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METHOD FOR TREATMENT OF HIGHWAY GRADE AND SUBGRADE MATERIALS

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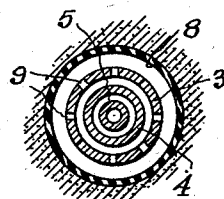
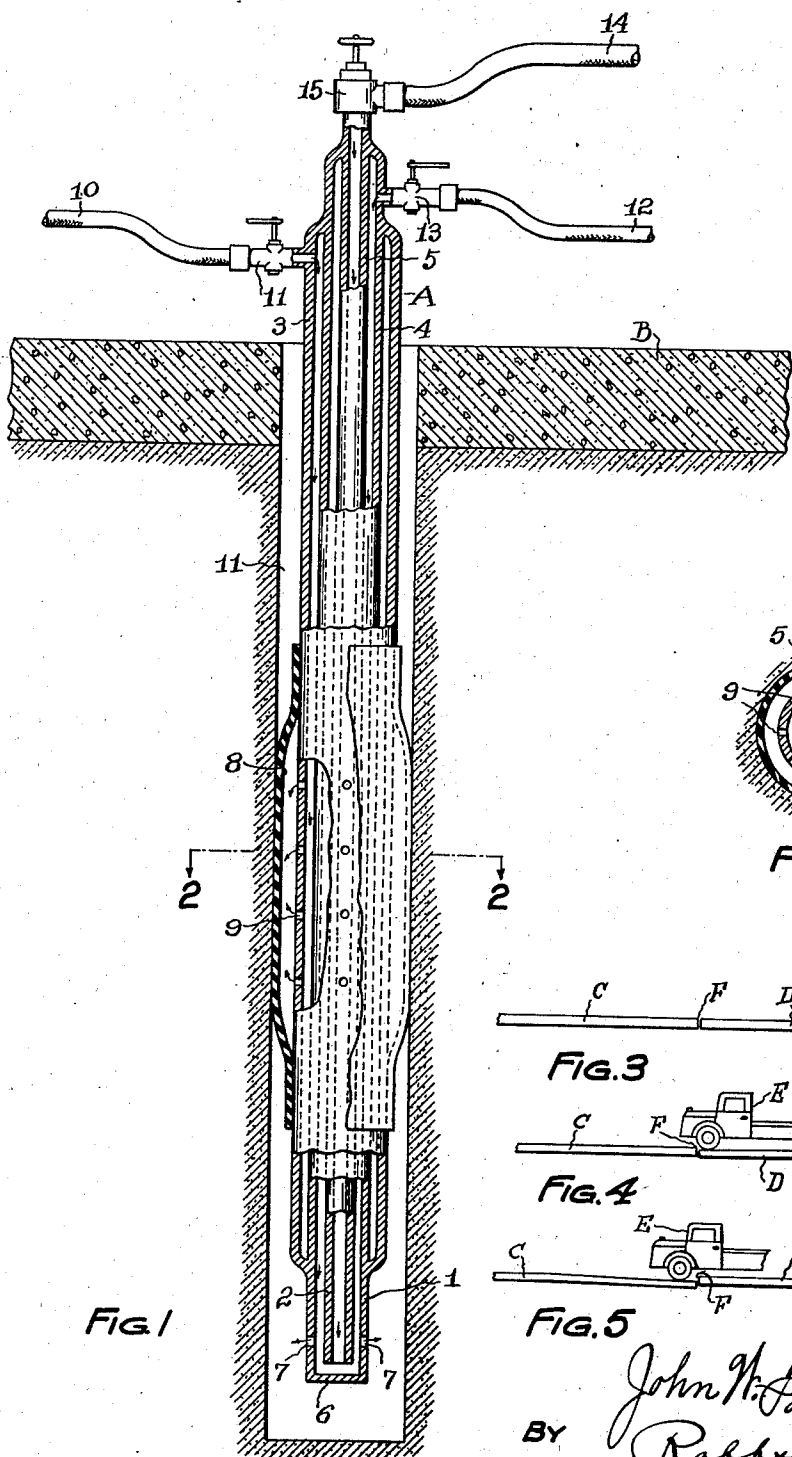


FIG. 2



FIG. 3

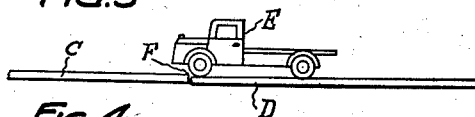


FIG. 4

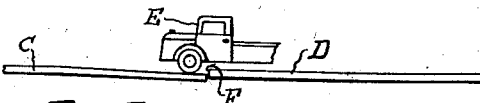


FIG. 5

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METHOD FOR TREATMENT OF HIGHWAY
GRADE AND SUBGRADE MATERIALSJohn W. Poulter, Milwaukee, Wis., assignor to
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9 Claims. (Cl. 61—36)

This invention appertains to the art of highway or pavement construction or maintenance and involves a novel method for the treatment of materials designed to form the supporting subgrade for the pavement structure or materials found beneath such structure.

