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Knowledge and experience with earthworks in cold weather conditions

In the beginning a banality is to be repeated: Earthwork constructing means to create a building, which has slopes with sufficient grade of stability and which has neglectable settlement. To reach this aim, we have to use a suitable soil and we have to compact him. Compaction means the reduce of air void. For that the compaction machine has to overcome the strength of the uncompacted soil.

When a wet soil is frozen, the strength of the soil increases so heavy, that it is impossible for a normal used compactor to do his work. So we have to find a possibility to do the earthwork construction with unfrozen soil – an intention, which requires a lot of consideration and construction site management, when we have the problem to execute earthworks in the time of low temperatures.

In 1974 I made a research in international literature about earthworks in winter. I found the increase of strength depending of the temperature below zero (Picture 1), the increase of frozen surface area depending of time and temperature. For the weather conditions in Germany we have to calculate a frost penetration of about 2 - 3 cm/day. Some more theoretical proposals for earthworks in winter - like adding salt, using electricity for heating etc were made, and some contributions to earthwork practice in cold weather conditions. The following details I found in my research in papers from Sweden, Norway, Finland, England, Russia, USA and Canada:

- The working hours should go round the hole day – so the frost does not penetrate into the soil of the cut.
- A short way between cut and laydown-site, transport vehicles with a contents as big as possible, preferable with a heated skip (heated by the motor exhaust).
- The laydown site should be as short as possible – so the frost does not go into the the soil under the next layer. To reach that condition, we should not plan a constructing in horizontal layers as usual but in sloping layers (picture 2); the top of the slope should accurately be the formation level of the earthwork construction.
- It would be very helpful, when there are available two cuts – one with a not frost susceptible soil for the construction of the upper part of the sloping layers, and the other one for the lower part.
- When a break of the works is inevitable, the last layer should be constructed with the not frost susceptible soil. This layer must be so thick, that frost does not reach the sensitive soil during the break.
- In the beginning of the works after the break the frozen soil in the cut has to be removed.
- It may happen, that the upper part of the layer is freezing during the compaction works; therefor we should use a vibrating roller with a sheepfoot jacket (picture

3) or a jacket with pyramidal stumps (picture 4). In the beginning of the soil freezing the strength is rather low and these machines are able to destroy the thin freezing surface area.

- As well it can be possible, when the content of warmth of the soil is high enough, to thaw a thin layer of frozen soil.
- The cut must be executed so deep, that the frost protection layer can be installed immediately.
- When we have an inflow of water to the cut or when we have to expect precipitation, the drainage must be installed immediately after the removal of the soil at least in a temporary form as a trench.
- The result of a not sheltered formation (sheltered against low temperature and water) would be a frost heave and after the frost period a sodden soil.
- When there is to be built an embankment with a not suitable soil, for example with a too high water content, usually is chosen the "sandwich"-system: One layer with the "difficult" soil is installed, the next one is spread with a soil of good permeability, and so on. When the last layer is installed, we have to wait for the consolidation. Instead of the permeable soil it is possible to use a geotextile (picture 5). The time of the consolidation depends on the water content of the "difficult" soil, the thickness of the layers, the permeability of the "good" soil etc. When the embankment is built in winter and the soil is frozen, we have to wait not only for the time of consolidation but also for the time of thaw.

There is another detail, I have to tell from: In an earthwork-constructing-site we know a lot of different works (picture 6). In this order the different works are getting more and more difficult in cold weather conditions and in the same way costs are increasing. In my country we often have to remove waist, peat, sludge etc. For these works the contractor waits for a time with low temperatures - then it can be done with less effort:

- Excavation of waist,
- Rock blasting and crushing,
- Clearing and grubbing the site,
- Large culverts,
- Small culverts,
- Grading and compacting sand and gravel,
- Grading and compacting silt and clay,
- Grading the formation,
- Spreading the top soil.

After my study of international literature to that topic, the German guidelines got a new formulation: Earthworks may be carried out under cold weather conditions, when you can avoid frost heave and can fulfil the requirements of compaction (picture 7). Before that earthworks in winter were not allowed. You see that it is now a serious task for an Engineer.

A few years later I had the possibility to use the knowledge about earthworks in winter: Our department had to construct the ramp to a new bridge over the Kiel-Canal in January and February. It has a length of about 1 km; 300.000 m³ of soil had to be installed. January and February are the coldest months in Germany. In our invitation of tender we put two borrowed cuts at disposal, these cuts had a distance to the laydown site of only 500 m, the laydown had to be done in slopy layers - so as I mentioned above. The temperature temporary got down to 15 degrees below zero. We made a lot of tests to control the results of the compaction. We found out, that the whole work was in accordance to the specifications.

In the end of march, when we had not to expect temperatures below zero, we installed a soil stabilization with cement and an asphalt layer. In the middle of April the constructor of the bridge could drive on the ramp. After completion of the bridge two more layers of asphalt were led down and the road got in service. Since then we got no harmful settlement or problems with the stability of the slopes.