RESULTS OF A QUESTIONNAIRE ON REMEDIES AND TREATMENTS

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To secure pertinent information concerning the frost action problem throughout the country a questionnaire was prepared and circulated to all 48 state highway departments. The questionnaire was designed to secure information not only on the extent and seriousness of the problem but also to determine current practices employed in minimizing or eliminating this problem. A brief summary of the information received from the survey is shown in Table 1.

Extent of Problem

The question was asked, "Is damage caused by freezing of road bases, subbases, and/or subgrade soils a problem in your state?" The majority (40) answered in the affirmative. Only five southern states (Louisiana, Mississippi, New Mexico, North Carolina, and Oklahoma) indicated that it was not a problem. Twenty-two replied that the problem was a major one in their state. Some stated that the seriousness varied from year to year depending upon climatic conditions. Others indicated that the problem was more pronounced in certain areas, particularly those of high elevation.

Base and Subbase Types

The next question was, "What type(s) of base or subbase materials seems most susceptible to damage by freezing?" As might be expected, a variety of answers were received to this question. Some stated that they used base materials not susceptible to freezing and that the trouble was usually in the subgrade (or basement) soils. Two southern states mentioned limerock bases as being susceptible to freeze damage. Others reported that any permeable bases were troublesome. The majority indicated that soil bases containing predominatingly fine sands and silts were the worst offenders.

Subgrade Soils

A further question asked for information on the geological (or soil) formations or major soil types most susceptible to damage by freezing. Since a wide variety of soils exist it was anticipated that the information obtained in this respect would vary. Some gave pedological names of the soils, others gave physical test constants, and some H. R. B. soil classification. Still others gave general geological parent rock formations, or soil areas. For a complete tabulation of the replies to this question, the reader is referred to Table 1. In general, it appears that those soils most susceptible to frost heaving are those containing high silt contents. In one state they may be in the Coastal Plain, in another they are found as glacial lake deposits and in still a third as windblown or loessial materials.

Another question, "In soil areas susceptible to frost action, is the damage related to profile development?", was asked. It was intended to read soil profile development; however, the word "soil" was inadvertently omitted and some of those replying referred to the profile of the road. The majority of those replying were of the opinion that damage is related to soil profile development. Some observed that damage was mostly in cut sections. The experience of at least one state indicated that any soil except corase sands and gravels are susceptible to frost heaving when underlain by a more impervious formation within a depth of about six feet of grade elevation.

Current Design and Construction Practices

In those states where road damage by freezing prevails the replies indicated considerable thought has been given to remedies and treatments in current design and

TABLE 1. DATA FROM STATE HIGHWAY

State	Reported by	Is damage caused by freezing or road bases, subbases, and/or subgrade soils a problem in your state? Yes	No	Major	Minor	Base: What type or types of base or subbases materials are most susceptible to damage by freezing?	Base: % of State area affected. (Est.)	Subgrade: Give geological (or soil) formations, or major soil types most susceptible to damage by freezing.	Subgrade: % of State area affected. (Est.)	In soil areas susceptible to frost action, is the damage related to soil profile development? Yes	No	Remarks
Ala.	J.L. Land	x		Very minor		Those having high silt content A-4 Friable or plastic-L.L., P.I. or P.L. not necessarily related to frost action. Cont'd. low temp. plus good supply of fringe moisture accelerates damage.	25% slightly at intervals of every 4 years.	Those derived from disintegrated stone and those over hard pans or impervious & inclined strata of hard pan.	Practically none-such areas are corrected by base or subbase.	x		For the most part soils that could be affected by frost are treated or covered sufficient to prevent their reaching low temps.
Ariz.	H.H. Brown	x		In higher elevations		Those having a high percentage of material passing No. 200 sieve.	5-10% of State highway mileage	Frost damage is confined principally to the base.			x	None
Ark.	E. L. Wales	x		x		-	-	A-4 Type Soils	50 %			
Calif.	F. N. Hveem	x		Very minor		Trouble is usually in basement soils	-	Sandy clay	less than 5%	x		Damage occurs mostly in cuts.
Colo.	R.E. Livingston	x	x			Those in high percentage of No. 200 (15% or greater)	40 %	All of the A-2 group and the A-4 and 5 groups.	40 %		x	In snow areas, fill sections are much less susceptible to damage than are cut areas which allow infiltration of snow moisture.
Conn.	Philip Keene	x	x			None. Bases and subbases are clean bank run gravel or clean bank run sand.	-	Silt strata (glacial lake deposits) are worst formations. Clay strata (glacial lake deposits) are next. Glacial tills (ground moraine deposits) are moderately bad - they contain 20 to 50% silt and clay.	95 %	Sometimes		In the older roads, excessive heaving often occurs in the "A" horizon at the grade points. This has been largely eliminated in the newer roads by carrying the subbase 50 ft. into the fills and taking care to remove the "A" horizone material.
Del.	Frank Bowery	x		In severe winters.		None. Bases and subbases are dense frost proof gravel-sand-clay mixes.	30 %	Stratified silts in Atlantic Coastal Plain. Fine sandy silts with less than 50 % sand and gravel; 25% silt, 15-25% clay, L.L. 25-35%, P.I. 10 or less.	10 %	Sometimes		Topography is generally flat. Drainage difficulty & location of water table are prime considerations.

