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[54] **EMBANKMENT ON MUSKEG AND ASSOCIATED METHODS**

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Related U.S. Application Data

[63] Continuation of Ser. No. 258,457, May 31, 1972, abandoned.

[52] **U.S. Cl.** **404/28**; 404/82

[51] **Int. Cl.** **E01c 3/00**

[58] **Field of Search** 404/28, 27, 17, 71, 31

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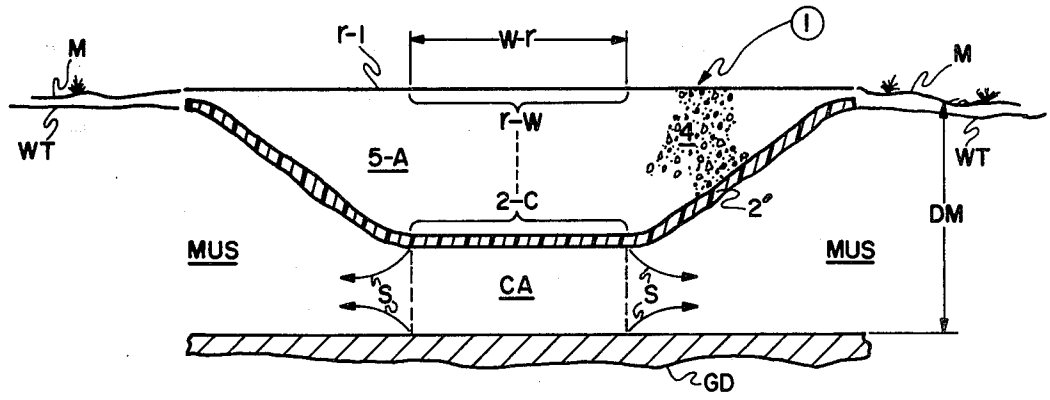
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[57] **ABSTRACT**

Described are techniques for building improved roads and embankments on muskeg terrain; with an embodiment for a timber haul road using a substrate mat of rigid polyurethane form supporting a properly-distributed embankment of native gravel (or like road building material), preferably distributed in a "counterbalancing berm" construction and providing an improved stable roadway embankment in the face of stress conditions typical of muskeg areas.

