Use local rock masses for development of transport and civil infrastructure in Longyearbyen, Svalbard

NVF stipend 2020 report

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Introduction

Last year, an application was submitted to NVF to support a research project in Longyearbyen, on the Svalbard archipelago. The main goals were to evaluate the current use of rock masses in Svalbard and to better understand the properties of the locally available rock for the needs of civil infrastructures and transport applications. Those goals were considered in line with the topic «Transport in cities and transport planning» of the NVF scholarship program. The final objective of this project was to give recommendations for the usage of the local crushed rocks for road construction (as a bearing layer in the pavement structure) and for winter maintenance (sand for icy surfaces).

COVID19 impacts and new schedule

The master student undertaking this project was stuck outside of Norway from the end of February 2020 to early September 2020 due to the border restrictions. Since this situation is exceptional and considering that no data were collected before the border closure, he was allowed by NTNU to pause his thesis from April 1, 2020 until his return to Norway. Initially, the project would have been done in three stages:

1. Meeting the local stakeholders, collection of the sample in Longyearbyen and shipping to Trondheim (approx. 7 weeks)
2. Intensive laboratory work at NTNU (4 weeks)
3. Compilation of the results and engineering application in Longyearbyen (9 weeks)

The sample collection and transportation to Trondheim occurred once the master student was stuck in Canada. Upon his return to Norway, he directly started with the laboratory testing, completed it and then flew to Longyearbyen to work on the remaining tasks. The mandatory travel quarantine was done in Trondheim, before he could access the university's facilities. The modified project schedule is presented in Figure 1.

The pandemic had other impacts on this project such as: an increase in costs for the flight tickets, difficulty to get in contact with the stakeholders (remote work situation) and a more complex access to the laboratory (new social distancing rules).

