ROAD READY R3 RESEARCH

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RESEARCH REVIEW: FROST ACTION

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> “Roadways in Minnesota, North Dakota and the surrounding northern region’s roadways experience wide temperature swings, ranging from summer highs above 100 degrees F to winter lows that can dip below -30 degrees F. As winter sets in, the freezing temperatures permeate throughout the roadway structure, extending down through the surfacing, the aggregate subbase and into the subgrade. Frost depths in excess of six feet are common. Freezing temperatures, water and poor subgrade soils can combine to create roadway problems such as frost boils and frost heaves that work their way up to the roadway surface. This combination leads to roadway damage, loss of road carrying capacity, and poor driving surfaces. The Minnesota Local Road Research Board’s “Frost Damage in Pavement: Causes and Cures” video provides a good explanation of the power of frost and means to reduce the damages. Understanding material engineering properties and the impacts of water are key to building a quality road.”
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> *– Benjamin Worel, PE, MnROAD Operations Engineer*

As fall turns to winter and temperatures drop below the freezing mark, frost begins damaging our roads — and the problem continues right through winter into spring. Humps, dips, cracks, potholes, and heaved sign, fence, and guardrail posts caused by frost damage are major cost factors. They damage our vehicles and consume major portions of our highway budgets.

Three factors work together to form ice that damages our roads:

- water in or near the soil,
- freezing temperatures,
- and frost-susceptible soils

These are sometimes referred to as the three W’s: water, winter, and wicking.

When these three things happen and the water freezes turning into ice, it exerts a very strong expansive force and, just like a can of soda left in the freezer, problems can occur. Frost damage to roads include bumps (heaves), sign/fence posts heaving out of the ground, guardrail post heaving up…and not uniformly. Frost can damage and lift almost anything embedded in soil, such as foundations, utility poles, and fence posts. Those objects will be lifted by frost action if they aren’t placed with their bottoms below the frost line — or if they’re not anchored in some other way.

Some questions that are often asked regarding frost and seasonal heaving include:

- Why does this occur?
- Why does it occur some years and not others?
- Why does it occur in some places and not all?
- Why doesn't it occur in small areas and not uniformly?
- What can we do when it happens?
- What can we do to prevent it?

As mentioned before, certain types of soils are more susceptible to frost and heaving. Typically, these are fine-grained soils with poor drainage characteristics that tend to "hold" water. Specifically, these soils are:

- lean and fat clay, silty clay, fine sand with silt, elastic silt (FHWA 7.5.6)
- soils >6% passing 200 sieve (US Army Corp, Table 2.1)
- areas of non-uniformity

These frost susceptible soils often act like sponges and illustrate the difference, think of two examples: water running through a sponge and water running through coffee grounds. The sponge will retain much of the water and slowly, over time, the moisture will drip and/or dry out. The water in the coffee grounds mostly drips right through, leaving the grounds only slightly wet. Over time both the sponge and coffee grounds will dry out.

In the Midwest, our soils are not uniform. About 10,000 to 15,000 years ago, after the glaciers moved through and then retreated, they left us with some amazing landscapes that vary from rolling hills, steep rock faces and valleys. Those same glaciers also left us with a hodgepodge of soil types scattered below the surface. Because of this, we have areas of random "pockets" of varying soils. The size of the pockets can vary from a few yards to miles. Pockets of frost susceptible soils in areas of predominantly sandy soil can cause localized frost heaves. That's why, when we build roads, we do cores and soil samples to try and identify what soils are present. The more closely spaced the cores are, the better "map" we create of the underlying soils.