12 Claims, 3 Drawing Figures



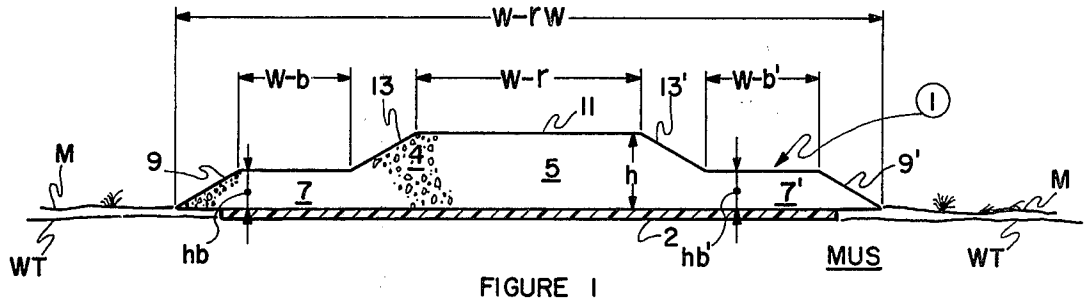


FIGURE 1

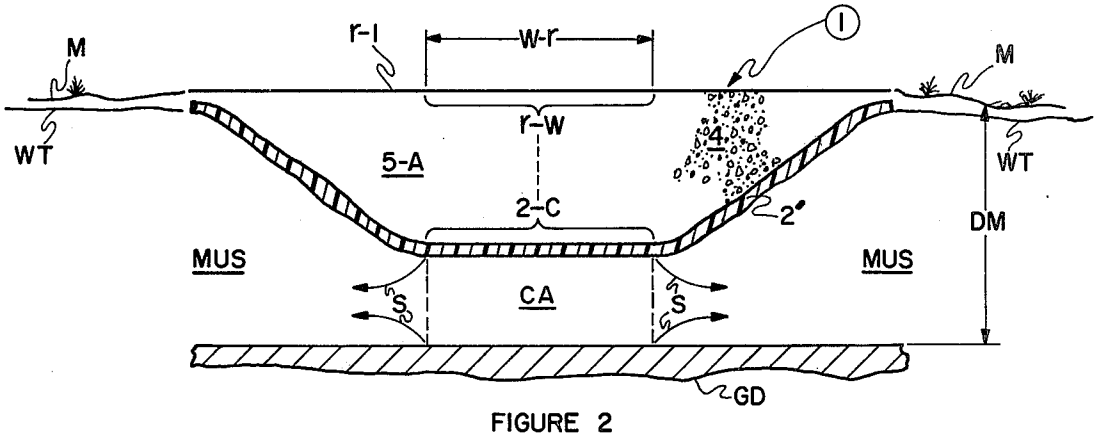


FIGURE 2

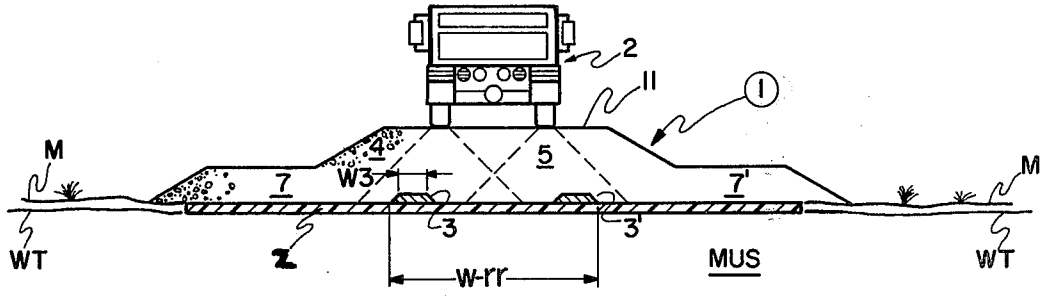


FIGURE 3

EMBANKMENT ON MUSKEG AND ASSOCIATED METHODS

This is a streamline continuation, of application Ser. No. 258,457 filed May 31, 1972, and now abandoned.

BACKGROUND, PROBLEMS, PRIOR SOLUTIONS

Muskeg is typical of highly organic soils characterized by a low unit weight, low shear strength, high moisture content, high porosity, and high compressibility. Obviously, muskeg is not generally considered in any way desirable as a substrate for road building; however, at times it must be used, for instance in constructing timber haul roads and other access ways in various sub-Arctic regions such as parts of Southeastern Alaska and Southern Canada.

Methods commonly employed for building roads on muskeg are, as yet, relatively crude. They include the "excavation method" wherein the muskeg material is dug out and replaced by a suitable granular fill of roadway material, such as native gravel. Another method involves "preconsolidation" or artificially containing and pressing the muskeg to reduce void percent. Another is the "displacement" method (akin to causeway construction by gravity displacement) wherein fill material is continually piled upon muskeg at the site until enough sinks to completely displace the underlying muskeg.

"Floating" is another method and, in general, involves simply piling-up granular fill directly atop the muskeg bed as in normal road construction in a manner which prevents it from sinking (floating the road). In its crudest form this method is quite inexpensive initially but limited in load-bearing capacity and apt to involve costly maintenance over a period of time. Corduroy, brush, sawdust and/or consolidated straw (bales or fascine bundles) are frequently used in conjunction with this floating construction to provide buoyancy and weight distribution. Differential settlement problems can generate a top embankment surface which is so uneven as to be utterly useless unless repaired (and repairs are apt to be frequent with changing subsurface hydraulic conditions). "Pumping" and related problems of liquid intrusion into the gravel embankment are also common with "floated embankments" and can destroy a structure's integrity, dissipating the material outward, and requiring frequent repairs with supplemental fill. The present invention is directed toward improving such "floated" construction.

Further particulars on conventional construction like the foregoing may be had by reference to the "Muskeg Engineering Handbook" (1969) published by the National Research Council of Canada. None of the foregoing methods are fully satisfactory; in many cases, being unnecessarily expensive in terms of construction time and costs, and/or requiring extensive maintenance, and/or relatively unsatisfactory in performance.

In considering various solutions to the problem of constructing roads over muskeg, it occurred that a plastic web such as polyethylene film or sheeting could be employed as a combination moisture-barrier and embankment-containment means. However, such a web must not be readily ruptured since this will result in contaminant intrusion and/or escape of embankment material, leading to failure of the road section. A solution, described according to this invention, as indicated in the embodiments below, is to employ a rigid synthetic polymeric foam to function as a somewhat resilient substrate mat placed atop the muskeg and on which the gravel (or other particulate) roadway material may be properly distributed to form a "floating embankment-mat" structure. Preferably this gravel material is so distributed on the mat so as to generate a high degree of uniform consolidation in the muskeg under the roadway (load-bearing portion), primarily by producing a prescribed integral mat-embankment structure (or a monolithic pad) which bears upon the muskeg substrate so as to effect this. In most cases this will be effected by the use of the described "flanking berm" construction whereby the contemplated roadway track (load bearing portion) is flanked by berms of gravel on both sides acting to counterbalance one another and stabilize the overall embankment. Workers in the art will discern that such improved embankments can readily result in major reductions in the cost and associated problems of building and maintaining roads on muskeg and offer significant cost/benefit factors. Further advantages and distinctions of the invention will become more apparent upon consideration of the following disclosure in conjunction with the accompanying drawings wherein:

DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 comprise isometric sectional elevations, in cross-section, of a preferred muskeg road embodiment, with FIG. 1 indicating schematically the general plan whereby the supporting mat and the various masses of embankment gravel are to be distributed; while FIG. 2 indicates the contemplated "finished" condition of this embodiment, after settlement and other equilibrium conditions have been reached; and

FIG. 3 indicates an embodiment after the manner of FIG. 1, however, modified to also include a pair of reinforcing track strips.

SUMMARY OF THE INVENTION

The present invention contemplates using web mat structures to support particulate embankment construction on muskeg (or similar) terrain, with the form and placement of the mat and the embankment material masses being arranged so as to effect a proper high degree and uniformity of consolidation at least below (supported) working portions of the roadway.

It will be evident that a primary object of the subject invention is to resolve at least some of the foregoing problems and provide at least some of the associated features and advantages. A related object is to provide an improved method of embankment construction for muskeg terrain. A further object is to provide such an improved method using mat construction for supporting embankment material upon the muskeg substrate. A related object is to so arrange and distribute this mat material and the supported embankment (particulate) material as to provide an integral floating load structure, acting to uniformly compress the muskeg substrate to a high degree over a fairly extensive area and thereby stabilize (at least the traffic portions of) the roadway and improve its performance in service. A further object is to provide such a construction and thereby present a floated embankment having a more stable, uniform load distribution. A related object is to provide such a construction with a moisture-barrier which is relatively impervious to liquid intrusion into the embankment mass. Yet another object is to provide such a structure, using "flanking berm" construction

and thereby better stabilize and balance the overall structure upon the muskeg, while reducing shear and rupture stresses upon the mat material, while also acting to spread and better distribute the masses and inertial loads across the embankment (and mat). A further object is to provide such a structure, as reinforced, at least beneath load-bearing regions, so as to reduce the prevalent "rolling wave" phenomenon. How the foregoing and other more specific objects are achieved will become evident through consideration of the ensuing description of preferred embodiments of the invention in conjunction with the associated drawings.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a schematic, idealized cross-sectional indication of one advantageous method of constructing an improved embankment according to the invention. More particularly, FIG. 1 indicates the placement and distribution of a supporting mat 2 and embankment gravel material disposed thereon to comprise a particular roadway structure 1 supported upon muskeg terrain (the muskeg ground surface being indicated schematically at level M; while the water table level is indicated slightly below, at level WT). While FIG. 1 particularly indicates the manner of gravel distribution for roadway 1 and is somewhat idealized, while FIG. 2 comes closer to representing the actual operational form of the embodiment, once all the gravel has been piled on in the appropriate manner and, it and the muskeg substrate M have settled and become properly consolidated, etc., under the loading this presents (i.e., after the system has come to equilibrium). Roadway embankment 1 will be more particularly understood as an improved haul road (e.g., for timber) over muskeg, with the embankment material 4 comprised of native gravels of typical (e.g., properly graded and drained) roadway material as commonly used in the art for such areas, thus road 1 is assumed to be relatively conventional in characteristics and construction except as herein described.

The environment and locale for placement of roadway 1 will be better understood as comprising a muskeg bed of the type commonly found in Southeastern Alaska, the muskeg material "MUS." comprising about 90 percent water with the balance mostly organic matter and having a relatively typical void ratio (understood as about 10 here) and well-saturated with water below the water table WT, being on the order of about 6–10 feet above solid footing (GD) (see depth DM in FIG. 2). Other characteristics of the muskeg will be better understood by reference to Table I below.

TABLE I - MUSKEG CHARACTERISTICS

Water Content	700–1000%
Specific Gravity	1.3–1.6
Void Ratio	10–15
Organic Content	20–90%
pH	4–7
Vane Shear Undisturbed	250 psi
Vane Shear Remolded	100 psi
Depth of Muskeg	6–10 ft. — to hard bottom

