FROST ACTION AND SPRING BREAK-UP

DAMAGE TO NEW HAMPSHIRE HIGHWAYS FROM FROST ACTION

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Freezing of the soil beneath the highways of New Hampshire begins early in the fall in the mountainous regions. Slowly progressing southerly and easterly, freezing is quite general by December 1, and it is from this date that we compute degree days for frost heaving purposes.

Penetration of the frost progresses rapidly until a maximum depth of about 48 in. is reached beneath the bare pavements. Maximum heaves are observed between the second week in February and the first week in March. There is a more rapid subsidence through March until the time when the frost "comes out" around the first of April.

Mud time in New Hampshire, today, is quite different from that depicted by cartoonists, since all but the very poorest class of roads have had at least one coating of gravel. The modern version of mud time is a breaking up and costly disintegration of pavements constructed over a weak subgrade material or upon a gravel base course too thin to support heavy modern traffic. Cracking of the pavement and the appearance of large amounts of water from below are all too often followed by rutting, mixing of the subgrade material with the gravel base, and eventual loss of the roadway surface. Signs similar to that in Figure 1 tell the sad story of inconvenience to the public and financial loss to the department.

That this type of spring breakup, or damage by frost action, is expensive is shown by the following table of costs charged directly to "Pavement" from January 1 to June 30, for the past three years.

Table 1

Pavement Maintenance Costs (Jan. 1 - June 30) Chargeable to Frost Damage

Year	Primary System	Secondary System	State Total
1948	$265,000	$302,000	$567,000
1949	189,000	204,000	393,000
1950	168,000	188,000	356,000

In attempting to arrive at a fair cost of spring breakup approximation was reached by using all costs charged directly against the pavement during the first six months of each year. There are, no doubt, some charges included which do not properly belong under frost damage, but, at least an indication is given of the large repair bill which the maintenance division must face for this one type of damage.

The New Hampshire Public Works and Highways Department maintains about 3,728 miles of primary and secondary roads of which 3,021 miles are considered as surface treated roads, requiring retreatment every three to five years (when properly constructed upon an adequate foundation). The average cost per mile of retreatment is $540.

It is conservatively estimated that at least 10 percent of the surface-treated gravel roads, or 302 miles, require retreatment every year due to frost action. Since they adequately support traffic during the rest of the year, there can be no doubt that the softening of the subgrade causes the pavement to break up. If we include the cost of treating, say 300 miles, at $540 per mile, we arrive at a figure of $162,000 which should be added to the yearly charges in Table 1.

The Maintenance Division operates on a budget of about $4,000,000. One million of this total is expended for snow and ice-free highways during the winter months, leaving $3,000,000 for all other maintenance activities. If then the yearly expenditure of $500,000 to $700,000 is necessary to repair damage caused by frost heaving, it is seen that this becomes a major item of expense from which no permanent benefit is derived.

A breakdown of pavement repair costs by type, from January 1 to June 30, 1950, gives the following results:

Table 2

Breakdown of 1950 Pavement Repairs by Type

Pavement Type	Total Cost Repairs	Total Miles	Cost Per Mile
Concrete	$19,000	261	$ 73
Mod. Asphalt	3,000	52	58
Bit. Macadam	17, 000	252	68
Tar	300,000	3,021	100
Gravel	17,000	132	130
	$356,000	3,728	

These costs of frost damage are composed only of those submitted by the patrolmen in their weekly time books and do not include the costs of major betterments or complete reconstruction projects which may have been prompted by the surface destruction during spring breakup but actually only hastened the day when this section would have ultimately been rebuilt. Neither do we include the cost of removing isolated differential heaves which may cost several hundred dollars each.

An examination of the cost for repairing frost damage to the several types of pavement shows that the higher types of surface do not greatly differ in this respect. However, with the fairly small amount of money available for the number of miles to be built, New Hampshire has concentrated upon giving hard-surfaced highways between every community. The less expensive gravel road with a tar surface treatment has, therefore, become more predominant. It is far less expensive to repair a highway of this type and stage construction plays a prominent part in the highway program. Normal repairs to a badly broken up section outside a built-up area would include correcting drainage deficiencies, installing under-drains where needed, adding a minimum 12-in. thickness of new gravel and a cheap surface treatment. By this method, many miles of old, obsolete roadway have been reconditioned to give many added years of service. A survey made by the Bureau of Public Roads on special maintenance sections a few years ago showed the economy of this method of repair when several old thicknesses of pavement and gravel base courses were found beneath the present roadway which had ultimately been built up to the point where they are now carrying extremely heavy axle loads.