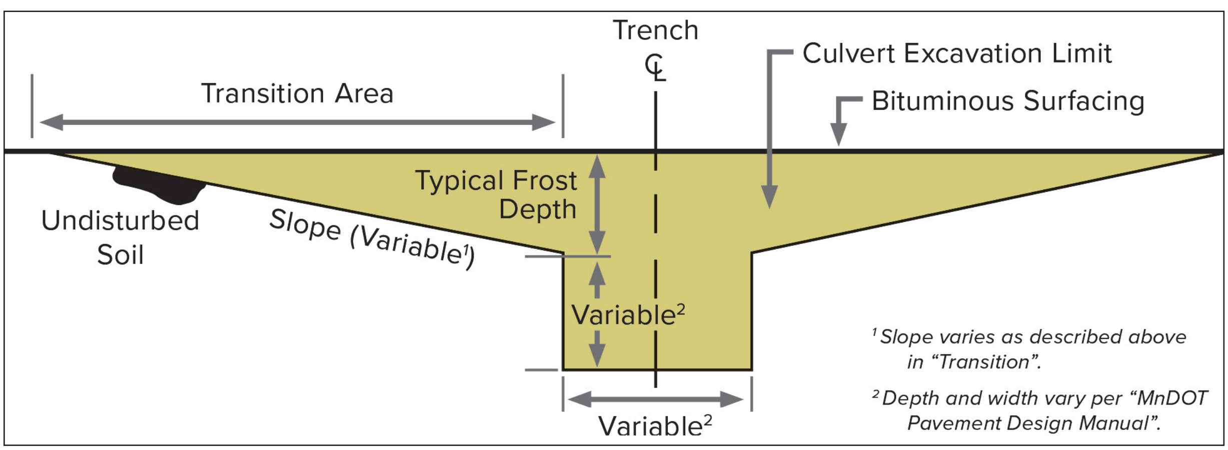
Another type of non-uniformity occurs when localized maintenance (replacing a culvert, fixing a pothole, doing a deep cut/patch) is done, but the new material does not match the old, in-place material. An example of this is if the roadways was built over mostly clay and when fixing an area of damaged pavement, we dig down and remove the base, replacing it with a good drainable gravel and then top with asphalt. The patch process was textbook; but that patch area will respond differently to moisture and freeze-thaw cycles than the original surrounding roadway. The clay area around the patch will absorb moisture (heavy rain or spring thaw) while the gravel under the patch will allow the moisture to drain through. When it freezes the clay area will expand and move but the gravel patched area will stay resulting in a dip; known as a frost sag. Transitioning and blending are ways to minimize the frost effect; more on this later.

As stated earlier, frost damage occurs by having frost-susceptible soils that get wet (saturated) and then freeze (expand). Because all soils have some type of natural draining ability, the amount of water retained varies. If the fall season is wet and an early winter comes, the soils will not drain much, and the retained water will be trapped and eventually freeze. Wet fall seasons with early freezing are one reasons why frost damage occurs sometimes, but not all the time. A wet fall and early freezing can also result in problems in the spring when the sun begins to warm the surface and some of the underlying materials, including the ice. Because the lower layer is still frozen, the melted water is trapped and pooled. Overnight this pooled water re-freezes, pushes the pavement up and the whole sequences happens again and again. This is how potholes form.

So, what are some of the ways to minimize frost damage? We can minimize frost damage by building a transition, using the appropriate materials and making sure the materials are compacted.

Transition. When working in areas where frost damage is being repaired, it is very important to taper/transition into and out of these areas. Typically, the transition/taper ranges from 1:5 to 1:20; the longer the transition area the better. The transition area is dependent on the depth of frost. The start of the taper should be below the frost line; the length of the taper is typically a function of surrounding geometrics conditions, roadway speed, the difference between in-place and backfill material and your available budget.

The figure below shows a typical trench detail:



Materials. Try to "match" any new material to what is already in place. After matching, blend the old in-place material with what is being added.

Backfilling/compaction. Making sure all layers are compacted well reduces settlement.

Resources

For additional information on frost, how it occurs, and how to fix:

- Frost Damage in Pavement: Causes and Cures (video): https://www.youtube.com/watch?v=cqgi-haAFf-8
- Effective Methods to Repair Frost Damaged Roadways: https://www.lrrb.org/pdf/RIS-27.pdf
- Dealing with frost and boils and heaves, Iowa LTAP Technology News article: https://intrans.iastate.edu/app/uploads/sites/10/2018/07/01_2016_TN_January-March.pdf
- Why there are Spring Load Restrictions, NDDOT: https://www.dot.nd.gov/roadreport/loadlimit/load-limitinfo.htm#restrictioninfo
- Frost Heaves and Frost Boils, NDDOT Memo from Matt Kurle: https://www.ndltap.org/resources/downloads/local-roads-frost-heave-boil-memo.pdf