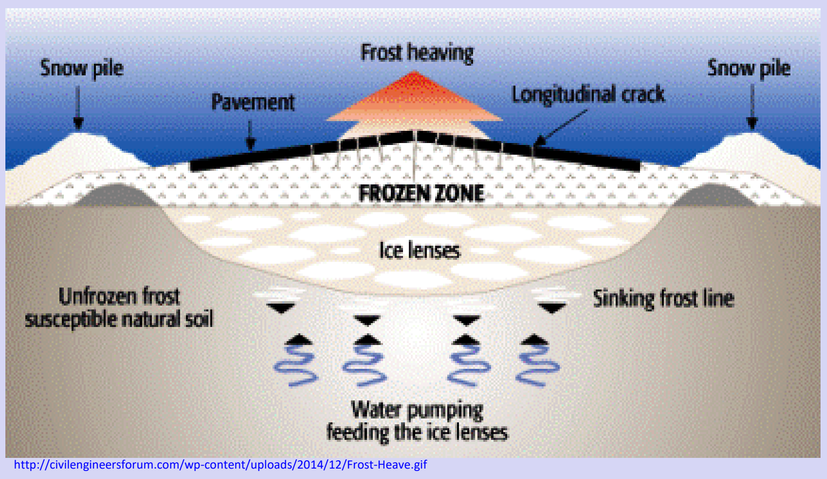
Effect of Freezing and Thawing on the Durability of Aggregated Soil and Cement Treated Soil

団粒化土とセメント改良土における凍結融解の影響

The durability of the aggregated soil which is subjected to freezing and thawing is not yet properly understood to be used as a major construction material in cold regions. In this study, the behavior of unconfined compressive strength (UCS) of aggregated soil and cement treated soil which are subjected to 12 freezing thawing cycles were studied and compared with the UCS of controlled specimens. The intension was to distinguish the behavior of aggregated soil compared to cement treated soil since higher amount of water is retained in aggregated soil.

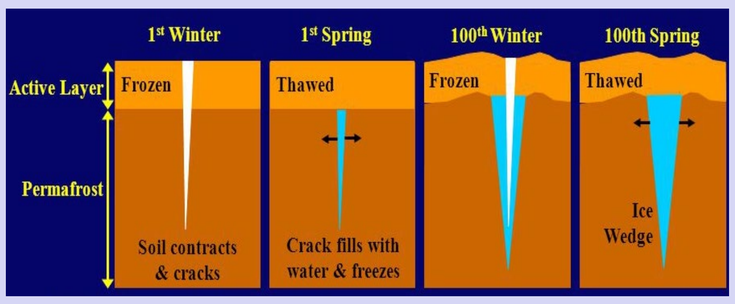
寒冷地で団粒土やセメント改良土を適用する場合、凍結融解による間隙水の体積膨張・収縮の影響が問題になります。団粒土とセメント改良土に、12回の凍結融解履歴を与え、その力学特性に与える影響を、一軸圧縮試験で調べました。

(1) Effect of freezing and thawing on soil



http://civilengineersforum.com/wp-content/uploads/2014/12/Frost-Heave.gif

- During phase transition freezing process associates with volume expansion of the water by about 9 + %.
- **Vertical shrinkage cracks** appear due to desiccation process.



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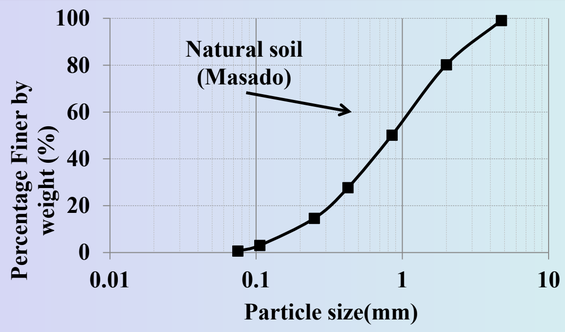
Repetition of freezing and thawing cycles increase crack widths while increasing number of cycles and lead to reduction in strength of improved soils.