Figure 1.

Sections not requiring this extensive rebuilding are repaired generally by filling in the pot holes with cold patch and paint patching the cracks with tar. This will suffice until the road has settled back into position and a light bituminous retreatment is applied during the regular tar season. A large amount of surface destruction is prevented by a timely heavy coating of sand over a threatening failure. This not only serves to distribute the load over the weak spots but acts as a filter to carry off the excess melt water while holding the cracked-up pavement in position.

When it is considered that some of these roads were built more than 35 years ago and more than half of the primary system is between 15 and 20 years old, it is no wonder that modern truck traffic puts a heavy strain on the thin gravel bases which were common practice in the early years. That these roads are today taking the punishment of modern traffic is a testimonial to the benefits of a gravel foundation course.

Table 1 shows that frost damage may vary considerably from year to year. The winter of 1948 was severe, but the East has experienced very mild weather during the past two years. Probably the greatest amount of damage to New Hampshire highways last winter was caused by a warm spell in January when the frost entirely left the ground. Road work along the coast in connection with the New Hampshire Turnpike continued uninterruptedly during the past two winters.

Measurements made by students at the University of New Hampshire of the amount of heaving on a test road show the peak of heaving to coincide with the peak in the degree-day curve. Differential heaving of 8 in. was recorded at one station at a peak of 1100 deg.-days in 1934 as against a few hundredths of a foot at a peak of 236 deg.-days in 1936. However, it has been observed that there is no direct correlation between the amount of heaving and the number of degree days, since some cold winters have caused less heaving than other milder winters. We may assume that groundwater conditions at the time of freeze-up and the occurrence of midwinter thaws have a major bearing on the total build-up of ice lenses.

Soil Conditions

Soil conditions in the Granite State are characterized by a plentiful supply of rock. Good farm land is scarce and is generally confined to the large river valleys, such as the Merrimack and the Connecticut, where floods deposit a rich sandy silt. A very thin mantle of topsoil covers much of the remainder of the state, in which the subsoil varies from a yellow sandy glacial drift with a low silt and clay content to a compact, dark-colored, silty hardpan or glacial till. Areas of sand and gravel, clay, silt and bedrock make up the remainder. Frost heaves of varying intensity may be found in all soil types and make the work of the soils engineer most difficult.

Glacial Till

The drifts and tills are very nearly ideal in grading and have great load-bearing value when below the frost penetration depth. The presence of boulders and their compact state make them sometimes difficult to excavate even with the largest power shovels. A survey of 85 glacial-till deposits made by the writer and Professor J. W. Goldthwait of Dartmouth College revealed intersting facts concerning these deposits. In-place densities of 150 lb. per cu. ft. were found while very few of the banks measured showed in-place densities less than 130 lb. The grading of the tills followed a regular curve in a narrow band and gave the following average analyses:

		Upper Till Percent	Lower Till Percent
Gravel		15	13
Coarse sand	(2.0mm- .25 mm)	23	20
Fine sand	(.25mm- .05 mm)	30	25
Silt	(.05mm- .005mm)	20	24
Clay	(less than .005mm)	12	18
Passing 200 mesh sieves		40	46

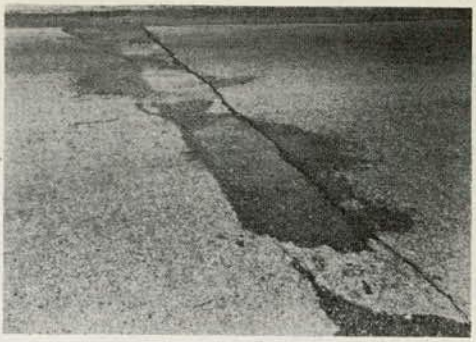

Figure 2.

Freshly exposed cuts up to 100 feet deep were studied. The so-called upper till, or brownish layer, was found to extend down as far as 20 ft. from the surface. Comparisons of this soil and its included stone content revealed very little difference from the lower blue till and indicate that both were formed at one time, The difference in coloring can be explained by weathering. Densities in the upper till are generally less than that of the lower and appreciable thicknesses of iron rust have been noted at the contact line of the two tills.

The drifts and tills are frost susceptible, but differential heaving is not a major problem, except at the contact point with other soil types and when the silt content is very high. They generally fall in the B. P. R. A2 classification while some are referred to as A2-4. The looser upper tills and drift quite often require underdrains to cut off the side-hill movement of water, while free water is rare in the more compact lower tills. An 18-in. gravel base course has proved adequate to support present-day axle loads and serious infiltration of the subgrade into the gravel has not been noted using the 18-in. depth. Thinner layers of gravel over the more silty tills have failed by rutting and shoving during the frost melting period. It is impractical to attempt to compact the lower tills to their original density; allowance is made for swelling instead of shrinkage, in computing earth quantities.