DEPARTMENTS ON THE FROST ACTION PROBLEM

State	Give current design and construction practices employed in minimizing or eliminating damage.		Does thickness of subbase and base construction vary with depth of frost penetration?		Is there correlation between degree of distress attributable to frost action and climatic conditions?			Is research underway or contemplated in near future concerning freezing of bases, subbases, and/or subgrade soils?	
	Bases & Subbases	Subgrade Soils	Yes	No	Give design thickness for var. frost penetration depths	Yes	No	Remarks	Yes	No	List research projects and state if in progress or contemplated
Ala.	1. A minimum thickness of 8 in. for base and surfacing the ordinary depth of frost action in this state. 2. Bases and subbases of non-frost affected soils for load support, free drainage and frost elimination.	Cover with non-frost action materials to a depth greater than frost will penetrate.	x		Frost is a minor problem ordinarily, our base courses are thicker than frost penetrates.		x	However, most of our damage comes from a rainy period followed immediately by a flash freeze.		x	None
Ariz.	Use 4-6in. thickness of base course; well graded nonplastic material with maximum of 8% passing No. 200 sieve. Subbase material having P.I. no greater than 5 and no more than 12% passing No. 200 sieve. Subbase varies from 6 to 15 in.	No special treatment		x	Thickness of base and subbase depends principally on character of subgrade soil.		x	Little or no distress from frost in altitudes below approximately 3500 ft. above sea level. Progressively worse above 5000 ft. Approximately little difference between 5000-8000 ft. Precipitation increases with increase of altitude.		x	Recent survey of bases taken from altitudes below 5000 ft. showed that some were prrforming satisfactory and some unsatisfactorily. The condition of the projects has been coordinated with a test for frost susceptibility. Additional work will probably be done this year.
Ark.	-	-		x	-		x	Most damage by frost action occurs in northern portion of state.		x	None
Calif.	No special effort is made to eliminate frost action because evidences of such trouble are comparatively recent.	Frost boils are removed. Affected areas back filled with gravelly material.		x	-		x	The mountainous regions in the northeastern part of the state are the only places where scattered minor damage due to frost action has occurred.		x	-
Colo.	Utilization of materials with a nonplastic filler binder. No. 200 material is controlled within narrow limits; i.e., 5-10% where possible.	No attempt other than densification of subgrade soils at proper moisture content.		x	One third of the weighted value which determines total thickness depends on the depth of frost penetration in highly reactive frost areas, range is thickness is from 15in. to 27 in.			If the soil conditions are favorable, there does not seem to be too much damage regardless of the climatic conditions.		x	Have underway a directly related research job concerning seasonal moisture changes and effect on seasonal density.
Conn.	These are clean bankrun gravel 100% pass 5 in. sieve, 30 to 65% pass ¼in., 5-30% passes No. 40, 0-10% passes No. 100, portion passing No. 100 has no plasticity. Underdrain at 5 ft. below surface is installed where needed to drain subbase or lower water table or intercept sidehill seepage.	-		x	20 in. pavement, base & subbase where 24 in. frost, 28 in. where 36 in. frost; 32 in. where 48 in. frost on primary roads. Thickness is about 75% of above in secondary roads. Use 6 in. subbase in fills on "borrow" jobs.		x	Soil type is the most important factor. Ground water conditions and frost penetration depth are next in importance.		x	1. Variation of frost heaving with depth of water table. 2. Aid given by washed sand underdrain backfill to capillary rise in silty soil. 3. Depths of frost penetration below pavements in various parts of the state. 4. Observations of heaves and boils in roads built with less than standard subbase. Items 1 & 2 are contemplated. Items 3 & 4 are in progress.
Del.	Constructing non-heaving bases and subbases of sufficient thickness to minimize damage by frost.	Lowering water table by drainage, employing free draining materials as capillary cut off. Using non-susceptible materials where practicable.	x		Design thickness of pavement + base + subbase = 20 in.	x		Distress is approximately proportional to climatic conditions for any particular winter.	x		Heat transmission of soils (in progress).