(2) Materials and testing method

Materials and mix proportions

Mix designation	Cement (by volume)	Crumb agent (by volume)	Water (by weight)	Degree of saturation	Ice forming system
Aggregated soil (A)	80kg/m^3	1.5l/m^3	16.5%	100 % (Saturated)	Open
				80 % (Unsaturated)	Closed
	20kg/m^3	1.5l/m^3	14.5%	100 % (Saturated)	Open
Cement treated soil (C)	80kg/m^3	-	16.5%	100 % (Saturated)	Open
				80 % (Unsaturated)	Closed
	20kg/m^3	-	14.5%	100 % (Saturated)	Open



Particle size distribution Curve

- Under each mix designation two controlled and two exposed specimens were prepared with the size of 50mm in diameter and 100mm in height by applying static compaction larger than 90 % of their maximum dry density.
- 12 cycles of freezing at -23^{o}C for 24 hours and subsequent thawing at 21^{o}C for 23 hours were applied.(ASTM-D559(1996).
- After that Unconfined compression test (JIS A 1216) were conducted on all specimens.

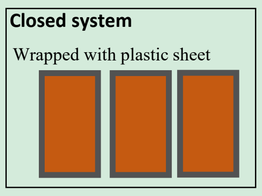
Testing procedure

Unsaturated- Closed system

Specimen preparation *Day 1* → Curing in the moisture room *Starts on Day 1* → Exposed → 12 freeze/thaw cycles **Sealed** *Starts on Day 8, Duration: 24days* → UCS test *Day 33*

Controlled → UCS test *Day 21*

Closed system: Wrapped with plastic sheet

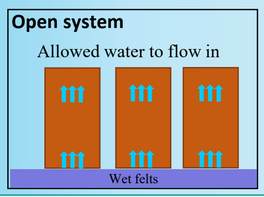


Saturated – Open system

Specimen preparation *Day 1* → Curing in the moisture room *Starts on Day 1* → Exposed → 12 freeze/thaw cycles **Allowed water to infiltrate** *Starts on Day 8, Duration: 24days* → UCS test *Day 33*

Controlled → **Saturation** *Day 20* → UCS test *Day 21*

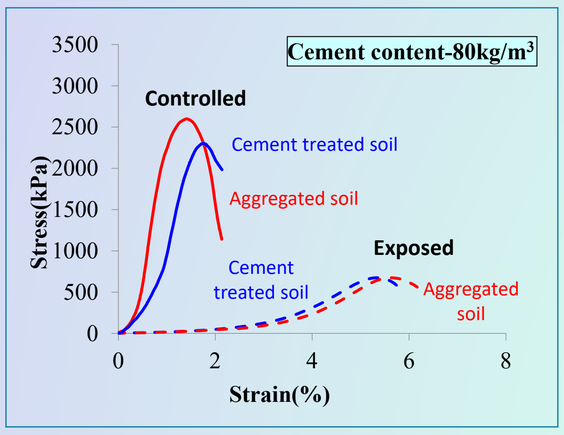
Open system: Allowed water to flow in

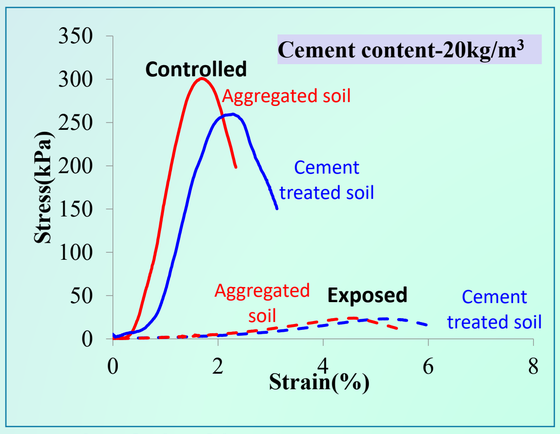


供試体作製・養生後、12回の凍結融解履歴を与える
凍結融解プロセスの際に水の出入りを許す場合（Open system）
は飽和供試体、許さない場合（Closed system)は不飽和供試体