In rare instances glacial tills in New Hampshire are capable of producing up to 8 in. of differential heaving and may double their thickness due to an accumulation of ice lenses. An exploration pit dug in the shoulder to ascertain the cause of a 5-in. frost heave in a newly constructed road revealed the reason why the total elimination of frost heaves may be very expensive. It was realized from the soil profile that frost-heaving silty till was present in this road cut, so 30 in. of gravel base was constructed beneath a 3-in. road mix pavement. In addition, a 6 in. perforated underdrain was constructed along both edges of the roadway to a depth of 5 ft. beneath the pavement. The test pit revealed that frost had penetrated to a depth of 48 in., that there was no infiltration of the subgrade into the gravel, and that numerous thick ice lenses were present beneath the gravel. The effected area was only about 20 ft. long.

Sand and Gravel

Large deposits of glacial sand and gravel are found generally throughout the state and are of excellent quality. Both the sand and gravel make excellent concrete aggregates with a minimum of washing to remove the infiltrated loam. The stone has a Los Angeles wear varying between 25 and 40 percent with a few deposits showing slightly more wear. Except for a narrow band along the ocean, the aggregates are considered sound and durable under frost action. Intrusions of silt layers or streaks are the only bad feature and must be avoided during construction.

Figure 3.

The features which make them ideal for road construction purposes is their free draining qualities and the ability of the road builder to obtain good compaction through the use of smooth rollers and sprinkling. Even the loose sands when once compacted through watering retain their stability under a thin bituminous mat, in spite of the lack of binder.

In order to insure that melt water in

Figure 4.

the gravel base course will be promptly drained from beneath the road, a maximum of 5 percent passing the 200-mesh sieve is allowed in the specifications. A recent survey of the cause of certain frost heaves disclosed the fact that sufficient water is present in clean gravel bases to freeze solidly during the winter, a phenomenon not observed in the gravel bank. This explains to some degree the large amounts of water which appear on a cracked pavement during a warm day in the spring. One 6-in. frost heave was excavated and found to have 12 in. of frozen gravel directly beneath the pavement. Below the frozen gravel, there was a 12 in. layer of dry loose uniform size coarse sand which could be poured from the hand. Below this layer a sandy till was found to be frozen an additional 18 in. with numerous contained ice lenses which caused the heaving. It is evident that capillary water could not have furnished the moisture necessary to freeze the gravel base but that the moisture must have been derived from temperature changes occurring beneath the pavement which brought up moist air from the earth below.

Figure 2 shows water emerging from a transverse crack caused by a frost heave. This was taken on a warm spring day. A 3 to 4 percent grade is downhill to the left and there is 18 in. of good gravel under the bituminous road mix pavement.

Clay

True clays, as found in other parts of the country, are rare in New Hampshire and occur mostly near the ocean as dried-out blue marine clay. Brickyards have flourished for many years in this area. Due partly to the more temperate climate near the ocean and the fact that the glaciers have covered much of this area with a stony drift, road building is not too difficult. Ledge outcrops are very common and extremely erratic, appearing and disapperaing in a very short space. Vertical faces are very common and most of the state's deposit of trap rock is found here. Frost heaving and breakup is not severe if a 12 in. blanket of clean gravel is used for a base course.

Silt

Silt, or a mixture of fine sand and silt, is responsible for the majority of the differential frost heaves so prevalent in the spring. While not nearly so costly as the spring breakup caused by frost action, these abrupt heaves are probably more wearing on the motorists' nerves than a longer broken up section of road. No sooner does one pick up speed after slowing down than another heave is found, and then again one may go for miles without any visibile evidence of heaving. A concerted effort has been made for years to rid our highways of these menaces, and each serious bump is now marked each winter by a large "BUMP" sign, shown in Figure 3. The cost of removing individual frost heaves will vary from a few hundred to several thousand dollars, and extreme caution is observed during the progress of any construction project to eliminate as far as possible all differential heaving.

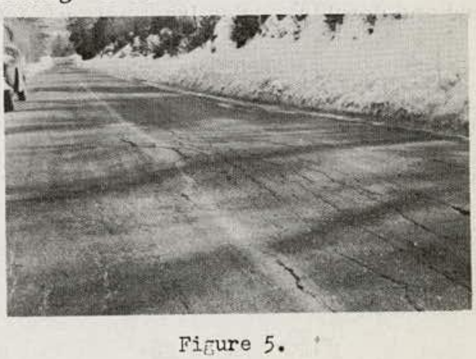

Figure 5.