TABLE 1. (Continued)

State	Reported by	Is damage caused by freezing or road bases, subbases, and/or subgrade soils a problem in your state? Yes	No	Major	Minor	Base: What type or types of base or subbase materials are most susceptible to damage by freezing?	Base: % of State area affected. (Est.)	Subgrade: Give geological (or soil) formations, or major soil types most susceptible to damage by freezing.	Subgrade: % of State area affected. (Est.)	In soil areas susceptible to frost action, is the damage related to soil profile development? Yes	No	Remarks
Fla.	H. C. Weathers	x			x	Limerock base	50 %	Not affected.			x	
Ga.	W. F. Abercrombie	x			x	Limerock	50 %					
Idaho	L. F. Erickson	x		x		Silt or clay bound bases with high % pass. No. 200 sieve; i.e. excess 10%. When % pass 40 is plastic, effects are worse & high vol. change soils appear to lose bearing capty. rapidly.	80 %	Clay silts, silty clay loams.	80 %	x		Higher grades believed best although total thickness of base & subbase of greatest imp. Grade limits amt. of water available for saturation.
Ill.	H. W. Russell	x			x	Those having high % of matl. pass. No. 40 & No. 200 seive.		Soils having a clay content less than 30% with silt & sand content seldom less than 50%, L.L. usually 13-26, P.L. usually 12-20, P.I. seldom more than 10; or having textural classification between a sand & a clay with silty & silty clay loams predominating.				Damage mainly due to conditions in cuts where several types are crossed.
Ind.	F.F. Havey	x			x	Differential frost heaves or noticeable detrimental frost act. is not apparent in bases or subbases		Wet or water bear. Silts and/or fine sand strata in the upper 3 ft. of the subgrade.	Localized areas.		x	Gen. confined to stratified glac. drift & outwash.
Iowa	W.H. Root	x		x		Bases & Subbases rarely affected by Frost Action.		Predominately silty clay, silty clay loams, silty loams, black soils with organic matter greater than 1%, glac. clays with high silt content & clay loams with L.L. greater than 35 and P.I. greater than 10.	50 %		x	In fill sections correction is secured by relatively high grades.

State	Give current design and construction practices employed in minimizing or eliminating damage.		Does thickness of subbase and base construction vary with depth of frost penetration?		Is there correlation between degree of distress attributable to frost action and climatic conditions?			Is research underway or contemplated in near future concerning freezing of bases, subbases, and/or subgrade soils?		
	Bases & Subbases	Subgrade Soils	Yes	No	Yes	No	Remarks	Yes	No	List research projects and state if in progress or contemplated
				Give design thickness for var. frost penetration depths						
Fla.	Made wearing surfs. thicker & more dense. Double course surf. treat. & retread with mineral seal have replaced single application S.T.	None		x		x	If excessive rainfall precedes a freeze the damage to limerock bases is considerably increased.		x	
Ga.						x	The greater the moisture in the limerock, the greater the distress		x	
Idaho	Use non-plastic bases & subbase with open drainage characteristics. Limit No. 200 to max. 12% prefer max. of 6 or 8% & non-plastic	Use sand blanket or 3/4in. to dust cr. gravel or cr. rock blanket over fine grained soils showing P.I. over 5 and/or linear shrinkage over 50%. Blanket course considered a part of base or subbase thickness & is generally non-plastic.	x	Design total thickness related to bearing capty. as indicated by performance. Records over similar soils in area.		x	Varies with amt. of moisture available and cycles of freezing & thawing. Exceed. wet fall or spring gives trouble for breakup. Use total thickness of 8-15 in. Frost penet. range to depths of 4 ft. in some areas.		x	
Ill.	Use of dense graded granular matls. in bases & subbases.	Replace questionable matls. with more stable soils or granular matls. Use drainage to lower water table.	x			x	Damage attributed to frost action confined to northern one third of state.		x	
Ind.	None	Depend on conditions treatment may consist of either or both: excavation and replacement of questionable soils with granular matl. to avg. depths. of 3ft. & subsurf. drainage				x	Most frost damage confined to north half of state.	x		Member of Proj. Committee No. 7, H.R.B., "Load Carrying Capacity of Roads as Affected by Frost Action."
Iowa	Bases & Subbases are rarely affected by frost action.	1. Mineral agg. salvaged from old roadbed, select. gravel backfill & glac. clay backfilled in depth. 12-24 in. 2. Frost Heave on surfaced highways excavate subgrade to depth. 2.5-3 ft. & backfilled with well comp., dense graded cr. stone.				x	Only with respect to seasonal rainfall.		x	

