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0/4 mm Project

October 17th, 2021

Trondheim

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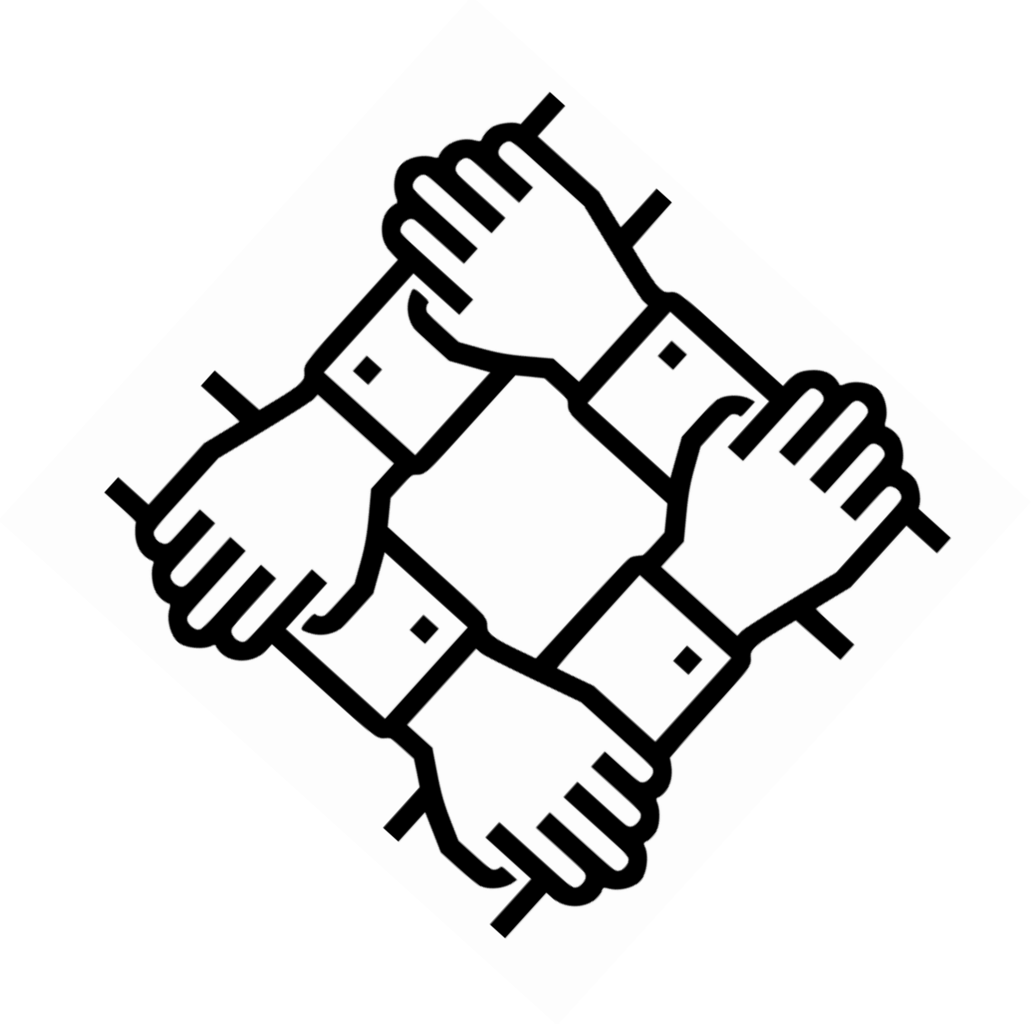
Scope

- Organization
- Background
- 0bjectives
- Methodology
- Results
- Conclusion and continuation

Organization

- Pr. Inge Hoff, project coordinator
- Elena Scibila, project coordinator
- Benoit Loranger, Post Doc
- Diego Barbieri, Post Doc
- Karlis Rieksts, Post Doc
- Siri Stolpestad, M.Sc. Student
- Jonas Økern, M.Sc. student



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Background

Table 1: Quarry fines produced at each crushing stage

Production Stage	Quarry fines produced by hard rock quarries	
Primary crusher	Igneous	3 – 6% (Jaw) to 10-15% (Gyratory)
	Limestone	6 – 7% (Jaw) to 20% (Impact)
	Gritstone	1 – 2% (Jaw) to 15 – 20% (Jaw & Gyratory)
Secondary crusher	Igneous	10 – 23% (Cone)
	Limestone	<10% (Cone) to <20% (Impact)
	Gritstone	4 – 5% (Jaw & Cone)
Tertiary crusher (& further)	Igneous	5 – 30% (Cone) to 40% (Impact)
	Limestone	<20% (Impact) to 40% (Hammer mill)
	Gritstone	~15% (Cone) to 40% (Impact)

NB These figures are weight percentages of the feed to the crusher.

Clive Mitchell, British Geological Survey

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- For economical, and environmental purposes, there is a need to develop knowledge on low quality 0-4 mm crushed aggregates:
  - Better land use and storage space management
  - Lower handling cost
  - Better use of the total crushed volume
  - Avoid/ limit sediment leaking and dust issues
  - etc.