Gravel road 1 is to be understood as supported and floated upon the muskeg bed by placement upon intermediate supporting mat 2, arranged (preferably as indicated below in the form of a laminate polyurethane foam), layed upon the muskeg bed to effectively span at least the entire roadway width *w–rw* and support the embankment (e.g., as shown after reaching equilibrium in FIG. 2). More particularly, mat 2 preferably comprises a relatively rigid polyurethane foam in multilaminate form, having a compressive strength on the order of at least 35 psi (at 5 percent deflection) and generally having the requisite tensile strength, moisture imperviousness, and other characteristics indicated for the subject environment. Mat 2 must be such as to maintain absolute integral continuity without rupture under the strain of supporting both the embankment road 1 and any contemplated loads thereon upon the subject muskeg bed without rupture of the passage of liquid or substrate contaminants or embankment material. Further, it must be somewhat rigid and able to maintain the desired configuration (FIG. 2 for example) despite localized differential support variations such as those due to localized variations in water content of the muskeg. It must also be strong enough to resist rupture and piercing by commonly available hazards such as sharp stones, sticks, and the like. For this purpose, as will be understood in the art, mat 2 may be provided with reinforcement means therein, such as nylon mesh material added as a supplemental layer.

Turning to the particulars of the embankment material comprising roadway 1, it will be noted that the primary embankment 5 comprises a prescribed mass of native gravel material piled into an embankment of prescribed width W–R and height H (here understood as about 12 feet wide by about 4 feet high assuming granular fill weight of about 125 pounds per cubic foot on muskeg MUS, which has about 100 psf shear strength). Embankment 5 will have a prescribed travelling surface 11 (or wear surface covered with the conventional wear coating if desired and as if conventional — not shown or discussed) and sloped shoulders 13,13' for structural stability as is conventional in the art.

In addition, roadway embankment 1 preferably also includes a pair of "flanking berms" 7,7', arranged along the margins of roadway embankment 5 and serving to impart a prescribed overall balanced embankment load upon supporting mat 2 and the muskeg material therebeneath. That is, berms 7,7' are comprised of the same native gravel material as embankment 5 and having generally speaking, respective height and width dimensions (W–B, W–B' and HB,HB' respectively) generally about one-half the corresponding dimensions of embankment 5, although this will vary somewhat as indicated below. Berms 7,7' will interrupt the ditch of shoulders 13,13' with these being continued at their outer margin as indicated respectively at shoulders 9,9' which are tapered into the surface of the muskeg bed M, as is conventional. Thus, the overall width W–RW of the entire roadway embankment 1 is somewhat in excess of twice the roadway width W–R for this embodiment.

It will be seen that the flanking berms function as a counterweight and to extend the gravel-load area upon mat 2 — most especially to help flatten the consolidation pressure profile (stress bulb) at the center, or working portion, of roadway 1. More particularly, as indicated in FIG. 2 with the equilibrium condition of the entire gravel system as indicated leaving a central roadway or traffic strip W–R, the portion of web 2 directly below this traffic strip (manely, central web segment 2–C, preferably being at least as wide and usually wider than strip W–R) will be so loaded by the overall gravel system as to impart a relatively high, yet uniform, loading pressure upon the bearing zone CA in the

muskeg (indicated in FIG. 2). As workers in the art will readily discern, the effect will be to load zone CA in the manner of a flat monolithic extended plate to impart relatively high, yet uniform, pressures upon this zone (preferably doing so on a gradual manner as indicated below) and gradually expel the liquid content of the muskeg in this zone without, however, dislodging a significant portion of the solids therein. As a result, zone CA tends to approximate a "structural pillar" supporting the (central portion of) embankment 1 upon the solid footing (ground level GD), thereby supporting and stabilizing the road so as to support a prescribed traffic loading. (Arrows S are intended to schematically indicate the gradual expulsion and squeezing-out of liquid from zone CA to consolidate and solidify it in the manner indicated). It will also be apparent that this mode of loading (i.e., creating the flat central segment 2-C of mat 2 and the smooth continuously decreasing loading outwardly thereof) will impart a relatively smooth, continuous conformation to mat 2 and will tend to minimize any sharp angles or consequent high shear-loading tending to rupture or over-stress the mat. It will further be apparent to those skilled in the art that the configuration of each flanking berm will be such as to distribute gravel (height and position) so as to impart the proper, balanced moments about the inertial center of the entire embankment structure. This mode of consolidation will distribute the loading stresses outwardly from the center of the web in the indicated gradual continuous decreasing manner. It will further be apparent why this "flanking berm" construction is especially helpful and advantageous in areas where such shear failure is more likely (e.g., where the water content of the muskeg is particularly high). Of course, these masses may be differently distributed (depending upon the density of the native gravel used, as well as its placement from the center) where a different "final configuration" of mat 2 is desired. For instance, whereas the mat configuration in FIG. 2 is relatively convex (viewed from beneath); in certain instances workers will perceive advantages in making (at least a portion of) the mat "concave-downward," expecially at the outer edges (e.g., to impart a "downward curl" to the outer mat edges and thereby help contain and restrain the underlying muskeg material, inhibiting its escape outward). In the embankment of FIG. 2, it will be noted that the mat configuration assumes a somewhat "bell-shaped" (or catenary) form, with a flattened central section (across the traffic bearing portion) so that contemplated traffic loads will have little effect upon the load bearing properties of the overall roadway 1 and especially will not change the degree of supporting muskeg consolidation significantly. This consolidation of fines under the roadway of course produces a more stable roadway (the muskeg in zone CA should be pressed or pre-consolidated so as to be relatively firm and unyielding upon application of the expected traffic loads). Workers in the art will further observe that the configuration of mat 2 in FIG. 2 will be such as to present no sharp discontinuities in (tensile) stresses along the cross-section of the mat with the inertial moments imparted by the gravel distribution (arrangement of berms) being such as to optimize this. The proper use of such counterbalancing berm masses can thus produce a flat uniform high degree of consolidation of muskeg under the working section of the roadway. Workers in the art will note that FIG. 2 shows essentially no raised center berm portion in roadway 1 as settled in equilibrium condition; this should present no problem as long as some small degree of "free-board" above the water line WT is present. (Note below that it is the inertial masses and not the shapes of the berm and center embankment that are most important here).

