced in by the traffic, resulting in, about ten days, in a dense, hard and compact wearing coat.

This action is demonstrated graphically in Figure 95. Part A shows the bituminous macadam surface after sweeping Here it can be seen that the top edges or corners of the stones are exposed to direct contact with vehicle wheels Part B represents the surface immediately after the application of light bituminous coating and sand Part C shows the resulting compact top Figure 96 shows a surface of this type about 4 days after spreading of the sand Figures 97, 98 and 99 show three sections of this type of pavement after 4 years service The writer last saw these pavements when they had been in service 10 years and their appearance was the same as shown at 4 years In these treatments, both asphaltic oils and tars were used on bases having both asphalt and tar binders, making four combinations, all with equally good results The treatments were renewed in from 3 to 5 years. The surfaces shown in Figures 97, 98 and 99 have only the original treatments

5. For cold patching, a stone of uniform size was more satisfactory than one in which the sizes were graded For this work cold asphaltic and tar preparations were mixed with the stone several days before using It was found that a mixture of 3/4-inch and 1/2-inch stone with a little sand, pushed considerably under traffic, a mixture of the two sizes of stone without the sand pushed less and the 3/4-inch stone when used alone did not push at all

6. In general, it could be said that figuring over a period of years it was cheaper to surface treat than not to, it was cheaper to lay a water-bound macadam layer before treatment than to maintain the original surfaces with treatments and it was thought in the long run, the surface treated bituminous macadam pavement would be most serviceable and economic

Based on 1912-15 prices, the maintenance of traffic bound surfaces ranged from 7 to 10 cents per square yard per year, or about $750 to $1000 per mile of road 18 feet wide. The cost of the water-bound resurfacing ranged from 18 to 35 cents per square yard or from about $950 to $1850 per mile of 18 foot wide road The surface treatments

Figure 96. Bituminous Macadam Surface About Four Days After the Application of Light Bituminous Material and Sand

Figure 97. The Pavement Shown in Figure 96 After Four Years of Service

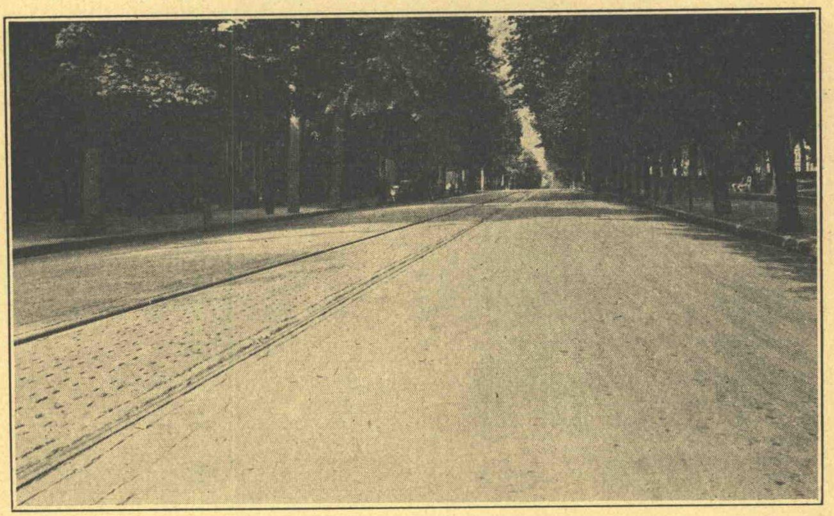


Figure 98. Penetration Macadam (Part with Asphalt and Part with Tar Binder) Four Years After Receiving Surface Treatment (Part with Asphalt and Part with Tar)

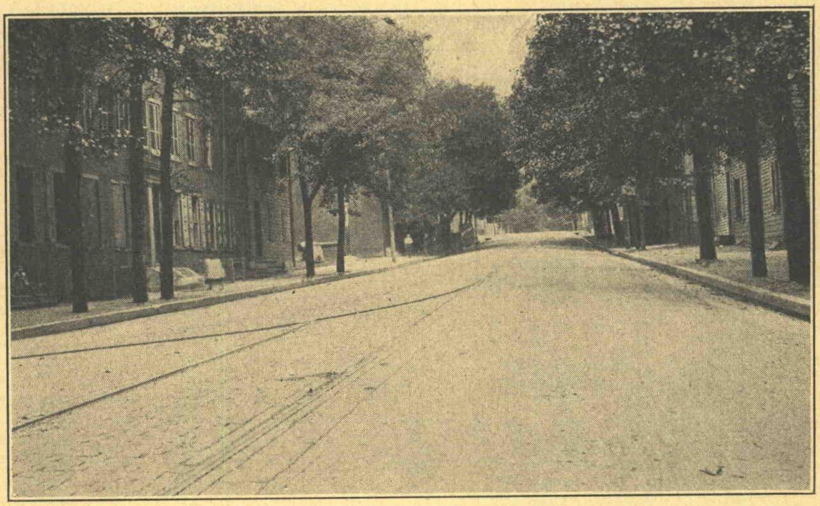


Figure 99. Penetration Macadam (Asphalt Binder) Four Years After Receiving Surface Treatment (Asphaltic Oil and Sand)

on the water-bound surfaces averaged about 4.5 cents per square yard for the first application and about 2¼ cents per square yard for successive applications. These prices per mile of 18 foot wide road would be about $240 and $120 per mile respectively. These treatments were repeated annually. The bituminous macadam surfaces cost about 50 cents per square yard or $2650 per mile of 18 foot wide road and surface treatment about ⅓ to ⅕ of those noted for the water-bound surfaces. This was because the bituminous macadam surfaces required treatments only in from 3 to 5 years.

Thus, by properly utilizing the value which had been gradually accumulating in these traffic bound surfaces through years of service, it was possible to give to at least one community first class serviceable pavements at a minimum cost.