Known uses of quarry fine

- Concrete application
- Soil manufacturing (e.g. mixing with water plant mud)
- Low volume pedestrian
- Uses in frost protection layer
- Landfill
- Etc.

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0/4 mm Project

Was a short term project of 5 months that developed into a full scale project

The main purpose of the project was to initiate a logical, scientific-based approach to evaluate behavior of quarry waste for both frost susceptibility and mechanical performance

The main goal is to move forward in developing high volume application in a road or railway infrastructure context for both economical and environmental gain (e.g. standardized use in frost protection layer)

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Methodology

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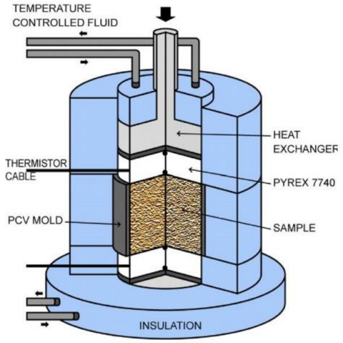
Rock type selection

Quarry	County	Municipality	Rock type
Lørenskog	Viken (Arkeshus)	Lørenskog	Gneiss
Vassfjell	Trøndelag	Trondheim	Gabbro
Sarpsborg	Østfold	Sarpsborg	Granite
Tau II	Rogaland	Strand	Quartz-diorite
Tromsdalen	Trøndelag	Verdal	Limestone

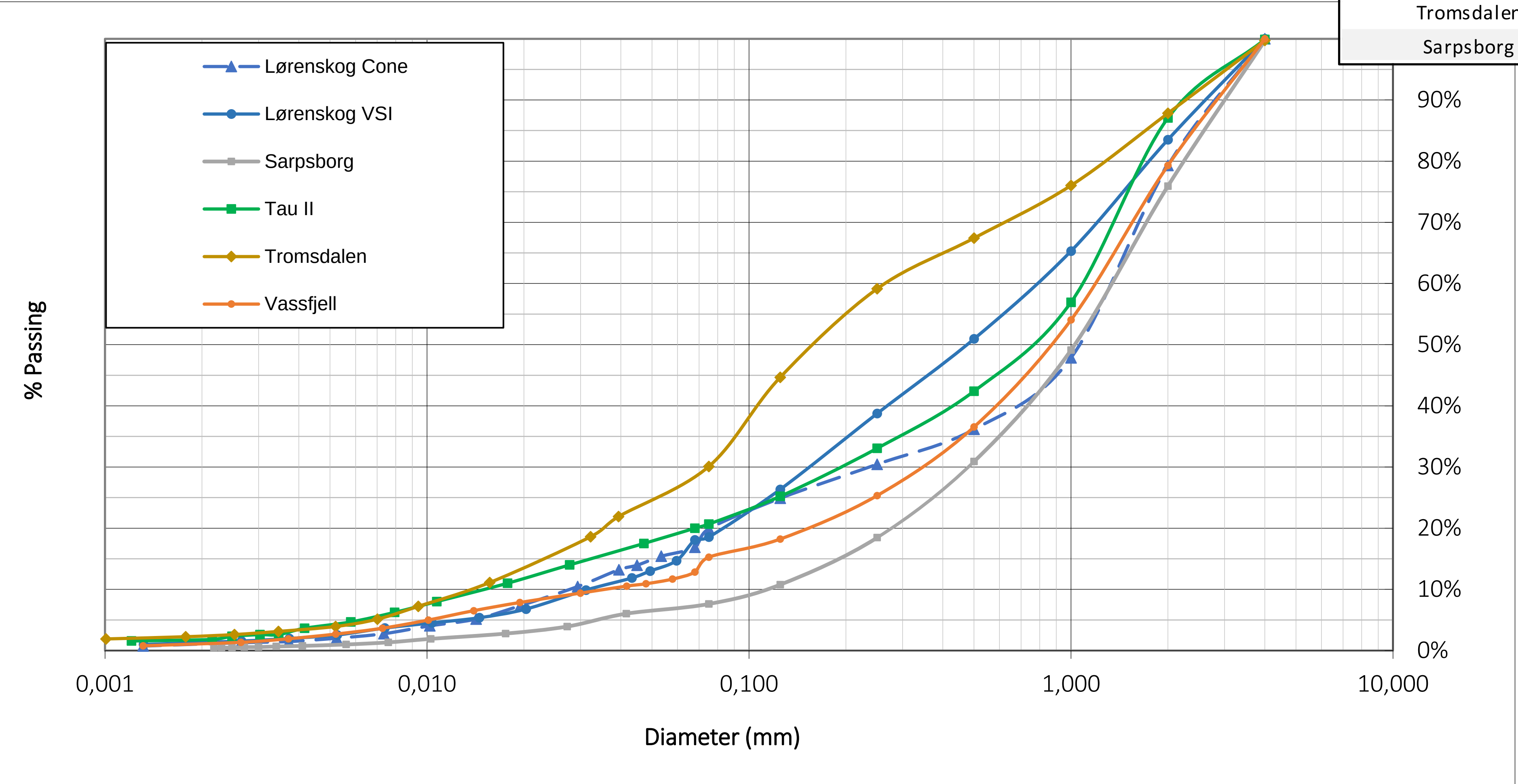
Approach

- Laboratory based analysis
  - Basic material characterization
  - Behavioral investigation
    - Frost susceptibility (Frost heave test)
    - Mechanical (RLTT)
    - Enhancement (use of additives)