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Kan.	No information											
Ky.	W. B. Drake	x		x		Bases not susceptible		Alluvial silts, Eden shale origin, Conemaugh	15 %			
La.	H. L. Lehmann		x									
Me.	L. D. Barrows	x		x		Gen. all soils with more than 10% pass. No. 200 sieve & where drainage is inadequate.	100 %	Silty glac. soils & any alluvial or marine deposits which are fine textured or have poor internal drainage.	75 %	Rarely		All horizons act similarly in general
Md.	J. E. Wood	x		x		Fine sands	20 %	A-4-silt coastal plain province A-7-clays-thru out state A-5-Micaceous silt-Piedmont plateau	50 %	x		In areas of high water table and soils of high capillarity frost action damage usually occurs in subgrade of cuts
Mass.	J. E. Lawrence	x		x Secondary Roads	x On prim. roads	Subbases containing more than 10% (by wt.) of silty material. PRA class A-4	65 + -	Glaciofluvial % Glaciolacustrine, alluvial & fill deposits	40 %+ -	x		Due to inadequate drainage capillary attraction in subgrade in swamp areas.
Mich.	A. E. Mathews	x		x		Silt and very fine sand	Throughout state	Moraines and till plains	Throughout state	Usually not		Heavy "B" horizon of gravelly moraine & outwash plains cause some trouble
Minn.	S. S. Watkins	x		x		Not particularly damaging to bases and subbases		Glacial drift silts; clays & their various combinations; wind blown silts; lacustrine silts & clays	90 % or more	x		Differential frost heaving is quite definitely related to profile development
Miss.	H. O. Thompson		x									
Mo.	W. C. Davis	x			very minor			Loessial (Marshall, Knox) Glacial (Grundy) Residual (Lebanon), all silt loams	50 %	x		Lebanon, an old, stagnant, thoroughghly leached soil with almost a pure silt top soil which gives trouble at times. Marhsall, Knox & Grundy give trouble usually only where silty top soil has been concentrated in swags by colluvial action

State	Give current design and construction practices employed in minimizing or eliminating damage.		Does thickness of subbase and base construction vary with depth of frost penetration?			Is there correlation between degree of distress attributable to frost action and climatic conditions?			Is research underway or contemplated in near future concerning freezing of bases, subbases, and/or subgrade soils?		
	Bases & Subbases	Subgrade Soils	Yes	No	Give design thickness for var. frost penetration depths	Yes	No	Remarks	Yes	No	List research projects and state if in progress or contemplated.
Kan.										x	
Ky.	None	None		x			x	Climate is fairly uniform		x	
La.										x	
Me.	Variation in thickness of base where needed to overcome severe cond.	Base is thickened when low stability is encountered in subgrade conditions.	x		18-30 in. used depending upon climatic region	x		Northern portion of state is very much more affected than in southern part where a milder climate exists	x		(No title given) Project is being carried out in cooperation with Bureau of Public Roads
Md.	Proper drainage removal of inferior soils 2-12 in. of well graded gravel to insure free drainage	No treatment of A1, A2, or A3 soils. For low cost roads blending of screenings cr. run or gravel with existing soil		x			x	Repeated freezing and thawing causes severe damage		x	
Mass.	Increase normal gravel subbase from 12-18 in. depth in known silty areas	No specifications regarding borrow	x		Increase normal gravel subbase from 12 to 18 in. depth in known silty areas	x		Short periods of extreme cold alternating with above freezing temperatures cause most of the frost damage	x		South Hadley - Rt. 116 Calcium Chloride experiment
Mich.	Excavate & backfill with granular material. Raise grade with granular material	Excavate & backfill with granular material Raise grade with granular material		x	Frost heave penetration varies from 2½ to 3 ft. in southern portion of the state to 3 to 4 ft. in the northern part	x		Degree of distress is in proportion to depth of frost penetration and degree of snow removal	x		Determination of subgrade support by measuring slab deflection on frozen and unfrozen subgrades (in progress)
Minn.		Soils selection in grading. Density control. Thicker bases & subbases, load restrictions			Treatment as deep as 6 ft. to eliminate differential frost heave. 2½ ft. treatment in southern part where frost penetration is 4 to 5 ft. 6 3½ to 4 ft. in depth in northern part where frost penetration is 6 to 7 ft. for a normal winter	x		The distress is greater where the moisture is more abundant	x		Loss of load carrying capacity on roads due to frost action (under way). Treatment of subgrade soils with calcium chloride to prevent frost action (under way)
Miss.				x						x	
Mo.		Undergrade 12 in. or more to eliminate undesir conditi ns and backfill with suitable soil					x	Worst frost trouble have occurred at time of spring thaw after a winter of cycle freezing and thawing		x	

