FROST ACTION AND SPRING BREAK-UP IN COLORADO

R. E. Livingston, Planning and Research Engineer,
Colorado State Highway Department

San Luis Valley

The San Luis Valley in Colorado is a high mountain valley with an average elevation of approximately 7,500 ft. It is confined between the Sangre de Christo Range on the east and the San Juan Mountains on the wet in the south-central part of Colorado and is part of the Rio Grande Drainage Basin. The valley is one of the most productive agricultural areas in the state, producing some of the finest vegetables to be found in the Rocky Mountain West. The entire area is subirrigated by water trapped in a major geologic fault, giving the effect of an underground lake. The entire valley is dotted with artesian wells which have constant flow when drilled to depths between 100 and 300 ft. The size of the valley is roughly 50 by 70 miles.

Yampa Valley

The Yampa Valley is situated in northwestern Colorado and is part of the Colorado River Drainage Basin. It has an approximate elevation of 7,500 ft. and is also subirrigated. It produces large quantities of mountain-valley hay and small grains, which thrive due to the constant source of water. The water table generally is not more than 2 ft. below the natural ground elevation.

Typical of the high mountain passes, which suffer frost damage, is Wolf Creek Pass located in southwestern Colorado. The pass is located on the Continental Divide, the eastern slope of which drains into the Rio Grande Drainage Basin; the western slope of which feeds the San Miguel River, which ultimately finds its way into the Colorado River Drainage. The elevation of the mountain pass at the point where the highway crosses the divide is approximately 11,000 ft. Snow falls, which aggregate from 300 to 600 in. annually, are normal in this area, the amount of water in the snow ranging from 7 in. of snow to 1 in. of moisture to as high as 15 in. of snow to 1 in. of moisture.

The affected areas described above are not the only ones of their type in the state, but are typical of a number of similar situations and probably have more pronounced characteristics than others that might have been selected.

Soil Types

In the San Luis Valley, a recent project awarded to contract lies between the Towns of Moffat and Mineral Hot Springs. It is 12.1 mi. long and has a maximum elevation of 7,745 ft. and a minimum elevation of 7,560 ft. From this it can be deduced that the total fall in the 12.1 mi. is 185 ft., an average of 15 ft. per mi., resulting in an average roadway grade of approximately 0.3 percent. This is typical of the type of grade that exists in the area. Such grades do not provide sufficient lateral difference in elevation to furnish the characteristics of good drainage. Recapped below are three of the typical soils that are to be found generally along the project, the range being from the best to the poorest. All soil classifications given are those established by the use of the Highway Research Board classification.

Soils

Type	A 2-4(0)	A 4(0)	A 7-5(20)
P. I.	N. P. to 5.4	7.7	32
L. L.	20.2 to 25	26.7	65
Percent -No. 200	30 to 35	36	90
C. B. R.	28.5 to 30	28.5	2

It will be noted that the soils range from a granular soil, the fines of which are nonplastic to highly plastic and having a high percentage of -No. 200, to silts and fairly heavy clays. The predominance of silt is to be noted in all of the soil samples. In order to diminish the amount of difficulty that has been experienced in the past, present design practice places finish grade lines 4 to 5 ft. above the side drainage ditches or the natural ground line. All fill sections are built of a selected soil obtained from side borrow pits. The best of the nonplastic soils are, of course, used for this purpose.

In the Yampa Valley, a project recently awarded to contract was 9.9 mi. long, located between Haybro and Phippsburg. The maximum elevation found on this project was 7,900 ft. and a minimum of 7,400 ft. This results in a total difference in elevation of 500 ft. or a fall of approximately 50 ft. to the mi. with a resultant average grade of 1 percent. As opposed to the areas of the San Luis Valley, the lateral grade is sufficient to provide good lateral drainage. Tabulated below is the range of soil types typical to the area.