Regarding the embankment masses, the following may be noted, the fill height of center primary embankment 5 (height H) may typically be varied from the order of 1½ to 4 feet, depending upon the recited properties of the muskeg encountered. The maximum height that can be placed initially on mat 2 without likely shear failure, and rupture (assuming mat 2 is constructed as indicated above) will occur at the order of between 4 and 5 feet (assuming granular fill of about 125 pound per cubic foot density and muskeg shear strength on the order of 100 psf). Of course, as height *h* is reduced, the masses of berm 7,7' may be reduced, and in certain cases eliminated where they are not needed to provide the counterbalancing and stability; although in most cases they will be useful to provide a margin of safety resulting from the wider distribution of gravel mass and the resulting larger counterbalancing moments. The advantages of such "flanking berms" will be apparent to workers in the art. For instance, they can reduce the need for compacting the muskeg substratum and can assist in assuring against shear failure of the mat, even when service conditions (e.g., loading, water level, pumping from outside, etc.) shift. Moreover, this in turn conserves the fill material since it is not lost, wasted or contaminated with "leaks" as in typical prior art structures (e.g., where the granular fill gradually spreads outwardly more and more invading the muskeg bed and reducing the working portions of the embankment). It will be apparent, moreover, that for a given amount of granular fill, the more "excess fill" (that is, fill not directly necessary as the roadway structural material, e.g., in embankment 5) is spread laterally away from the center of the roadway, the greater is the degree of stability and the more efficient is material usage for structures of the type described. Moreover, the ultimate consolidation (e.g., in muskeg zone CA of FIG. 2) realized by improved embankment construction according to the invention will produce a higher degree of consolidation than many prior art structures, depending upon the amount and distribution of the loads on the associate mate (the placement and weight of embankment material, service traffic and the like) as well as upon the characteristics of the muskeg (e.g., its void ratio, moisture content, materials make-up, overall depth and dynamic response). It has been found that the magnitude of settlement during service can be expected to depend to a great degree upon the change in "void ratio" of the muskeg — thisi in turn being primarily dependent upon loading. Thus, the configuration of the embankment mass indicated in FIG. 2 is intended to reflect this. Such "floating-mat" embankment structures may be readily distinguished from certain "apparently similar" construction, such as " bridging structures" which comprise a rigid platform or containment structures which is really floated upon the semiliquid musket body (a floating bridge). With such a "floating bridge," the necessary supporting strengths of the underlying material will need to be so great and the mass of required fill material so great as to dictate a structural support member which are vastly different from web 2 indicated, or the like.

APPLICATION

The characteristics and operation of the aforementioned muskeg road will be better appreciated from a description of the characteristics and method of application of substrate urethane foam web **2**. First, the ground area defining the right-of-way is cleared of all trees, stumps, rocks, and other large obstructions. Then, a specially developed Pre-coat material, described below, is laid down prior to application of the urethane foam layer. This Pre-coat allows the foam to be sprayed directly upon a relatively moist terrestrial substrate (a muskeg surface usually being relatively wet). Next, the urethane foam is spray-applied to a minimum uniform thickness of about three inches comprising a laminate of about 4 to 5 layers. The foam is allowed to cure and a moisture-sealant Top-coat layer is preferably applied thereafter. After this, the gravel fill may be piled on the so-formed foam mat and, settlement allowed to take place, with fill being piled on until a relatively flat, level roadway surface **11–A** is rendered.