Results and discussion

1. Geotechnical characterization



Quarry	<63 µm (%)
Lørenskog Cone	16
Lørenskog VSI	19
Vassfjell	12
Tau II	19
Tromsdalen	28
Sarpsborg	7

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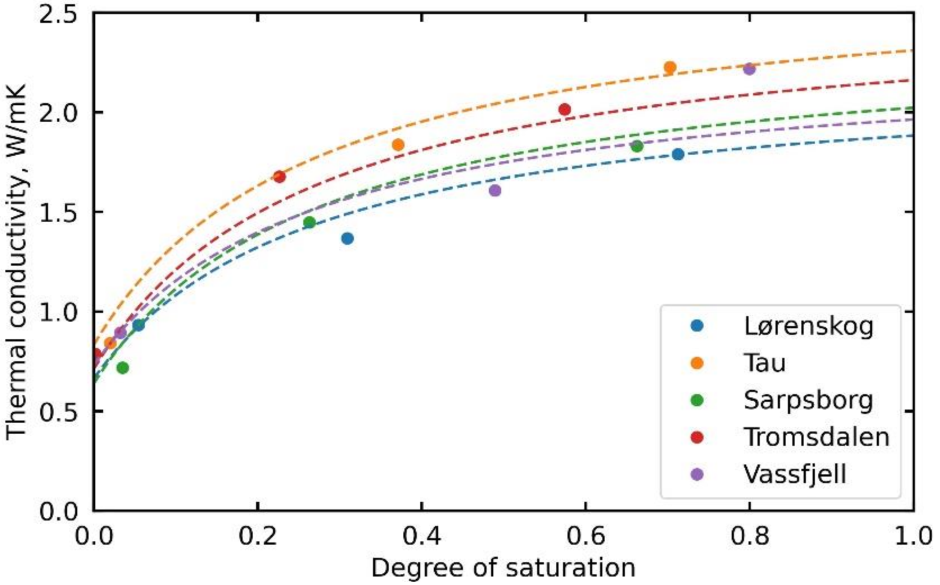
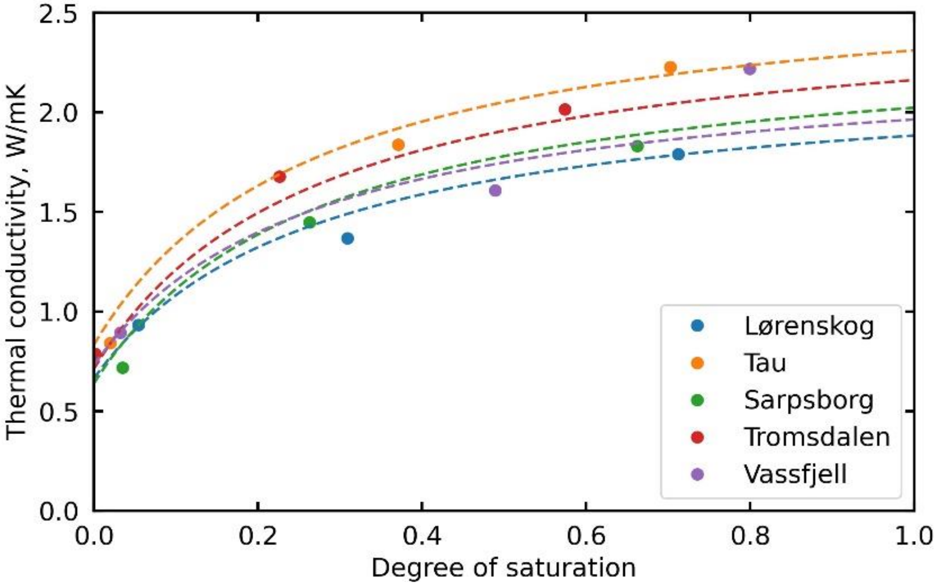
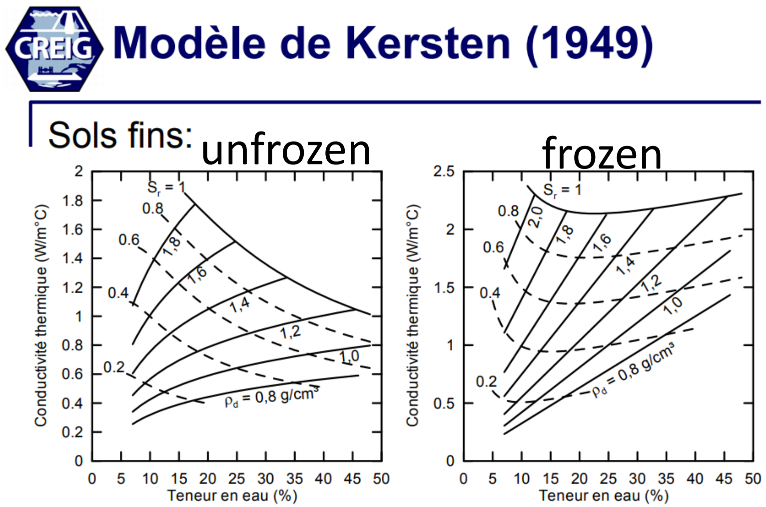
2. Thermal conductivity