TABLE 1. (Continued)

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Mont.	R.H. Gagle	x		Varies from yr. to yr.		All types from A2 to A7. A4 and A5 are worst.					x	When the water table height is involved.
Neb.	O.L. Lund	x		x		Silty sands and stabilized soil base courses with more than 10% passing No. 200 sieve especially those with high plasticity indices higher than about 4.	100 %	Peorian & Loveland Loess, Glacial Till, Pierre Shale, Niobrara Chalk, top soils & subsoils developed in lake bottoms of the sand hills	50 %	x		Frost heave may occur in any subgrade except course sand & gravels when underlain by a more impervious formation within a distance of about 6 ft. of grade elevation
Nev.	F. H. Morrison	x		x		Granular bases		Silts & silty loams	2 %	x		
N.H.	P.S. Otis	x		x		Bases containing more than 5 % passing No. 200	Quite generally on the older construction	All except A1 and the better A3 soils. Greatest damage in A4 silts and A-2-4 glacial tills having high percentage passing No. 200 sieve	90 %	x		
N.J.	J.R. Schuyler	x		x		Open crushed stone base placed in a box section surrounded by an impervious soil & granular bank run matl. containing more than 12% passing No. 200 sieve	40 %	Soil containing more than 10% finer than .05 mm. size. Environment & number of hvy. load repetitions have a considerable influence on susceptibility to damage	60 %	x		
N.M.	E.B. Bail	x										

State	Give current design and construction practices employed in minimizing or eliminating damage.		Does thickness of subbase and base construction vary with depth of frost penetration?			Is there correlation between degree of distress attributable to frost action and climatic conditions?			Is research underway or contemplated in near future concerning freezing of bases, subbases, and/or subgrade soils?		
	Bases & Subbases	Subgrade Soils	Yes	No	Give design thickness for var. frost penetration depths	Yes	No	Remarks	Yes	No	List research projects and state if in progress or contemplated
Mont.	In areas having high water tables, profiles are kept high. Careful attention is given to insure proper drainage.	If subgrade soils are A4 to A7 these materials are blanketed with a sand choker course					x	A dry season before winter freeze minimizes frost action. Slow and intermittent freezing and thawing increases frost damage.		x	Will make some investigation when conditions warrant it.
Neb.	Limit No. 200 material to 8 to 10% P.I. equal 3 or 4	Install subsurface drainage. Use of relatively greater subbase & granular base thickness.	x			x		Greatest distress in areas where low temperatures coincide with high rainfall.	x		Reduction of strength of loessial soils and granular base courses due to frost action. A laboratory experiment, using the triaxial equipment to determine strengths.
Nev.	Additional bases added			x	More base is used in colder climates	x				x	
N.H.	Use clean gravel having max. of 5% passing No. 200 sieve. Gravel shoulders to the full width of the section	Vary depth with type of subgrade soil. Use 12 in. over best A2 material 30 in. over poor A-2-4 soil. Extensive use of under drainage high profile wherever possible.	x		Gravel depths can be reduced about 6in. in a shallow band along the coast which has a lesser penetration of frost and higher average winter temperature	x		A dry season before winter freeze minimizes frost action. Midwinter thaws apt to increase frost action. Rapid spring thawing increases spring breakup.	x		Reduction of load bearing capacity during the thawing period.
N.J.	Generally broken stone, slag, bankrun & commerical gravel combined in thickness of from 8 in. to 12 in. These mat'ls have a high % of sand & gravel textural sizes & a very low % of fine sand & silt. Extra depth of subbase is specified in areas where ground water table is in close proximity to the subbase & where the bearing of the soil is low.	Removal of organic silts & mucks. Replaced with matl. having less than 10% pass No. 200 sieve. Cover soils having high clay content with a selected borrow, or excavation matl. have 15% or less pass. No. 200 sieve.	x				x	Degree of distress is attributable to the no. of hvy. load repetitions. Climatic conditions have not been studied very thoroughly	x		Contemplate obtaining field CBR values on subgrade and subbases during thaw. Determination of resistance of various soil types, covered with model concrete slabs, to the penet. of plungers with var. unit loads, (in progress).
N.M.											