<u>Soils</u>

Type	A 2-4(0)	A 6(12)	A 7-6(15)
P. I.	N. P.	20	20
L. L.	35	38	45
Percent -No. 200	24	85	98
C. B. R.	42	2	2

The design grade lines in this area are held between 4 and 5 ft. above the side ditches or the natural ground line. Embankments are constructed of the best available soils of the granular free-draining type. It has been found of particular necessity to superimpose a blanket of sand over the natural soils to prevent intrusion of the organic silt and clays. Where this practice has not been used, the intrusion of the inferior grade materials into the free-draining soils has taken place to such an extent that the ever-present moisture has been provided capillary columns through the free-draining material.

In Wolf Creek Pass, as in all mountain pass areas, lateral drainage is not a matter of consideration. Roads constructed to the mountain passes, in practically all cases, have a controlling 6 percent grade, and sufficient distance is introduced to keep the grade in this control limit. Practically all of the work is side-hill construction with numerous through-cuts always being present. Short sections of through-fill occur where the location crosses drainage courses. Soils normally encountered in the area are tabulated below.

<u>Soils</u>

Type	A 2-5(0)	A 2-7(2)	A 7-5(15)
P. I.	8	29	25
L. L.	45	55	68
Percent -No. 200	16	30	63
C. B. R.	36	10	2

The high liquid limits for the area are produced regardless of the soil type. This is most logically explained by the fact that the parent rock in the area includes considerable micaceous material. This is also an area where heavy annual snow loads are to be found.

Temperature Range

In the San Luis Valley area, temperatures of as low as -50 F. are experienced, and during normal years, temperatures in the range of -40 F. are common. Summer temperatures of ground surface may go as high as +110 F. The freezing cycle normally begins around the first of November with the extremes of low temperature usually taking place in January or early February. Frost penetration depths of as much as 5 ft. are common. Through areas of fairly uniform soil, the frost heave does not cause any particular difficulty because of its uniformity. Where mixed soils are encountered, or where the soil types change at frequent intervals and the amounts of consolidation of the embankments are distinctly different, there is sufficient differential frost heave to cause disruption of pavement surfaces. No record of the difference of elevation occasioned by frost heaving has been kept.

In the spring breakup period, which usually starts at the end of April, there is a boiling action which is quite severe. Areas of frost boils with breakup approximately 18 in. to 2 ft. in depth are common on those sections which do not have a blanket of approximately 30 in. of granular soil immediately underlying the paved surface. Boils occur on sections with an ordinary gravel surface as well as those covered by bituminous mat. The more recent construction projects in the area all carry the 30-in. granular blanket, and on these projects there is practically no frost damage.

In the Yampa Valley, the freezing cycle starts in early November and the minimum temperatures are generally present during January with temperatures of -30 F. being common. The maximum ground surface temperature during the summer is in the range of +90 F. Similar to the San Luis Valley area, where areas of uniform soil are involved, there is practically no damage due to frost heave. In the non-uniform soil sections, or where soil types change rapidly, there is differential heaving which disrupts pavement surfaces. The frost penetration in this area ranges from 36 to 48 in. During the thawing period, which starts in April and May, frost boils are common and extend as much as 18 in. below the pavement surface. The newer construction projects, similar to the San Luis Valley, have heavy courses of granular material, and in such cases there is practically no frost damage.

Wolf Creek Pass

In this area the snow falls start at the higher elevations in October. The snow load builds up to its maximum in early March. The temperature ranges as low as -30 F. to -40 F., with maximum temperature in the summer months being in the neighborhood of +60 F. Possibly because of the extreme snow load carried in areas of this type, there is very little differential frost heave. During the thawing periods, starting in April, frost boils are noted at any point where there is not a granular blanket of approximately 24 in. made up of either normal excavation or imported material. Frost penetrations of 24 in. to 36 in. are common.