Unfrozen

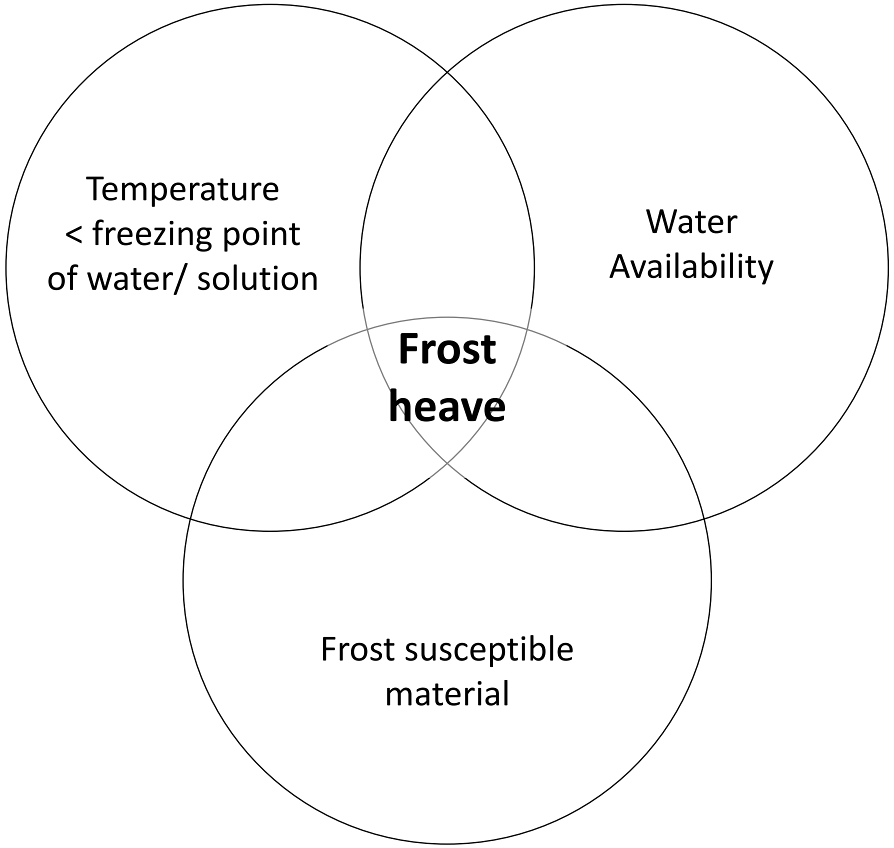


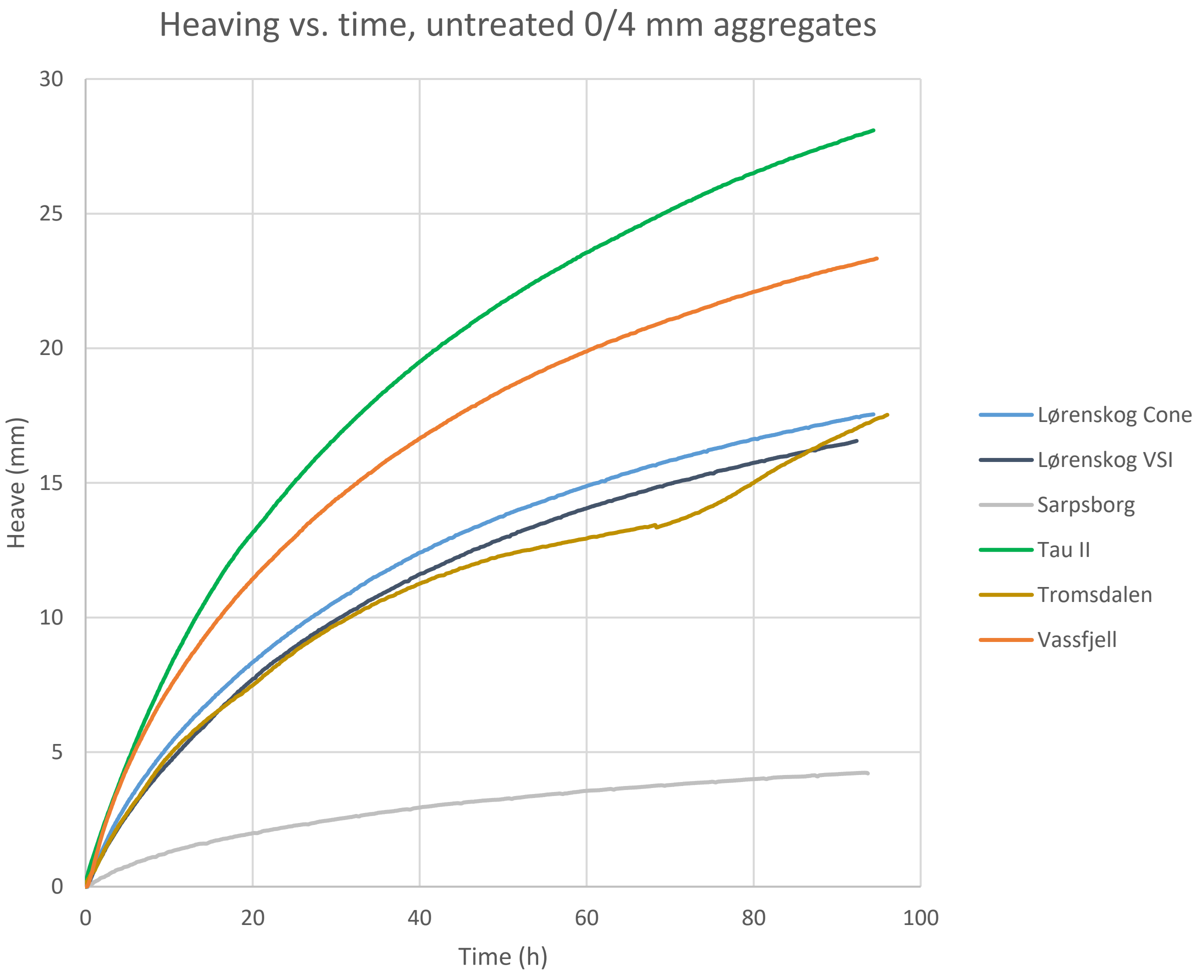
Frozen





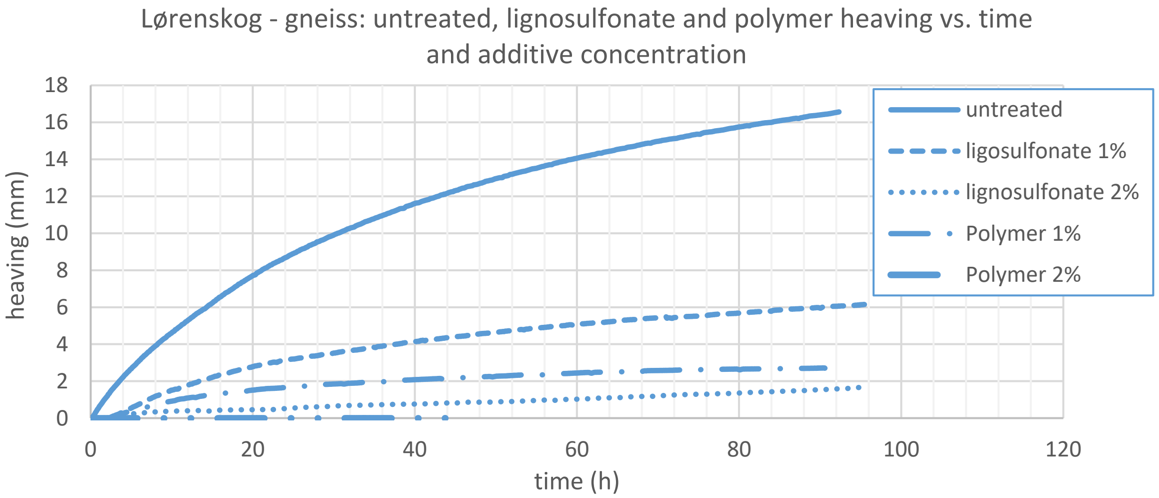
Frost heave test

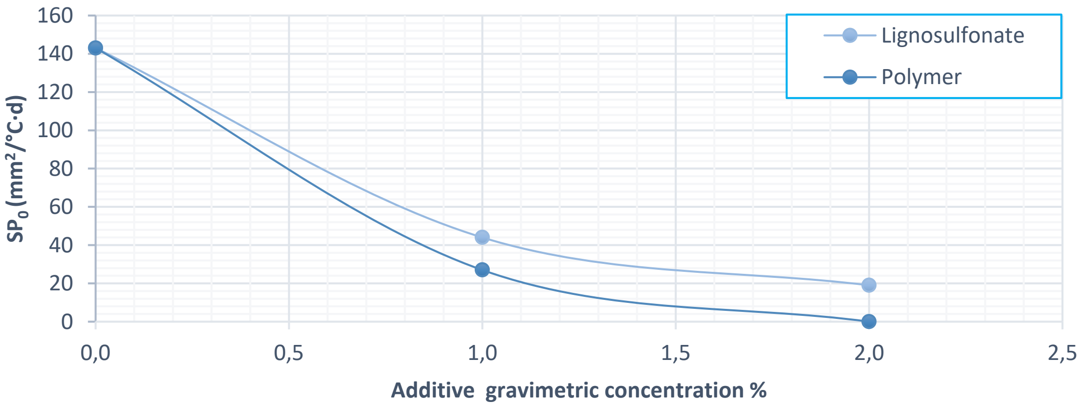




Frost heave test

- Lørenskog