Mat **2** is preferably fabricated as follows. To the surface of the muskeg bed (substratee) a hydrophobic, or water-impermeable, base (Pre-coat) layer is applied with conventional, manual, hot-spray equipment, heated so that, after application, the base layer will be at about 70°F. This layer is a liquid bituminous mixture of Prudhoe Bay 70 volume percent crude residuum. For cold-flexibility it may also be extended with low molecular weight polymer as described below. Depending upon the condition of the substrate, the thickness of this base layer is from about one to several tenths of an inch. The colder and wetter the surface, the thicker this base coat. Since it is a hydrophobic material, any minor amount of moisture that may be in evidence upon the muskeg surface should not be sufficient to inhibit subsequent foaming. Under these conditions the Pre-coat applied warm as has been described, will allow the first foam layer to react fully, foam properly and thus provided a strong, coherent initial foam laminate.

Thus, after this bituminous base layer has been applied and while it is still warm, polyurethane foam insulation is applied on its surface with conventional foam spray equipment, such as a Gusmer pneumatic-mix spray apparatus having a base heater providing a 140°F. block temperature and a 115°–120°F. hose temperature. The polyurethane is obtained from equal parts of a polyether-polyol and a polyisocyanate wherein the polyol has a Brookfield viscosity of about 250 cps at 70°F. and a density of about 9.8 pounds per gallon.

The foam components are sprayed-applied, preferably in superimposed layers (laimnates) wherein each layer is allowed to set (skin forming) but not to become completely cured. This will provide a multi-laminate structure having superior strength and resistance to moisture intrusion. A foam of 1½ inches in total thickness is applied in successive layers with 4 to 5 per inch of foam, so that each layer is separated by a high density laminar skin several mils in thickness, the skin being formed by exposure of the upper surface to air for a period which is a function of the ambient temperature. At an ambient temperature of about 70°F. this foam will rise in about 6 seconds and set in about 12 seconds, while the time for complete curing will range up to 30 minutes or more. Artificial heating catalyst additives or the like can, of course, accelerate curing.

Properties of the spray-applied polyurethane foam are shown below in Table II.

TABLE II

FOAM PROPERTIES			
Property	Units	Rating	Test Method
Core Density	lbs/ft³	2.1–2.4	ASTM-D-1622-63
Overall Density	lbs/ft³	2.7–2.8	ASTM-D-1622-63
Closed Cell Content	%	90	Pycnometer
Open Cell Content	%	6.8	
Compressive Strength			
5% Deflection	PSI	50	ASTM-D-1621-64
k Factor at 70°F.	BTU/hr/ft²/°F/in	0.11	ASTM-D-2326-64T

After the uppermost layer of polyurethane foam skin has fully cured, the top skin is coated with a second hydrophobic (or water-impermeable) layer. This Top-coat may be the same composition as the described base layer, but preferably contains a greater proportion of extender (i.e., of the order of up to 25 percent or more), and has a thickness of 0.1 inches or more. This will optimize protention of the uppermost foam laminate, not only from moisture penetration but also from mechanical stresses and consequent rupture. With mat **2** so fabricated, it will of course be necessary to protect it mechanically from traffic loads, abrasion, etc., by covering it with the usual mantle of "highway gravel" or the like. For particularly heavy vehicular traffic, it is advised that such a mat be covered with a minimum of about 18 to 24 inches of native graded gravel. This will prevent vehicles from damaging the mat, distributing the heavy vehicular loads over a wider mat area, as is known in the art.

The composition of the hydrophobic (or water impermeable) Pre-coat layer is preferably bituminous as mentioned. Although asphalts, pitches and the like could be used because of their water-impermeability characteristics, these could form steam from the wet muskeg and might rupture the asphalt coating. If applied as "cut-backs" (i.e., naphtha or solvent solutions) there would be a fire hazard when the hot polyurethane reactants were applied. Aqueous emulsions are not desirable since, as is known, water is very deleterious to the polyurethane reaction. Moreover, the Pre-coat should be sufficiently warm so that the adequate foaming occurs, and quickly.

It has been found that a "long" crude oil residuum can be used for the bituminous Pre-coat barrier. Thus, for example, the crude oil from the North Slope of Alaska may be "topped" to remove the most volatile part of the crude amounting to about 10 volume percent. The topping can be used as fuel or added to other crude for shipment or transport. The next 20 volume percent of the crude is removed for diesel fuel (e.g, trucks, machinery, power generation and the like). The

next 70 volume percent residual fraction boiling above range of the diesel fuel fraction has been found to be particularly suitable as a hydrophobic (or water impermeable) base material for the Pre-coat. This can be used without further treatment, or it can be air blown to increase its viscosity and oxidized material employed.