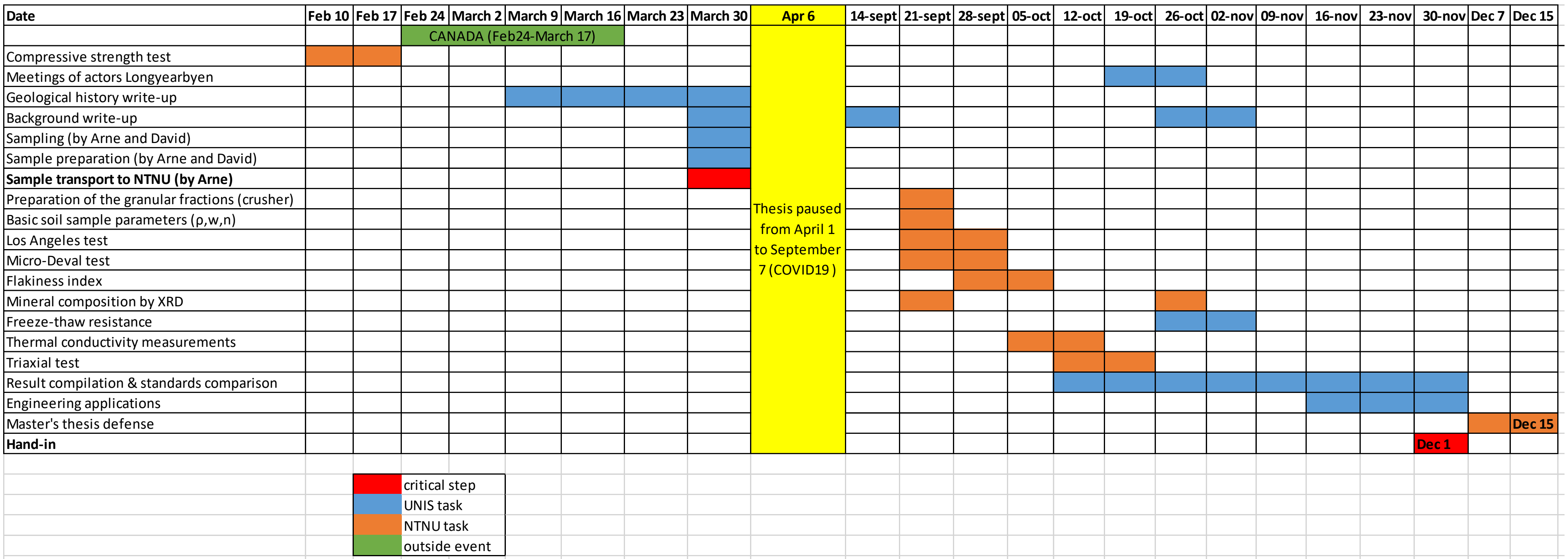

Figure 1: Modified project schedule

Methodology

The laboratory testing campaign was successful and provided various useful parameters derived from the crushed Longyearbyen granular material. Once on Svalbard, the stakeholders were interviewed in order to obtain a good understanding of the local construction market and to evaluate the quantity of material imported yearly. Site visits of past and current construction projects occurred to supplement the interviews.

The following list summarizes the work that was done during this project:

NTNU (Trondheim):

- Abrasion tests (5 x Los Angeles and 5 x Micro-Deval)
- Determination of particle shape (3 x Flakiness Index)
- Repeated load triaxial test (4x)
- Mineral identification by X-Ray Diffractometry (5 samples sent for analysis)
- Thermal conductivity (1 x saturated gravel and 1 x rock core)
- Specific density (2 x with a pycnometer and 2 x with a cobble apparatus

UNIS (Longyearbyen):

- Freeze-thaw resistance of particle (1x)
- Interviews and site visits

Results

Construction contractors, municipal engineer and consultants were interviewed to evaluate the current use of rock masses in Longyearbyen. They provided quantities, past experiences and insights that proved very useful for this project. The main findings are listed here:

- The rock imported from mainland is used for the following construction activities: concrete and asphalt production, riverbank and coastal erosion protection, road structure, structural embankments, gabion retaining walls, road repairs and winter road maintenance (sand).
- The local road designers follow the Norwegian pavement design manual N200 as much as practical and economical for Longyearbyen's context (thickness of layers and material specifications). In general, imported rocks are used for the pavement and base layer. Local rocks have been used for the subbase layer to reduce costs of most roads in town.
- Each year approximately 20 000 tons of granular material is imported by the construction contractor that is in charge of this operation. Additionally, the company operating the local airport

imports around 1700 tons of sand and fine gravel to use for the winter maintenance of the runway. This amount lasts for one or two years depending on the intensity of the winter.

- The Norwegian Water Resources and Energy Directorate (NVE) currently executes two large projects in Longyearbyen that are increasing the average quantity of granular material imported from mainland. The Longyearelva riverbanks protection required a significant amount of large boulders that was imported in the last two years. The avalanche protection wall's construction started in 2020 and it requires significant volumes of imported rocks for its completion (roughly 70 000 tons of different sizes).

The properties of the crushed rocks from Longyearbyen were obtained by various standardized tests. The results that are more relatable to road structure are presented here. The remainder is available in the complete thesis.

The abrasion tests are used to categorize material in road standards for various countries. The Los Angeles test indicates how the particle will resist to fragmentation (i.e. under heavy construction traffic) and the Micro-Deval test indicates the particle's long-term resistance to wear (i.e. during the road design life). The determination of particle shape quantifies the proportion of flat and elongated particles in a sample (flakiness index). Those particles might break down under loading due to their weakness and this can become problematic for some construction applications. Material that cannot resist the annual freezing and thawing cycles should be identified prior to construction in cold regions. The freezing and thawing resistance test assesses if an aggregate of a certain size will change after 10 freeze-thaw cycles (crack formation, loss of mass, etc.). Table 1 shows the average result for those tests.

Table 1: Test results

Parameter	**Value**
Los Angeles	34
Micro-Deval	47
Flakiness Index	14
Freezing-thawing resistance (%)	0.5

The Los Angeles value obtained is at an intermediate level (approximately class LA_{30}-LA_{35}) and the Micro-Deval result is in the worst category (MDE_{45}-MDE_{50}), both according to the European Standard *DS-EN-1324: Aggregates for unbound and hydraulically bound material for use in civil engineering work and road construction*. The flakiness index value obtained is in the best category (FI_{20}) according to the European Standard *DS-EN-1324.* The resistance to freezing and thawing was below 1% mass loss, which corresponds to the best frost resistance class (F1) according to the European Standard *DS-EN-1367-1 Tests for thermal and weathering properties of aggregates - Part 1: Determination of resistance to freezing and thawing*. The results obtained were compared to the Norwegian pavement design manual N200 and to other foreign cold regions standards to assess its possible use in a pavement structure.