Soaking Characteristics

In the San Luis Valley the normal water table lies practically at the grass roots. The high subsurface water table is a constant feeder source for the capillary soils which predominate. For this reason, there is never a period of the year when water is not available to feed the areas of frost action. Ice lenses start building the minute the temperature range drops to where freezing takes place. The buildup of the ice lenses continues during the period of freezing temperatures.

The Yampa Valley, being similar to the San Luis Valley, has no distinct differences in the manner or extent of frost heave and ice formation.

In the Wolf Creek Pass area, as in all other mountain pass areas, the predominant source of water contributing to frost damage comes from snow. During the early fall snows, when the temperature moves back and forth between freezing and nonfreezing temperatures, water is fed into the subgrade and side ditches, and the entire area surrounding a road structure becomes completely saturated. Ice lenses are built up until such time as the snow load is sufficiently heavy to act as a thermal insulating blanket. The reverse condition occurs in the spring thawing period, and for this reason, the amount of boil experienced is not as severe as experienced in the valley areas where the snow load never is sufficiently heavy to act as an insulating medium.

General

A review of the temperature ranges, soil types, and the water sources indicates that frost heave in itself is rearely a problem of great magnitude in Colorado. It does have significance in the fact that those soils having a high percentage of fines and which lie in close proximity to a water source take on sufficient moisture in the form of ice during the freezing periods to become a matter of major concern during the thawing cycle. From the previous discussions, it is noted that in the mountain valley areas, frost penetrations of 4 to 5 ft. are common. This entire frozen area immediately becomes a matter of concern when the thawing cycle starts.

In the fine-grained soils, the amount of moisture present has been found to be in excess of the plastic limit and often approaches the liquid limit during the thawing cycle. Under such conditions, it is obvious that the amount of support provided to any pavement structure could never be adequate to prevent complete disruption. The obvious answer, as we have found it, is to provide sufficient thickness of non-frost-reactive material together with grade lines which provide complete drainage of the roadway prism to a depth equal to the frost penetration. In high mountain areas, where the frost penetration is of a lesser depth, the granular blankets over soils similar to those in the high mountain valleys can be reduced only to the extent that the frost penetration is reduced.

FROST ACTION IN MICHIGAN

O. L. Stokstad, Engineer of Soils, Michigan State Highway Department

Michigan's cool and moist climate is typical of the Great Lakes Region. The annual percipitation of 35 in. is well distributed throughout the year. The freezing index ranges from about 600 in the southern limits of the State to about 1800 in the Upper Peninsula. The Great Lakes have a moderating influence on temperatures thus preventing extremes of both heat and cold. Under this climatic environment the soils of the state have developed profiles belonging to the Podzol and Gray-Brown Podzolic soil groups. The northern Podzol group grades into the Gray-Brown Podzolic on a line extending across the central portion of the Lower Peninsula of Michigan.

The problem of frost action in Michigan is usually discussed under the headings of frost heaves and spring breakups. Common usage defines a frost heave as a bump or series of bumps high enough to be damaging to pavement and often dangerous to traffic. The term spring breakup is used in referring to the detrimental softening of the subgrade and associated surface failures which occur during spring thawing periods. Such softening is often most destructive when it occurs during a sudden January or February thaw.

Frost Heaves

Differential frost heaving is a spectacular expression of frost action now seldom seen on the main roads because of corrective measures consistantly applied. It occurs when certain soil textures, certain drainage conditions or a combination are found within the subgrade frost zone. Silts and very fine sand are soil textures commonly referred to as frost-heave materials. It would be more correct to say that a frost-heave material is a soil texture in which silt and fine sand are the dominating constituents or soil fractions. These materials are easily identified in the field visually and by feel. They have the capacity for moving large quantities of capillary water rapidly through the soil to points where such water is being removed, as, for instance, by evaporation or by the formation of ice crystals in the soil. Silt pockets do not necessarily depend on some water table as a reservoir for capillary water. Water stored in the body of the deposit as capillary water is normally sufficient in quantity to form ice layers and detrimental heaving.