DESIGNING YOUR RINK FLOOR TO AVOID SUB-SOIL FROST HEAVING

Any rink which operates for extended periods, which can be classified for more than 1 month, is susceptible to potential frost heave problems from perma-frost formation beneath the rink surface. The condition of rink floor heaving is similar to building foundation frost heaving which is a critical design concern for northern geographic locations.

Frost heaving has been known to raised rink floors by 12" running the skating surface, breaking perimeter concrete rink perimeters, and actually creating irreparable damage to building foundations. Frost heave damage is not a risk worth taking since it could literally ruin your complex beyond repair. Fortunately the conditions which create under floor heaving damage are known and can be eliminated with a proper design sequence.

Frost heaving is cause by ice layer formation with the soil. We classify the location where this happens as a freezing plane. This will occur underneath any rink despite its location in the country if proper soil preparation is not done, and/or if a well designed sub-soil heating system is not installed. Even the hottest climates face this risk if proper design policies are not adhered with.

Even rinks which feature an insulation membrane but not a functional sub-soil heating system will undergo potential freeze heaving since the insulation slow the flow of heat from the soil but does not stop it. In fact, insulation alone with a sub-soil heating system does little but deter the potential for frost heaving by as little as two (2) to six (6) weeks.

As with the design of the building structure, vapor pressure and the principals of condensate formation will be the basis for a water accumulation under the ice rink. The cold soil environment created shortly after making the ice sheet is ideal for condensing moisture vapor into liquid form. When an adequate supply of water is available, even at very great depths, the moisture vapor will flow upwards through the soil to the underneath side of the ice rink. The term given to this condition is "capillary action". Capillary action is dangerous because it bring the moisture to the freezing plane where freezing can occur.

As the moisture vapor travels to the underneath side of the rink, if eventually reaches a location in the soil where dew-point (condensing) occurs. After condensing into liquid form, this fine layer of water eventually falls to freezing temperatures creating a thin layer of ice in the soil called "lensing". Even while this layer of ice is forming, the cooling effect of the floor continues to create the environment for additional moisture migration to the lower side of the rink floor. This new moisture continues move towards the underside of the freshly made ice layer we call the ice plane.

Finding this location the moisture vapor again continues to condense to create another ice plane layer directly below the first layer. In fine soils this is the condition which creates the frost heave problems we need to avoid in rink construction. As the new ice layers form and grow their expansion has only one direction to push - upwards. Once a condition of this nature is notice through actual floor movement, it can be assumed that the heaving condition will continue until the ice sheet ice removed. Since the water migration can be literally pulled through extensive amount of soil mass, even a dry season may not prevent heaving if the poor soil conditions exist. Even in regions with very low water tables, migration through capillary action will transmit moisture to the underneath side of the rink floor.

Silty soil or clay layers are the most adverse soil type for ice rink beds. These create the ideal environment for a highly expansive lensing or freezing plane of ice in the soil. At all cost, these type of soil should not be utilized in the rink bed construction. Special engineered fill can be frozen with little risk of frost expansion. Utilization of engineered fills to depths lower than the expected dew-point have proven successful when in combination with a sub-soil heating system.

Since heaving requires freezing temperature, a supply of water in the soil combined with a fine silty or clay based soil, the evaluation of the site for site engineering must be done on an individual site by site basis to assure the proper soil conditions at the minimum site preparation expense.

Granular soils such as sand or engineered fill material similar to road base will normally not create problems resulting from frost heaving. In some locations, the need for a drainage system underneath the rink area may be required.

Gravel Fill Alone May Not Be The Answer

In many parts of the country the earth features a layer of clay known as a "fragipan layer". A fragipan layer is a solid mass of clay which is often located only a few feet below the surface. These clay layers are solid for up to dozens of square miles at a time. These characteristics of clay are so dense that it becomes impossible for water to penetrate through them.

In an ice rink application clay in the small form can spawn disastrous results. Attempts in the past by rink designers when encountering this condition included the installation of a thick gravel mass directly below the ice rink. This eliminated the problems from the clay below the rink, however without proper drainage and evacuation system of run of water, this effort was equally as poor for the rink. This arrangement without a proper drainage system act like a holding pond for water under the rink. When rains afflict the area, the rain water is absorbed by the ground and perks through the soil until this clay layer is encountered. Upon encountering this solid clay mass the water begins gathering and moving horizontal. When this type of soil condition is prevalent in an area, placing a gravel, or self-draining material under the ice rink without the combined installation of a drain tile system, results in creating a pond within the soil beneath the ice rink. All the ground water from adjoining areas gathers in the large gravel pit created beneath the ice rink. With gravel only, and no sub-soil heating system - now real freeze/ heave problems could result since this water has no place to go.