It may be preferred, where "cold-flexibility" is important, to also add a small amount of polymeric material to the residual fraction in order to provide the residuum with increased viscosity and better ductility and flexibility at low temperatures. A satisfactory water impermeable Pre-coat consists of 85 weight percent of the 70 volume percent Alaskan crude residuum, 10 weight percent of commercial low molecular weight polyethylene (19,000 number average molecular weight) and 5 weight percent of a commercial styrene-butadiene rubber having a Mooney viscosity (ML4′ at 212°F.) of 105–110. In general, the polyethylene can have a number average molecular weight in a range of 18,000 to 30,000 and the styrene-butadiene rubber can have Mooney viscosities, (ML4′ at 212°F.) of 45–110.

The polymeric material is incorporated into the residuum at a temperature sufficiently high (for example 140°F. or higher) that the residuum is highly fluid; thereafter the warm (50° to 70°F.) mixture is applied to the substrate. The polymer content of the residuum-polymer mixture can range conveniently from 5 to 25 weight percent of the mixture with the amount of polyethylene to styrene-butadiene rubber ranging in weight ratio from 1:1 to 3:1. Although none of these proportions are extremely critical, large deviations from them give less desirable materials both from the standpoint of cost and also performance.

Since a relatively thin Pre-coat is applied (to 30 mils), the viscosity of such material should not be so high that a uniform coating cannot be attained. When the Pre-coat is applied to wetter substrates it can be somewhat more viscous since thicker coatings are desired, but uniformity is also a desirable object in these applications. If desired, the residual component may be air blown to increase its viscosity somewhat and thus little or no polymer need be added to give the proper viscosity. As stated, some elastomeric polymer will be desirable where the Pre-coat should have good low temperature ductility and flexibility. This is also desirable where freezing and heaving of the muskeg surface may occur.

Although workers skilled in the art will contemplate other mat construction modes, the described embodiment of a rigid polyurethane multi-laminate foam layer is advantageous for many applications. Further advantage will usually be derived by adding one or both of the described base and top hydrophobic (or water-impermeable) protective layers.

In certain instances where reinforcing strips (see strips 3′/3′ in FIG. 3 for instance, described below) are employed, these strips will be placed after the initial foam thickness is applied, being properly adhered thereto; e.g., with a conventional adhesive, and the overall structure topped with a final moisture-sealant coating of the type described in copending application entitled Structure for Protecting and Insulating Frozen Substrates and Method for Producing Such Structures, Ser. No. 205,381, filed Dec. 6, 1971 by by A. C. Condo, G. R. Knight, G. R. Burt, and A. E. Borchert. As a preferred and further improvement of the foregoing structure in FIGS. 1 and 2, reinforcing means may be applied to the support mat to strengthen it in the area of maximum stress (e.g., below the track area — indicated schematically as directly below the wheels of vehicle 2 in FIG. 3, where reinforcing strips 3, 3′ are located). Thus, as indicated in FIG. 3, a pair of polyurethane foam reinforcement strips 3 are provided upon the underlying mat 2 and positioned so as to generally underly the track area of the contemplated vehicular traffic. Strips 3, 3′ comprise polyurethane rigid about 4 inches high by about 18 inches wide. They are preferably prefabricated and laid upon mat 2 once it has been sufficiently cured, being adhered thereto in any suitable manner. Similarly, compatible reinforcement material such as polystyrene strips or boards or the like may be substituted for strips 3, 3′ as understood in the art. With such reinforcement means it will be apparent that the normal "rolling wave" which may be expected to precede some forms of vehicular traffic, over such a composite web-supported embankment, will be abated and minimized. Without such reinforcement, as the vehicle proceeds along an embankment like embankment 1 herein it may build up and be preceded by a "standing wave" of granular material along the surface of the roadway 11; especially in the cases of heavier, faster-moving loads.

Workers in the art will appreciate the improved desirable results achieved by the foregoing construction and especially the use of urethane foam web such as those described. For instance, tests have indicated that the modules of rupture for the described foam is about 60 psi (calculated from Bean formula).

Workers in the art will recognize that the novel features of this disclosure may be applied, alone or together, in other contexts to solve different but related problems and that the implementation suggested in the foregoing embodiments may be modified to achieve the described results. For instance, where roadways were mentioned primarily in the embodiments, it will nonetheless be apparent that the same kind of restoration and construction techniques may be applied for gravel building-pads or other embankments in muskeg or the like wet, high-void, soils. Similarly, for the insulating material; while urethane foam has been suggested in the embodiments, there will be instances recognized by those skilled in the art where other equivalent synthetic web material will serve, such as polystyrene foam, or in certain cases ceramic materials or various native structural materials. In particular, where inexpensive insulation is particularly desired, a mat may be formed from a petroleum-extended polymeric foam (extended with the residue of a crude distillate or the like). In certain instances the incorporation of air or other blowing and/or oxidizing and thickening agents will be preferred (e.g., conventional air-blowing techniques), so that the active hydrogen content of the material be increased — similar to what is done for asphalt coatings in like instances. Likewise, although certain preferred application techniques for the foam, the Pre-coat, and Top-coat have been described, workers in the art will in some instances contemplate other application and/or fabrication techniques as suitable.