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N.Y.	George W. McAlpin	x			x	"Dirty" Run of Bank Gravel; that is, where the percentage finer than No. 200 mesh is greater than about 10 in.		Tills with "Hardpan" or "clay pan" layer, morainic soils, thin tills. Heave on lacustrine soils is minor and tends to be uniform causing comparatively slight damage, except on fine sandy deposits. Heaves are troublesome on half bog, bog, hydromorphic and planosols if grade is not kept high. Heave sometimes occurs on outwash if the ground water is high and drainage not good. Northern districts have trouble with boulders heaving beneath the pavement.			x	Nearly always a heave where "B" horizon is crossed in zonal soils
N.C.	L.D. Hicks		x									
N.D.	W.A. Wise	x			x	Stabilized granular base containing high P.I. of 6-9 where excessive moisture is present.	100 %	A6-7, hvy. clays & A-4, 6 & 7 - silty loams.	70 %	x		Heaving & swelling occur in cold & wet weather resp. Instability occurs in thawing, & serious shrinkage during dry periods.
Ohio	C.W. Allen	x			x	High silt content soils usually with 50% or more particles between .05 & .005 mm. P.I. less than 10, HRB Class. A-4. Occasionally bad & frost heaving on very fine lake sands in northern Ohio.		Glacial drift particularly morenic areas. Also some alluvial silt.	75 %			Not noticeably.
Okla.	G.E. McCamy		x	200-220 frost free days per yr. Avg. frost penet. 5-10 in.								
Ore.	J.H. Schaub	x			x	Soils containing 3-10% by wght. of matl. less than .02 mm. diam.	60 %	Silty & clayey type soils generally of an alluvial character.	60 %	x		

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	Bases & Subbases	Subgrade Soils	Yes	No	Give design thickness for var. frost penetration depths	Yes	No	Remarks	Yes	No	List research projects and state if in progress or contemplated
N.Y.	Have incorporated a gradation for R.O.B. gravel in specifications requiring that less than 10% shall pass No. 200 sieve.	Raise grade to at least 4 ft. above water table. Removal of frost heave matl. Install underdrain where applicable. Make transitions from cut to fill so that action of "B" layer is nullified. Place extra depth of foundation course matl. Removal of boulders to depth of 4 ft. and replacing soil.	x		In an empirical manner. We have no design thickness for any specific frost penetration. Our minimum thickness of foundation course is 6 in., avg. about 9 in., in extreme case have gone to 24 in., but this is not only for reasons of frost penetration. Our frost penetration averages 30in. with a max. of about 50 in.		x	Not from limited observation. Frost heave is greater in the northern, central & eastern sections where frost penetration is greatest, but damage from frost action is great all over the state.	x		Research into correlation of frost action with soil, perhaps on a pedological basis, and to discover if possible the relation of frost heave to profile development, all tied in the precipitation & freeze index. Now engaged in load bearing tests to determine the loss of strength in subgrade soils & flexible pavements due to frost action. We contemplate laboratory research into the effect of chemical additives to subgrade soils, effect of freezing & thawing on strength of undisturbed & compacted samples, max. heave on undisturbed samples. Effect of frost on different gradations of foundation course. Field research on the amount of uniform heave that takes place in lacustrine soils, particularly the sandier members, & the effect on pavement is now in progress. Effect of frost on slopes correlated to soil type direction of slope & climate.
N.C.											
N.D.	Pit run sand, gravel or scoria granular subbases are used having open gradation with either no binder content or low binder content.	Inferior soils are wasted when practical. If infer. soils are used, granular subbase is increased to satisfactory meet conditions found.	x		Design thickness varies as per subgrade bearing power determined by N.D. cone device.			No data available.	x		"Load Carrying Capacity of Roads as Affected by Frost Action" (in progress)
Ohio	Limit to granular matls cont. not over 20% pass. No. 50 sieve. Limit amt. pass. No. 200 sieve to 20 %	Deep drainage (4-5 ft.) located within 2 ft. of pavement edge & replacement with nonfrost susceptible, granular matls.	x		12 to 18 in. thickness. Attempt is made to provide nonheaving material to at least ½ the depth of frost penetration.			Damage is more severe in northern part of state.	x		Plate bearing test made at different seasons of year. (in progress)
Okla.											
Ore.	Use of 18-24 in. of base by following table for % -No. 40 sieve % P.I. 0-3 -20 3-4 -15 4-5 -12 5-10 - 6 10-15 - 4 15-20 - 3 25 0	Compaction to 95% optimum moisture cont. Some experimental drainage in use. Cushioned course of subbase matl. used whenever feasible.	x		Approx. ½ depth of frost penet. Gen. 18-24 in.	x		Greatest distress occurs when there is a wet fall season.	x		