Heaving Without Frost? How ?

Another condition of heaving can result from the clay itself. If a sub-soil heating system were installed, it would keep the soil between 35 and 40 degrees F. This is adequate to eliminate freeze/heaving problems, but will not eliminate the condensation condition previously described and the resulting moisture accumulation in the soil directly below the ice rink.

As the soil below the rink hits dew point, the moisture vapor will condense. The problems results when the elevation of the dew-point condition occurs within a substantial layer of clay. It becomes critical to create a soil composition where a clay layer is always maintained below the expected dew-point level within the soil.

Certain clays are highly expansion when exposed to moisture. It is this moisture absorbing/expanding characteristics which make clays ideal for "kitty liter", floor absorbing compounds, and other like absorption uses.

Clay has the ability to absorb a substantial amount of water when dry. During the absorption process the clay will expand up to three times its dry casted volume. Since the roof of an arena is typically the first item installed for a new rink, any clay located in the rink bed would be dried and compacted throughout the construction process making it ideal for future moistening and expansion after installation of the ice sheet.

This aspect of soil expansion if often overlooked by rink designers. Many feel the mere installation of a sub-soil heating system will be the solve all to future heaving potentials. If you see a rink with heaving despite having a fully functional sub-soil heating system, you can probable count on clay expansion as the culprit.

Soil Preparation

Now that we know what soils to avoid with the rink bed construction, we should evaluate the proper material selections and their method for installation.

New building construction requires the taking of soil samples to determine the compression strength and drainage considerations of the site. This testing procedure is known as "test borings". Over specific pattern, boring are literally taken on the site to depths of 20'. Such testing procedures show soil types, compression ratings of the soil, density, the prevalence of organic matter, and if any deleterious man made fill is present on the site.

Soil testing should be one of the first procedures of land acquisition before committing to a confirmed site. If conditions exist which prohibit building the structure in a cost effective manner, the site should be aborted and the project moved to a new location. While literally every site could be prepared to accommodate a structure and an ice rink, the budget may not provide for the preparation required to eliminate poor soil conditions through extensive excavation, backfill and/or pilings for concrete foundation support.

The material best suited for backfill under the rink bed is a granular material capable of being compacted to a 98% by modified proctor and providing a stable base for ongoing phases of the construction. The actual material selected can vary depending upon the most cost effective material available which is indigenous to the geographic area. The material should conform to an ASTM C-33 with granular size from 0" to 1". A combination of "fines" to 1" stone material gives the rink rough grade a high drainage performance while also providing a sealed surface suitable for fine grading. While it would provide good drainage, typical gravel will not provide a sealed surface.

Since the next stage of the rink floor include fine grading with a 100 sieve size sand (masonry type). A sealed rough grade with the material we described will keep the sand from filtering into the rough grade. When wash 1" gravel or a like material is used, an expensive geotextile fabrics is also required to keep the fine grading sand in its proper location. When considering the extra cost, labor, possibility of problems of this arrangement, it is understandable why this practice is no longer employed.

For seasonal rinks operating 6 months the frost level can extend from 30" to 50" into the soil. This will be varied by various elements such as the conductivity of the soil, location, and activity of ground waters. With insulation the depth of frost penetration over this six month period is only altered by 6" total inches. As mentioned previously, insulation alone does not deter soil freezing and possible heaving conditions.

Without exception yearround rinks must have a sub-soil heating system. Seasonal rinks can often operate with little risk of floor heaving provided that the soil composition is proper to the 30" to 50" depth. Further, while a small amount of heaving may occur for some seasonal rinks, the amount of heaving is often minor and settles upon removal of the ice sheet at the end of the operational period. This does not hold true for yearround rinks.

Yearround rinks must install a sub-soil heating system. The soil beneath the rink should be a engineered, self draining material to a minimum depth of 24" below the ice sheet. With extremely bad water table conditions this may need to be deeper in some or all areas to accommodate a drain tile system.

Any materials other than engineered fill must not be utilized in the rink floor for any purpose. While product such as cinders or foundry sand can be acquired for little to no money, their chemical compositions and resulting effect on the soil in the rink could be disastrous for all steel objects and for ice making applications. Cinders will often contain a high amount of sulfuric acid. Foundry sand could equally bring with it a very acidic pH which would promote excessive corrosion of the floor system and structural members.

For More Information About Your Specific Project Or Specialized Site Conditions, Contact an EI Engineer At:

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