Since the commencement of the construction of hard roads or pavements on a large scale in this country, many problems and difficulties have arisen owing to the nature of the subgrade materials, particularly where these materials have objectionable qualities in so far as the efficiency thereof for supporting the pavement structure without permitting deflection vertically, and breaking up or disintegration of such structure, is concerned. Practically speaking, only in recent years have these problems arising due to the nature of the subsoil or subgrade materials supporting concrete and like hard road structures become recognized. Prior to the building of a concrete or like road, where the subgrade materials are found to be objectionable, recourse may be had to removing the materials and replacing the same with more suitable materials, under certain conditions, while under other conditions recourse has been had to changing entirely the location of a road to obtain subgrade soil characteristics advantageous for the maintenance of the road in use. In still other instances it has been proposed to change the existing soil characteristics of the subgrade by treatment with certain admixtures.

The primary object, of course, in order to obtain satisfactory and long-lived road structures, is to make sure of the integrity or stability of the subgrade, earthy or soil materials, and this has been a problem of great importance and involving much difficulty under more recent conditions of heavy traffic passage over hard roads, many of which were not originally designed for such traffic.

One of the difficult conditions met with in regard to subgrades of roads lies in the high capillarity of the soil of the subgrade in many places. Such a condition of subgrade materials enables subsoil or other low lying water to be carried up into said materials, in many cases to those immediately adjacent the lower side of the pavement structure. This comparatively high moisture content of the subgrade soil takes away its supporting power and settlement in subgrade, and failures of the pavement structure from this cause are common. Also, the presence of this water in that part of the subgrade adjacent the pavement and for some distance below it is largely

responsible for frost heaving of pavement in the winter time and the breaking up of these sections as the frost goes out in the spring of the year. Furthermore, the action of traffic with any slight movement of the pavement and the supporting grade increases the capillary capacity of the subgrade material and because of this causes a further accumulation of water immediately adjacent the lower side of the pavement.

One of the interesting phenomena that occurs when water enters or pockets or distributes itself in the subgrade soil involves the "pumping" action of the slabs of the pavement, especially concrete pavements that are made in sections with center joints. It has been discovered that this pumping is due to the fact that shifting of the subgrade soil with water therein, or the forming of voids or pockets underneath the pavement, will permit the pavement to actually move up and down under the load forces of vehicular traffic passing over the road. Thus, as the loaded wheels of a vehicle reach the end of a road section adjacent to a center joint, speaking with reference to the direction of travel of the vehicle, or approach and reach the end of a portion of a slab of the road where a crack has been caused, it is known that the vehicle actually starts to depress the slab as the load approaches the center joint or crack, as the case may be. The depression is relatively slow often, dependent of course upon the condition of the subgrade at this particular point of joint or cracking, but when the load reaches the portion of the slab or road at the crack, beyond the joint or crack, the movement of the slab is accelerated. These movements of the concrete structure or portions thereof when water is present beneath the structure produce the pumping mentioned above. This may be graphically illustrated and appreciated when traveling over road behind a heavy vehicle where the condition is so bad at times that water may be actually seen to squirt or splash up through the center joint or laterally out from beneath the side of the road at the shoulder in greater or less quantities.

It has been discovered that under normal conditions, the vertical displacement of a pavement slab as caused by a heavily loaded wheel passing over it is greater at the joint or crack than at any other point along the slab. Also, that this greater vertical displacement along with the relative rate and time of displacement of adjacent ends of adjoining sections of pavement will cause a shifting of the water and subgrade material which results in a greater accumulation of water

with its greater rate of shifting or washing away of subgrade material and resultant loss in pavement support and pavement failure.

Different expedients have been resorted to in the effort to cure the objectionable subsoil or subgrade conditions above generally referred to, but without complete success. Drainage at times will afford some relief, but in many instances, owing to the high capillarity of the subsoil, drainage produces little or no effect.