Workers in the art will further appreciate that the so-constructed urethane foam mat 2, having been foamed in place will insure a totally "monolithic" structure capable of performing at least two very desirable functions; namely, distributing a point load uniformly over

a great area of the underlying muskeg; and acting as an impervious barrier to prevent "pumping" and eventual contamination of the granular fill by subsurface moisture. To perform these two functions the urethane must be sufficiently rigid, yet have the ability to eventually conform to the underlying muskeg substrate conformation. As a further beneficial side effect, such a foam mat will also provide a thermal barrier preventing seasonal frost penetration into the subsurface muskeg and any resultant, damaging heaving, etc.

What is claimed is:

1. A method for constructing improved, more stable embankments upon muskeg-type terrain, such embankments contemplating the imposition of relatively high loading on a prescribed bearing portion thereof, the method comprising the steps of:

a. Placing a continuous, structurally integral water-impervious mat structure upon the surface of the subject terrain so as to cover and define the contemplated embankment site and

b. Distributing particulate embankment materials upon this mat structure so as to generate a center region of maximum static loading of the mat structure, thereby depressing the mat configuration thereunder and thereby tending to uniformly consolidate the underlying muskeg terrain to a high degree sufficient to be relatively rigid and incompressible under the contemplated surface loading.

2. The method as recited in claim **1** wherein the embankment materials are distributed according to a "flanking berm" mode so as to counterbalance the said center high loading materials by the weight of embankment materials distributed outward therefrom in a counterbalancing manner.

3. An embankment road constructed of a prescribed particulate material on terrain comprising a surface layer of light compressible soil material of relatively high water content, this road comprising: a substrate mat structure placed upon this terrain so as to define the contemplated road and support said particulate road material; and an array of said road particulate materials distributed upon said mat structure so as to develop sufficient static loading on said compressible soil material at the center of the roadway to thereby render it relatively rigid and incompressible under contemplated surface loading and thus form an improved highly stable roadway structure; said mat being formed to comprise a continuous structural-integral layer of water-impervious materials while supporting the described loads without rupture thereof.

4. The road structure recited in claim **3** wherein said mat is comprised of relatively rigid polymeric materials.

5. The composition as recited in claim **4** wherein said mat includes rigid stiffener means affixed thereon directly under the maximum-loaded traffic sections of the road so as to minimize any "rolling wave" phenomenon.

6. The combination as recited in claim **4** wherein said mat comprises a layer of polyurethane foam material of sufficiently high compressive strength to support the contemplated loading without rupture and a supplemental reinforcement layer.

7. The combination as recited in claim **6** wherein said polyurethane foam is applied in a multi-laminate form and wherein a precoat of water-impervious material is applied prior to application of the foam and said reinforcement layer is nylon mesh material.

8. The combination as recited in claim **7** wherein said precoat is comprised primarily of bituminous materials extended by a polymeric extender adapted for low temperature flexibility of the mat in service.

9. A method of floating an improved more stable gravel road atop muskeg-type terrain comprising the steps of:

a. Placing a continuously structurally integral polymeric water-impervious mat upon the terrain surface so as to define the roadway site;

b. Distributing particulate materials upon this mat so as to form the roadway embankment in a manner that develops a central traffic-supporting region of maximum uniform weight, tending to depress the portion of the supporting mat thereunder and consolidate the supporting muskeg materials thereunder.

10. The combination as recited in claim **9** wherein the particulates are distributed in a "flanking berm" mode so as to develop said depressed central mat section and maximum central static loading while also counterbalancing and stabilizing this and gradually diminishing the static loading upward therefrom thereby minimizing any sharp discontinuities of stress upon the underlying mat and minimizing resultant shear and a tendency to rupture.

11. The combination as recited in claim **9** wherein rigid reinforcing stiffener means is affixed to the mat structure along portions thereof underlying the contemplated traffic load, said means being sufficiently rigid to minimize and "rolling wave" phenomenon.

12. The combination as recited in claim **9** wherein said mat is so formed and comprised of materials as to render a monolithic structure distributing loads over a larger area of supporting terrain and so as to function as a barrier, both to the intrusion of moisture and to the escape of particulate roadway materials therefrom.

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