TABLE 1 (Continued)

State	Reported by	Is damage caused by freezing of road bases, subbases, and/or subgrade soils a problem in your state? Yes	No	Major	Minor	Base: What type or types of base or subbase materials are most susceptible to damage by freezing?	Base: % of State area affected. (Est.)	Subgrade: Give geological (or soil) formations, or major soil types most susceptible to damage by freezing.	Subgrade: % of State area affected. (Est.)	In soil areas susceptible to frost action, is the damage related to soil profile development? Yes	No	Remarks
Penn.	W.H. Herman	x		x		Fine grained soils & soft shales with L.L. & P.I. over 10.	50 %	HRB Classif. A-2-7, A-4, A-5 & A-7.	50 %		x	
R. I.	No Answer											
S.C.	L. W. Heriot	x		very minor								
S.D.	A.W.Potter	x		x		Bases & subbases now in use show no detrimental effects due to freezing. However, we consider that when P.I. is over 6 & amt. passing No.200 sieve is greater than 10 a loss of density is caused by freezing.	We have no known base failures due to frost within the base itself.	Silty loam & silty clay looms of glacial or aeolian origin with P.I. below 10 with water present. Also heavy clays having high capillarity.	75 %	x		Failures predominate in cut sections but are also present in fill sections
Tenn.	No answer											
Texas	L.O. Ortolami	x		During severe winters	As a rule	Those having excessive fines(35-40%) or more, except materials with P.I. below 10 and S.L. below 20. Any condition causing subgrade to be highly permeable will increase freeze damage.	75 %	Very little damage in subgrade. Most occurs in top 2-6 in. of base but sandy subgrades that feed water to the base contribute to the base damage.				Negligible
Utah		x		x		Fine sands, silts & clays	75 %	Fine sands, silts & clays having access to underground & surf. waters.	75 %	x		In most cases.
Vt..	R. I. Rowell	x		x		All construction carries 15 in.-24 in. of glacial gravel base.		Clay & silty soils.	35-45 %			Due to hvy. frost act., all work carries constructed gravel subbases of 10-24 in. No pavements are laid on natural subgrade
Va.	D.D. Woodson	x		x		Bases cont. high % of silt & clay size particles.	5 %	Triassic "Red Beds" & carboniferous sandstone & shales.	7 %	x		

State	Give current design and construction practices employed in minimizing or eliminating damage.		Does thickness of subbase and base construction vary with depth of frost penetration?		Is there correlation between degree of distress attributable to frost action & climatic conditions?			Is research underway or contemplated in near future concerning freezing of bases, subbases, and/or subgrade soils?		
	Bases & Subbases	Subgrade Soils	Yes	No	Yes	No	Remarks	Yes	No	List research projects and state if is in progress or contemplated
Penn.	Use of 6 in. min. dpth. of granular matl. over ent. grading width as insulation	None		x		x			x	
R. I.										
S. C.	No change in design due to small area affected.									
S. D.	Base & subbase are placed full width. Base thicknesses vary from 6 in. to 12 in. Subbase thicknesses using pit run gravel vary from 6 in. to 24 in.	Replaced by 24 in. granular subbase in critical cut sects. Use 12 in. granular subbase for critical fill sects. Undercut subgrade soil is placed deep in fills.	x		Give design thickness for var. frost penetration depths: NOTE: Thicker bases are used where hvy. clay soils predominate & where silty soils (50% silt or greater) having P. I. under 10 appear. Thicknesses are not directly established by depth of frost penetration.	x	Degree of damage due to frost action dependent largely on the amt. of moisture present in the soil at the time of freezing. A wet fall, followed by a severe winter & a quick spring thaw causes most damage. A great number of freeze thaw cycles also play an important part in causing frost damage.	x		
Tenn.										
Texas	Seal leaky surfacing, strengthening a few ins. of the top base. For new material keep P. I. below 12, the % - 40 below 35 after rolling.			x			Not definite in the freeze damage area.		x	
Utah	Elev. profile 4 ft. + water tables & providing dense graded base course also provide underdrains.	Usually select granular matls.	x			x	Distress is most severe in abnormally cold weather.	x		Construction of 2 projects over areas of bad frost heaving & breaking soils. In progress. Have watched for two years.
Vt.	15-24 in. gravel subbases laid on old work. Dpth. depends on soil characteristics & road class.	Heavier grav. subbase laid where silty and/or clay subsoils are encountered.	x		Frost penet. is more or less constant throughout the state.					
Va.	Not taken into acct. in pres. design methods.			x		x	High precipitation plus low temp. causes extensive damage. (Occurs about every 10 years.)	x		Conducted Statewide Road Condition Survey at time of 1948 spring breakup.