My present invention involves a method for treatment of the subgrade soil of pavement structure at the time of construction where tests have shown the soils to have a high capillary capacity or during maintenance after construction, where the pavement is being affected by such soils or action, by introducing a suitable material into the soil to reduce its capillary capacity or otherwise seal the flow of water through such soils.

I have found, according to my present invention, that it is necessary to treat the subsoil itself to change its characteristics, and I have found further that it is necessary to employ a filling or treatment material or composition which is sufficiently fluid or free from suspended particles that it can be caused to flow into the very fine soil pores and associate itself with the individual soil particle. Also, that it must be such that in its relation with the soil particles, it will reduce the capillary capacity of the soil mass as well as forming a stable and lasting relation with the soil mass.

In addition to the foregoing, I have found that it is necessary, not only to use a special type of treatment material that will itself resist erosion or other action of water or liquid beneath the pavement, and also effectively distribute itself throughout the subgrade area being treated, but I have also found that it is necessary to make a particular application of the treatment material in order that it be efficiently caused to penetrate and distribute itself throughout the area that is being treated. The foregoing discovery has led to the development of the method of handling the treatment materials as embodied herein, and also the discovery that a light asphalt, asphaltic oil, or other similar asphaltic materials will serve as a suitable treatment material, as disclosed in my application executed of even date herewith, Serial No. 377,276, filed February 3, 1941.

Efforts have been made heretofore to impregnate the subgrade soil with fluid material such as oil in order to change the soil characteristics or otherwise seal off the flow of water, but such attempts have not been very successful because when the fluid material is forced under pressure into the soil it tends to form narrow penetrating channels and passes to the surface of the subgrade materials without affecting but a small proportion of such materials. In other words, the subgrade condition is not materially changed and successful results cannot be achieved in this manner.

According to the method of my present invention, I have found that by forcing compressed air into the subgrade materials to be treated, for some time previous to the introduction of a fluid material such as an asphaltic oil or the like, it is possible for a greater part of water contained in the subgrade material, prior to the application of the air to be blown out of the pores of the subgrade soil. Thereupon, by continuing the forcing of the air into the soil and introducing along with it a light asphalt, asphaltic oil, or other suitable bituminous or cementitious mate-

rial or fluid mixture, it is possible for such material to enter the soil under treatment and fill up the pores or soil voids therein. Thus, when the fluid material has been applied by the special process referred to, it will distribute itself throughout the soil voids of the subgrade soil and will not only greatly reduce the capillary capacity of the soil shutting off the movement of the water through the soil, but will greatly add to its stability or supporting power as well as its resistance to the eroding power of water, which has not been heretofore achieved in the art.

I have illustrated in the accompanying drawing an apparatus for the purpose of my method herein described and shown in said drawing, wherein—

Figure 1 illustrates a partial side view and partial sectional view of said apparatus.

Figure 2 is a cross sectional view on the line 2—2 of Figure 1.

Figure 3 is a diagrammatic view to illustrate a longitudinal section of slabs of a concrete pavement and showing a heavy vehicle traveling along said pavement toward a center joint between the slabs.

Figure 4 is a diagrammatic illustration similar to Figure 3, but showing the loaded wheels of the vehicle as when they depress the first slab while moving toward the end in the direction of travel to the center joint.

Figure 5 is a view similar to Figure 4 but showing the load transferred to the second slab and the almost instantaneous depression of the end of the second slab adjacent to the depressed end of the first slab.

Figures 3 to 5 above briefly described are illustrative of the action of vertical movement of slab ends of concrete or like pavement adjacent to the center joint produced by heavy traffic travel over the slab ends, and the action is the same where cracks appear in hard road surfaces, approximating the effect of the joints between slabs, so far as formation of openings or water passages may be concerned.

For the purposes of my invention herein described, it is notable that the treatment mixture or composition employed by me is produced by admixing a fine silty loam along with about 10% Portland cement to provide a binder, and about the same amount or 10% of light asphalt, asphaltic oil, or similar bituminous material, so as to produce a very thin slurry having a high percentage of water, say 60 to 80%. To obtain proper filling of the filler material into the voids or spaces beneath the pavement structure, using a minimum number of holes bored into the pavement through which the material is to be introduced, therebeneath, my filling material as above described must be very fluid and also have a smooth creamy texture at the time it is introduced and hence the amount of fine silt loam used will be employed with a view to obtaining such a characteristic mixture. The loam referred to must not contain any coarse or harsh material for such would interfere with the proper flow or filling action. It should preferably contain some clay or other fine material which with sufficient mixing will produce a colloidal suspension affecting not only the soil particles of the loam but the bituminous substance of my composition, as well.