Silt generally occurs as layers in a sand or gravel deposit, as shallow pockets or as dikes. One dike was found in a

Figure 6.

Figure 7.

coarse sand plain to extend across the highway for a width of 10 ft. A grain-size analysis showed 24 percent fine sand, 65 percent silt and 11 percent clay. A concrete pavement constructed over the old road on a 4-ft. fill cracked in this location during the first winter. A pocket of silt encountered in the bottom of a 20-ft. deep gravel cut consisted of 50 percent fine sand and 50 percent silt and extended for 50 feet along the full width of the excavation. It is general practice in New Hampshire to remove silt to a depth of 4 ft. below the pavement and to backfill with gravel or selected excavation. Care is also taken to drain the resulting low point and to make long tapering cuts.

Silt layers occur so frequently in fine sand deposits that it is rather common practice to make a series of auger borings into the subsoil after excavation is completed to detect their presence. It is sometimes very difficult to distinguish between the fine sands and silts by inspection, so a laboratory analysis is required. Cut banks containing a high percentage of silt are difficult to maintain at ordinary slopes. Upon thawing in the spring, the liquid silt flows down the banks and into the roadway and sometimes requires sandbag barricades to keep the pavement clear. The expense of cleaning the ditches and removing the sloughed material is an added expense to the maintenance division. Good success has been obtained with the use of flat slopes and a hay mulch spread over the raw banks to encourage vegetation.

Underdrain

The presence of copious amounts of water in shallow underground streams tremendously complicates the soil engineer's prediction of future frost heaves. It is normal practice to make very complete records of the existing frost heaves during survey work for new construction. If time is available, the old road is studied the winter and spring before construction starts. If not, the old pavement is studied for cracks and failures and the section patrolman is consulted. When the soil profile is made during a dry season it is extremely difficult to determine the necessity for side drains. However, unless it is extremely dry, underground springs and water channels can usually be located by the resident engineer during the construction period and the side drains installed. It is not unusual to construct underdrains through every cut on a project through sheer necessity. The most difficult drainage problem is that encountered when the roadway runs perpendicular to the contours and side drains are not effective in cutting off the flow of water in a longitudinal direction. Since the gravel base courses in New Hampshire are constructed from slope-to-slope and ditch-to-ditch, water has an opportunity to follow the crown of the subgrade and escape from beneath the pavement.

Figure 8.

Ledge

Frost heaves are common in ledge excavation and a 2-ft. gravel base course is always constructed through the ledge sections. Many small veins of water and large springs flow from cracks in the ledges. Underdrains are installed if there is any sign of water entering the roadway. This is not generally the case in good sound rock.

Most of the heaving in ledge is caused by the undulating surface of the rock cut by the grade line in such a manner as to leave alternate short stretches of ledge and soil. Moisture trapped in the soil pockets causes unequal heaving.

Boulders

Boulders beneath the surface have been the cause of much rough-riding pavement and are not always suspected of being responsible since the strength of the pavement has a tendency to flatten out the heaves. The writer has seen several long sections of highway excavated to remove a frost heave only to find one boulder 2 to 3 ft. in diameter the only apparent reason for the heaving. An example of this condition is shown in Figure 5.

Illustrations

Figures 4, 5, 6 and 7 illustrating typical highway destruction through frost damage, are included to show the effects of traffic upon a bituminous surface inadequately supported by a thin, gravel base course constructed over a frost susceptible soil. In each case heavily loaded trucks can probably be blamed for the damage. While no rigid load ban is placed upon New Hampshire highways in the spring, a cooperative agreement has been worked out between the Division Engineers and the heavy truckers whereby the truckers are notified when the roads are in a weakened condition and they voluntarily reduce their load weights to the desired limits. If a freeze occurs, they are permitted to increase the weight of the loads until another thaw weakens the subgrade support.

The damage shown in the illustrations is confined mostly to highways which have not been constructed in recent years. It is generally true throughout the state that modern highways designed and built with proper attention to soil and drainage problems have not suffered excessive frost damage. A few projects where it was necessary to use a poor grade of gravel or where the grade line was set too low in wet areas are now showing signs of distress. Figure 8 shows a modern bituminous road mix pavement containing a considerable amount of longitudinal cracking caused by a deeper penetration of frost in the center of the road than under the snow banks on the shoulders. The unequal heaving in the cross section has exceeded the tensile strength of the bituminous binder and the cracking has required sealing.