Frost heave test

	SP_0 ($mm^2/^oC{\cdot}d$)				
	Lør	Vass	Tau	Sarp	Trom
untreated	143	158	202	32	115
Lig 0.6%	---	---	---	---	61
Lig 1%	44	---	73	11	---
Lig 2%	19	0	28	---	---
Pol 1%	27	---	2	---	114*
Pol 2%	0	---	27	---	---

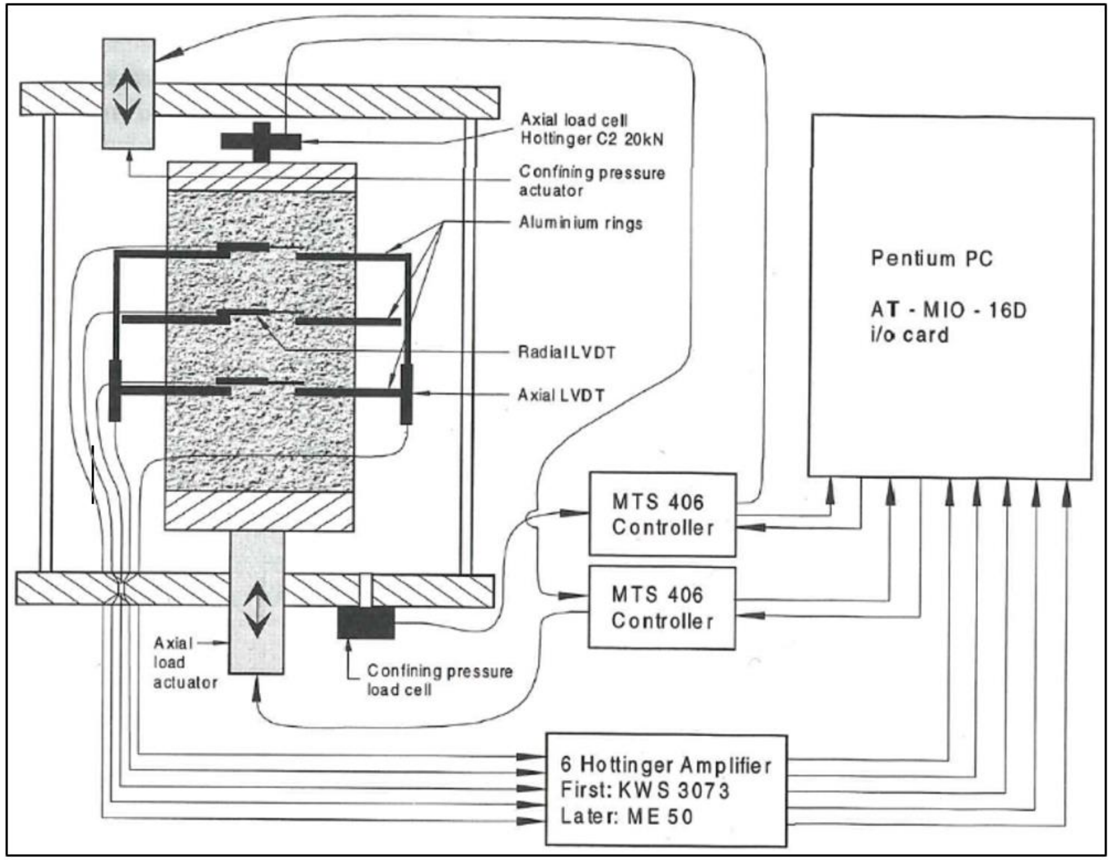
Frost	SP_0	FH rate
Suscept.	$mm^2/^oC{\cdot}d$	mm/d
Neg	<12	<0.5
Low	15-35	0.5-2
Med	35-75	2-4
High	75-200	4-8

Frost susceptibility reduction

Lignosulfonate 0,6% : 53%
Lignosulfonate 1% : 66%
Lignosulfonate 2% : 87%
Lignosulfonate 2,5% : 100%