The purpose of the bituminous material is not only to produce resistance to erosion, but it also causes the mix to remain somewhat plastic when it has hardened to a degree. The bituminous material used likewise aids the flow or fill-

ing as it reduces the rate of drying out of the mix when it comes in contact with a dry fill or other material.

I have found that the bituminous material is further advantageously used for its effect upon the subgrade materials below the pavement. There is some migration of the bitumen from the mixture pumped down into the subgrade that increases its resistance to washing or erosion mentioned before. Bituminous material conducive to obtaining the above effect should preferably be used.

The apparatus shown in Figures 1 and 2 of the drawing comprises a nozzle unit A so designated as a whole and having the nozzle ends 1 and 2 at its lower portion. The unit A is made up of three concentric tubes 3, 4, and 5, so assembled, by being welded to each other, as to remain spaced apart to provide suitable passages for the fluids to pass therethrough and therebetween. The lower end of the tube 4 at the nozzle 1 is closed as shown at 6 and is provided with small openings 7. The innermost tube 5 extends past or to a point below the openings 7 and terminates just short of the closed end 6 of the tube 4.

Upon the outer side of and adjacent to the lower end of the tube 3 is located an expansible or inflatable rubber tube 8 which is applied to the tube 3 by being sealed at its upper and lower ends to the tube as by means of any suitable process of vulcanization. The tube 3 has openings 9 at its intermediate portion so that air introduced from an air conduit 10 under the control of the valve 11 may pass into the space between the tubes 3 and 4 and from said space through the openings 9 into the rubber or elastic tube 8, thereby to inflate or expand the latter against the walls of the opening or hole 11a into which the nozzle unit is introduced for the purpose of practicing the method of this invention. The hole 11 is typical of a number of holes that are drilled through the pavement B into the subgrade by any suitable drilling machine as a preliminary to the use of my apparatus and method for the treatment of the subgrade materials of said pavement B.

When the nozzle unit A is sealed in the opening or hole 11 by the inflation of the rubber or elastic tube 8, air under pressure from any suitable source, which may be the same source as that supplying the conduits 10, may then be caused to pass into the space between the tubes 4 and 5 from the conduit 12 under the control of the valve 13. This air under pressure passes out into the subsoil or subgrade materials through the openings 7. This step of forcing the air into the subsoil through the openings 7 from the nozzle unit will be continued sufficiently long to open the pores of the soil, whereupon a light asphalt, asphaltic oil, or material such as the composition or mixture previously described herein is introduced into the nozzle unit from a conduit 14 by the valve 15 to enter the innermost pipe or tube 5 and pass from the latter at its lower end along with the pressure air through the openings 7 into the subgrade materials surrounding the lower portion of the nozzle unit.

It appears that when the apparatus disclosed is used in the above manner, instead of breaking promptly through the subgrade materials along one or several separate narrow channels as when introduced alone, the treatment material will be carried by the air under pressure or along with said air into the soil pores, thereby to fill these pores. And when the pores are thus filled

by the fluid mixture described, the bituminous or other substances of said mixture build up resistance points in the path of movement of the air and mixture and cause the channels of penetration of the air and mixture to spread and follow new paths, opening new pores and filling these pores effectively. In this way it may be said that the subgrade materials are completely filled as to the soil pores or voids, and that largely each soil particle has been affected by the material introduced, which is the obviously desirable and needed action if the capillary capacity of the soil is to be reduced to such an extent that the movement of the water through the soil is largely shut off, and also if the soil is to be given the necessary stability required for the proper support of the pavement with its traffic.

Suitable means are illustrated for controlling the flow of the air through the conduit 12 into the tube 4 from which it passes to the subgrade, and the pressure of the air may be varied by any suitable means and will be preferably handled to this end to meet with problems involving the different conditions of subgrade materials that may be encountered as regards the degree of porosity or extent of voids of the latter, the capillarity of said subgrade soil, and like characteristics that may be met with in the operation of my apparatus and the carrying out of the process referred to.