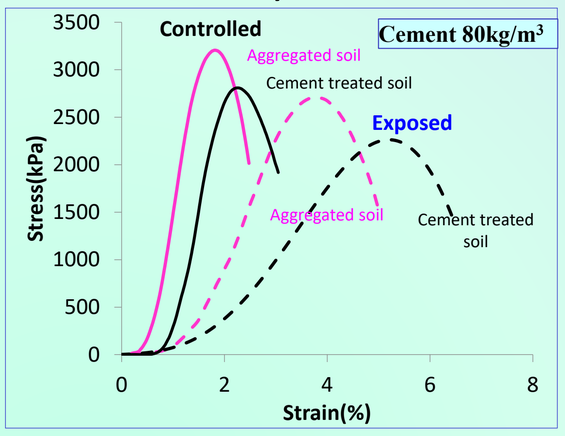
(3) UCS Test results

Saturated- Open system

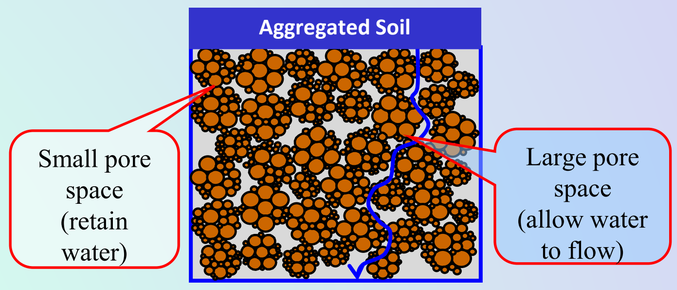




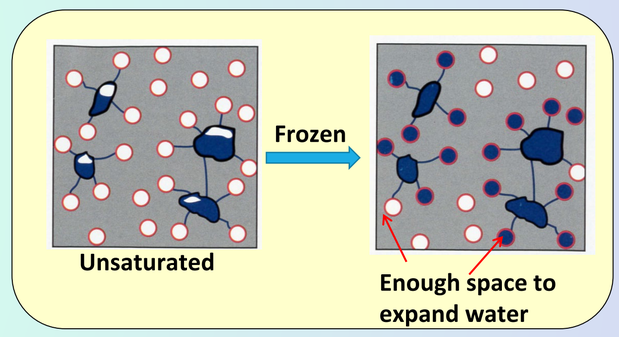
Unsaturated- Closed system



stress –strain relationships



- Under unsaturated condition reduction of E_{50} is lower and reduction of strength is higher in aggregated soil than in cement treated soil.



http://precast.org/2012/12/air-entrainment-versus-air-entrapment/

- The behavior of aggregated soil under freezing is complicated. Availability of **macro pores** resist expansion of soil on the other hand the **ability of water retentivity and permeability** provide more water to expand .
- More studies are required to understand the relationship between soil freezing and soil water retention characteristics of aggregated soil since those factors depends on the amount of cement and crumb agent .

(4) Discussion

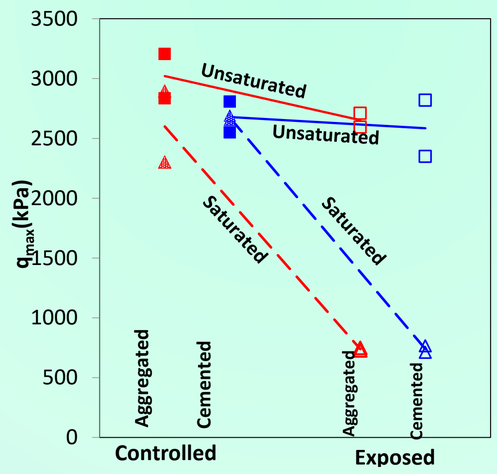
Effect of cement content

Cement content (kg/m^3)	Soil type	Reduction relative to controlled data (%)	
		q_{max}(kPa)	E_{50}(MPa)
80	A	72	92
	C	72	87
20	A	92	98
	C	91	97

- The maximum strength, (q_{max}), and deformation modulus, E_{50} , of both aggregated soil and cement treated soils were reduced due to the freeze and thaw exposure.
- When increasing cement content reduction of q_{max} became lower.
- Both used cement contents were not suitable to resist against freezing thawing effect in open system.

団粒土とセメント改良土は、凍結融解履歴により強度と剛性が著しく低下する。低下の程度は団粒土とセメント改良土でほぼ同等で、セメント量が多い方が低下の程度はやや小さい。

Effect of degree of saturation



Reduction of q_{max} and E_{50} is lower in unsaturated condition (closed system) than in saturated condition (open system).

Sr (%)	Soil type	Reduction (%)	
		q_{max} (kPa)	E_{50} (MPa)
100	A	72	92
	C	72	87
80	A	12	36
	C	4	48

凍結融解履歴による強度と剛性の低下は、供試体が飽和している場合に著しい

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