Polymer 1%* : 81%
Polymer 2% : 93%

*Tromsdalen not considered



2 key mechanical propertie

- Stiffness (Resilient modulus)
- Deformation

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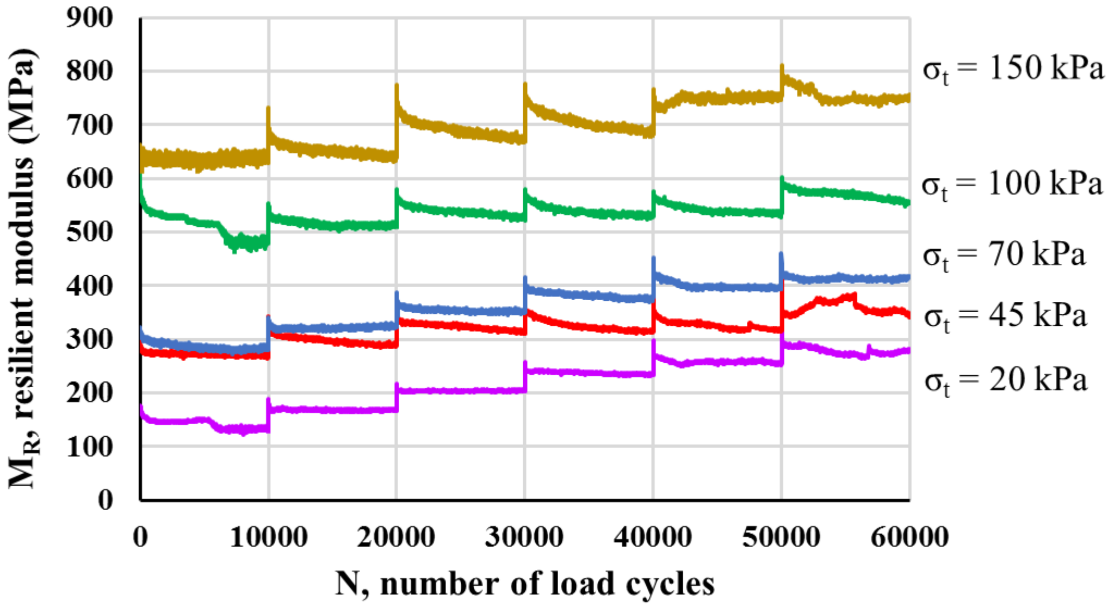
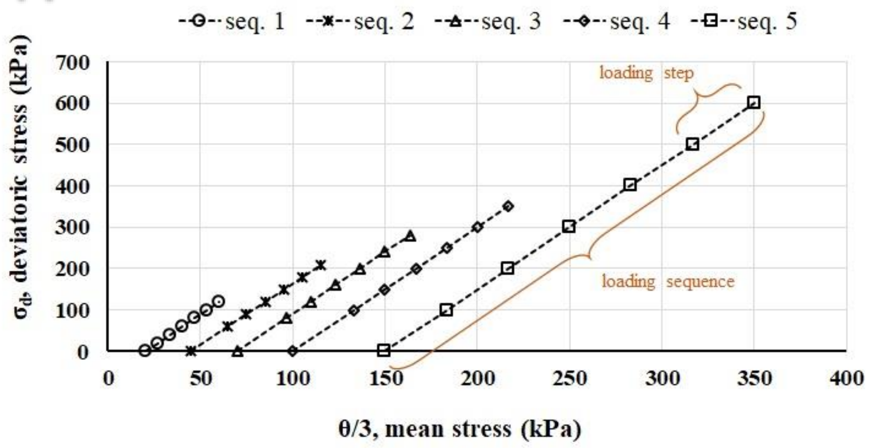
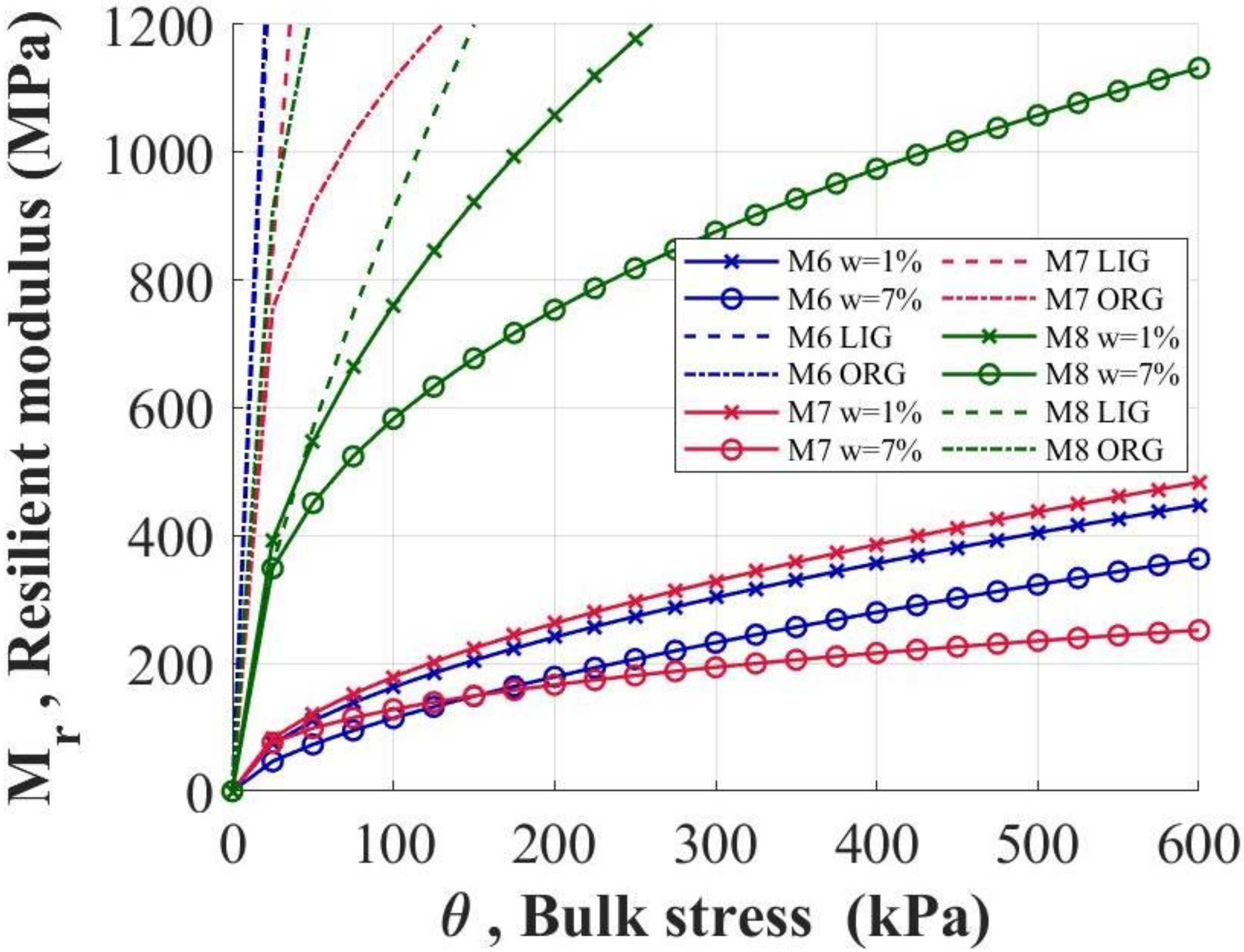
EVALUATING M_R