It has been found that certain advantage is derived in providing an intermittent or pulsating flow of both the air caused to pass to the subgrade materials and the filler material often called "mud," as well. Of course, it is contemplated that the air shall be forced to the subgrade at the same time the pressure is applied for forcing the filler material thereto, and when the pressure on the filler material for the above purpose is discontinued the supply of the air under pressure should also be discontinued.

The pressure of the air passing from the conduits 12 into the nozzle unit A, as well as the flow, may be regulated to a certain extent by the same valve 13.

By simultaneously controlling the valves 13 and 15, it is possible with my apparatus to cut off and re-establish the flow of the filler through the tube 5 and the air through the tube 4.

Figures 3, 4, and 5 are illustrative of the manner in which heavy traffic vehicles upon a pavement move the slabs of the pavement vertically, when weakness is developed by voids or the particular character of the subgrade material beneath the ends of the slab. In Figure 3 the slabs C and D are in horizontal alignment as should be their normal condition for efficient road construction. The vehicle E has its front wheels approaching the end of the slab D in the direction of travel of the vehicle. Figure 4 illustrates how, when the weight of the vehicle upon its forward wheels is caused to lower the slab D as the vehicle approaches the end of the slab, this action causes a pumping of water or liquid content of the subgrade material below said slab end largely in the direction of the slab C being approached by the vehicle E. The pumping action of the slab D described is somewhat slow but when the wheels of the vehicle mount the end of the slab C adjacent the slab D, the end of slab C receiving the impact of the load passing thereto from slab D is caused to suddenly lower, causing additional pumping of water which will have to escape usually through the center joint F or

laterally of the road structure at the nearest shoulder thereof.

It must be borne in mind that in the practical employment of my invention, its usefulness may be found, to a considerable extent, in the mere treatment of subgrade soils or materials that have been discovered as liable to produce defects in the pavement support and subgrade conditions even when defects in the pavement itself have not yet been created. Of course, the larger utility of my invention lies in the correction of conditions that are found to exist due to the actual breaking down of pavement structures to the extent of creation of offsetting of sections of pavement, or to the correction of the sub-soil condition itself before the breaking down of the pavement when indications of inadequate support and movability of the pavement structure arise and are observed in time to enable correction of the subsoil condition before the destruction of the pavement itself takes place.

In lieu of the composition of materials hereinbefore referred to, there may be used in conjunction with my invention hereof, a composition of materials proportioned by volume substantially as follows:

Portland cement	8
Lime dust	6
SC2 road oil	13
Black loam	25.5
Clay	6.5
Water	41

In the above composition the oil keeps the slurry plastic on long hauls to the job, retards the setting, and prevents trapped water under the slab from combining with or diluting the slurry. The use of stone dust assists in holding the oil in the mix or slurry. It has a tendency to reduce the composition's resistance to erosion. The clay, as previously indicated, produces a colloidal suspension affecting not only the soil particles, but the bituminous material, as well. The clay, in conjunction with the bituminous material, also seems to increase the resistance of the mixture to erosion after it has set up in place under the slab. SC2 road oil is a slow curing road oil, one in which the thinner used is such that it will evaporate comparatively slowly.

Within the purview of my invention it is contemplated to initially blow out the water from the paver subgrade, introduce the filler material, as described, and apply pressure to the latter to lift the pavement if the pavement has settled, employing generally the process of my previous Patent No. 1,915,032 in this connection.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of loam, binder, bituminous material, and water.

2. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially dis-

placing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of loam, binder, bituminous material, and water with substantially homogeneous distribution of the mixture throughout the mass.

3. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a very fluid creamy mixture of loam, binder, bituminous material, and water.

4. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of loam, binder, bituminous material, and water, devoid of harsh coarse substances.

5. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of loam, binder, bituminous material, water, and a small amount of clay only sufficient to produce a colloidal suspension of the soil particles and bituminous material.

6. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of loam, a binder, water, and an erosion resistant substance having the property of remaining plastic when the mixture has hardened to some degree.

7. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of loam, binder, bituminous material, and water, homogeneously distributed throughout the mass by a source of pressure, thereby to shut off passage of water through the mass so treated.

8. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture of Portland cement, lime dust, light asphalt, loam, clay, and water.

9. The method of reducing the capillary capacity of a pavement subgrade soil mass, which includes the treatment of such mass to stabilize the same against displacement by initially displacing therefrom water contained in said mass, and thereafter impregnating the mass with a mixture proportioned about as follows: Portland cement 8%, lime dust 6%, asphaltic oil 13%, black loam 25.5%, clay 6.5%, and water 41%.

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