TABLE 1 (Continued)

State	Reported by	Is damage caused by freezing of road bases, subbases, and/or subgrade soils a problem in your state? Yes	No	Major	Minor	Base: What type or types of base or subbase materials are most susceptible to damage by freezing?	Base: % of State area affected. (Est.)	Subgrade: Give geological (or soil) formations, or major soil types most susceptible to damage by freezing.	Subgrade: % of State area affected. (Est.)	In soil areas susceptible to frost action, is the damage related to soil profile development? Yes	No	Remarks
Wash.	L.H.Morgan	x		x		Sands, gravels contain small to moderate amts. of silty binder. Generally nonplastic or feebly plastic.	10 %	Glacial areas (glacial till) & loessial soil areas (Palouse series)	25 %			Usually poorly developed in frost damage areas.
W. Va.	R. F. Baker	x			x	No information	50 %	No information	50 %		x	Much excavation in solid rock.
Wis.	A.T. Bleck	x		x		Any type having more than 10-15 % - 200 matl.	100 %	All soils except those having less than 10-15 % - 200 matl.	75 %	x		Degree of severity depends upon stratification of soils column & character & proximity of bed rock formations.
Wyo.	M.A. VerBrugge	x			x		5 %	A-4, A-5, A-6, & A-7. Most damage occurs in alluvial valleys. Bentonite causes some trouble.	1.5 %	x		

construction practices. Many of them indicated that where soil susceptible to frost action are encountered that they are excavated and a backfill is made with granular materials. The replies emphasized the importance of an elevated or raised profile, particularly in areas having a high-water table. The survey revealed a wide variety of specification employed by the individual states in minimizing or eliminating frost action damages.

Only ten states replied that design thickness of subbase and base was varied depending upon depth of frost penetration. In some cases the states indicated that the character of the subgrade soil was the governing factor rather than the depth of frost penetration.

The majority (31) noted a correlation between pavement distress attributable to frost action and climatic conditions.

Research

Fourteen states have research projects underway or contemplated in the near future concerning freezing of bases, subbase, and/or subgrade soil. Others replied that such studies have been made in the past.

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State	Give current design and construction practices employed in minimizing or eliminating damage.		Does thickness of subbase and base construction vary with depth of frost penetration?			Is there correlation between degree of distress attributable to frost action & climatic conditions?			Is research underway or contemplated in near future concerning freezing of bases, subbases, and/or subgrade soils?		
	Bases & Subbases	Subgrade Soils	Yes	No	Give design thickness for var. frost penetration depths	Yes	No	Remarks	Yes	No	List research projects & state if in progress or contemplated
Wash.	Soil mortar shall have L.L. not over 25: P.I. not over 1.	Additional surfacing used over frost susceptible areas.	Sometimes		Use from 1/3 to 1/2 of max. frost penet. depth in frost damage areas only.	x		Some areas are so dry that frost does no damage even in silty soils.	x		Investigation of frost penetration in progress.
W. Va.	% passing No. 200 sieve is rarely greater than 10.	No particular design practice has been used.		x				No information		x	Use of fly-ash as an admixture for soil stabilization (Planned).
Wis.	Utilize full width pervious sand or sand gravel subbase courses, 9 to to 15 in. thick. Base courses are of crushed & graded gravel or stone, having less than 10 % passing No. 200 sieve. Base course thickness varies from 6 to 12 in. depending on traffic.			x		x		Intimately associated with the meterological conditions of the particular winter.		x	
Wyo.	Use dense graded matls. of low P.I. in both base & subbase.	Excavate soils containing traces of Bentonite & backfill with satisfactory matl. Some increase in surfacing thickness.	x		See Wyo. method of pavement design.	x				x	