Multi-stage Low Stress Procedure (*EN 13286-7*)

- 5 sequences
- 6 steps for each sequence
- 10 000 repetitions for each step
- both σ_t and σ_d gradually increase







M6: Vassfjell (Gabbro) M7:Lørenskog (Gneiss) M8: Tromsdalen (Limestone)

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Conclusions and continuation

Conclusions

- On characterization
  - High frost susceptibility and poor mechanical behaviour of untreated crushed rock aggregates made them a challenging material for their uses

- On frost susceptibility
  - Crushed rock aggregates tends to be moderately to highly frost susceptible for fine content of ca 12-25%, and low at fine content of 7%.
  - Additive had a major impact in lowering the frost susceptibility of the material. Testing showed a decrease of as much as ca 50, 65, 85 and 100 percent for lignosulfonate concentration of 0,6, 1, 2 and 2,5 percent. The lowering was slightly higher for the polymer (ca 85 and 95 percent decreases for 1 and 2 percent concentration).

- On mechanical aspect
  - Both additives were effective to enhance the mechanical properties of fine materials. The study has characterized the improvement attained in terms of resilient modulus and resistance against permanent deformation.

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Utilization of fine fractions (0-4 mm) from crushed rock production - final report

Produced by Benoit Loranger, Diego Maria Barbieri, Karlis Rieksts, Inge Hoff and Elena Scibilia.

Department of Civil and Environmental Engineering

April 15, 2021

- Upcoming scientific paper on the 0/4 project

- Crushed rock related work

Karlis Rieksts PhD, NTNU (2018)
Heat transfer characteristics of crushed rock and lightweight aggregate materials.

Diego Maria Barbieri PhD, NTNU (2018)
Use of local materials for road construction - Innovative stabilization techniques for crushed rocks

Benoit Loranger PhD, NTNU (2020)
Laboratory investigation of frost susceptibility of crushed rock aggregates and field assessment of frost heave and frost depth

Continuation

- The promising results assessed by the laboratory tests could be further investigated:
  - Field-testing (Mixing/introduction of additives, practical solutions)
  - Life Cycle Cost analyses – to investigate the economical aspect
  - Long term durability of the solutions
  - Expanding of laboratory program (materials and additives)
  - Etc.

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Thanks / Takk!!

Thanks to all partners!!

Nye veger	Gunnar Holth Grusforretning
Statens vegvesen	Veidekke
Bane Nor	Norsk Pukkservice as
Skolt pukkverk	Norsk Stein
Franzefoss Pukk	Franzefoss Minerals
Feiring Bruk	Zydex Industry
Heidelberg Cement	Sparks AS
Halsvik Aggregates	Borregaard
John Myrvang AS	