Four repeated load triaxial tests were ran based on the European Standard *DS-EN-13286-7: Unbound and hydraulically bound mixtures - Part 7: Cyclic load triaxial test for unbound mixtures*. The gradation of the test specimens was based directly on the requirements for a road base layer (0-31.5mm) from the Norwegian pavement design manual N200. Two tests were done at a water content of 2% and the two supplementary ones at 7%. Figure 2 shows the axial plastic deformation of one of the samples throughout the test (water content 2%). The different colored lines correspond to different confining pressures.

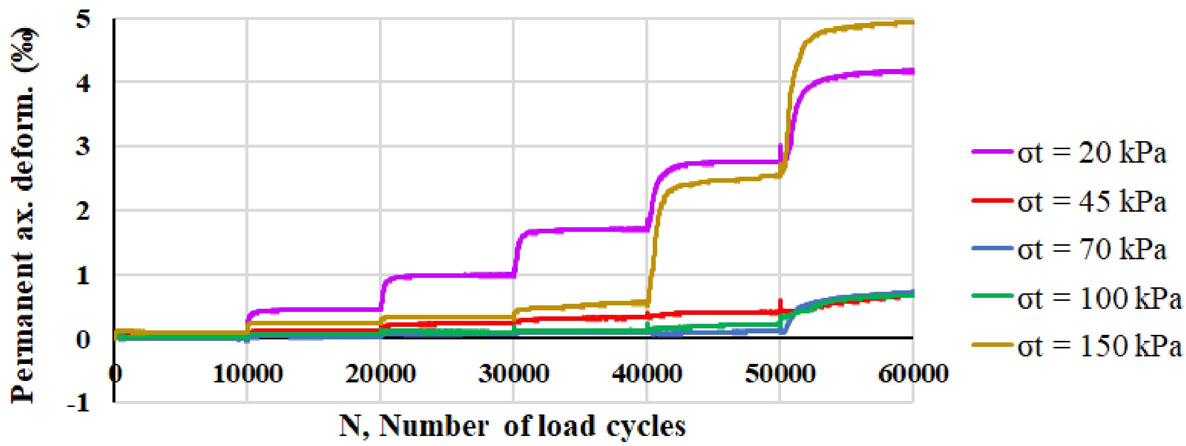

Figure 2: Axial plastic deformation as a function of the number of load cycles (specimen 2)

Figure 3 shows the results of the resilient modulus in relation to the bulk stress applied on the specimen. The resilient modulus is an important parameter in order to use empirical-mechanical road design software.

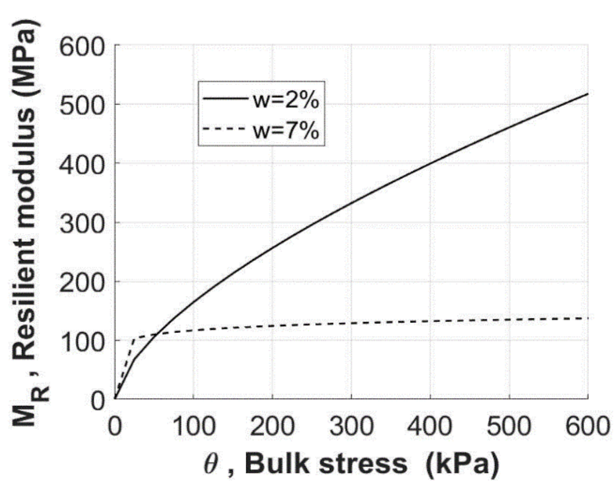

Figure 3: Resilient modulus and bulk stress according to the Hicks & Monismith model

The resilient modulus values are smaller in comparison to crushed granular material from mainland Norway. Nonetheless the material from Longyearbyen can stand some loadings and presents a certain bearing capacity.

The information derived from the laboratory tests were used as input in the i3c-me road design software. This computing tool uses the mechanistic-empirical approach to design a pavement structure with a two-steps process. Firstly, i3c-me calculates the stresses, strains and displacements using a mechanistic model. Secondly, the performance of the road is assessed using empirical damage functions. The current typical road sections in Longyearbyen were assessed and compared to sections with a larger quantity of crushed local material. The results, although preliminary, showed that it is possible to use local rocks in the road structure layers (base and subbase). A more thorough calculation should be made with more detailed information on the asphalt layer and mainland granular material.

Other usage for the local rocks were identified and investigated. The crushed material could be used for the construction of granular pads for storage purpose (i.e. maritime containers or snowmobiles). It might also be possible to recommend it as supporting layer for a concrete slab floor (e.g.: garage, warehouse, etc.), with further structural verifications. The thermal properties measurements of the Longyearbyen crushed material were used to verify if it would be suitable for an «Air-Convective Embankment». It resulted that the local rock masses could be appropriate to increase the cooling rate of mainland granular material used for load-bearing tasks (i.e. the core of a road embankment). Additionally, gabion baskets could be filled with local rock (crushed or natural) instead of importing rock from the mainland. In order to maximize the efficiency of those retaining walls, special care should be made during the installation to avoid crushing the rocks. The Micro-Deval test results showed that the local material wears down easily under traffic loading. The preliminary recommendation for winter maintenance would be to avoid using a locally crushed sand unless specific investigation is made for such purpose.

Communication of the results

The complete master's thesis will soon be available in the NTNU digital library (1). The data from the abrasion tests and the repeated load triaxial test will be published in February 2021 as a data-in-brief article (2). Part of this project have been submitted for a short conference at the Arctic Science Summit Week 2021. Final decision by the scientific committee will occur at the end of January 2021. The author is considering writing an overall journal article to cover the whole testing campaign, but there is no timeline yet.

Budget

As mentioned in the original submission to NVF, this research project was included in a SINTEF AS application to the Svalbards Miljøvernfond. The application was rejected in September 2020 and no funding from SINTEF AS was obtained to complete the project. The author is very thankful that the NVF grant covered most of the expenses incurred. Table 2 compares the actual cost of the project with the planned budget.

Table 2: Cost-tracking

	in NOK		
	Planned	**Actual cost**	**Remarks**
UNIS			
Accommodation	20000	8145	only one stay instead of the two initially planned
Local transport	2500	1740	
Food	8600	7500	
Flight NTNU lab	10000	14757	significant cost increase due to the modified airlines schedules
Sampling supplies	1000	1538	
Sample maritime shipping	10000	12000	a slightly heavier sample was brought back (300kg instead of 250 kg)
NTNU			
Accommodation	5000	10783	the stay was extended to undergo quarantine and to allow for all the lab test to occur at NTNU
Local transport	400	505	
Food	2200	4500	increase due to the longer period spent in Trondheim
Total			
	59700	61468	

The main variations are explained by the new schedule. The master student had to adapt his stays to the new duration of his thesis (September to December 1st). The stay in Trondheim was extended and the one in Longyearbyen was shortened. Consequently, the cost for accommodation, food and local transport was different than anticipated. The COVID19 pandemic also had an impact on the price of the flight tickets. Overall, the research project kept a total budget close to what was submitted to NVF.

Conclusion

The objectives of this project were satisfactorily met. The current usage of granular material was evaluated after the interviews. The evaluation of the properties of the local material was done during the laboratory portion of the study. Following the data processing, it was possible to classify the material according to the Norwegian pavement design manual N200 and to give recommendations for the possible use of crushed local material. This study opens the way for other research projects to fill some other knowledge gaps. A full-size test section could be built to ascertain the load-bearing capacity of locally produced crushed aggregates (e.g. a road embankment section or a granular pad). If a thermal design was being considered, a more thorough assessment of the thermal parameters of the gravel should be made.

Bibliography

(1): Dorval, J-G. (2020) «*Using local Svalbard rocks as a construction material*». Master's thesis. NTNU Open: https://ntnuopen.ntnu.no/ntnu-xmlui/

(2): Barbieri D.M., Dorval J-G, Lou B. & al. (2021) «*Dataset regarding the mechanical characterization of sedimentary rocks derived from Svalbard for possible use in local road constructions*». Elsevier. Data in Brief Volume 34