Effect of Curing Conditions on Long Term Strength of Lime and Cement Treated Soils

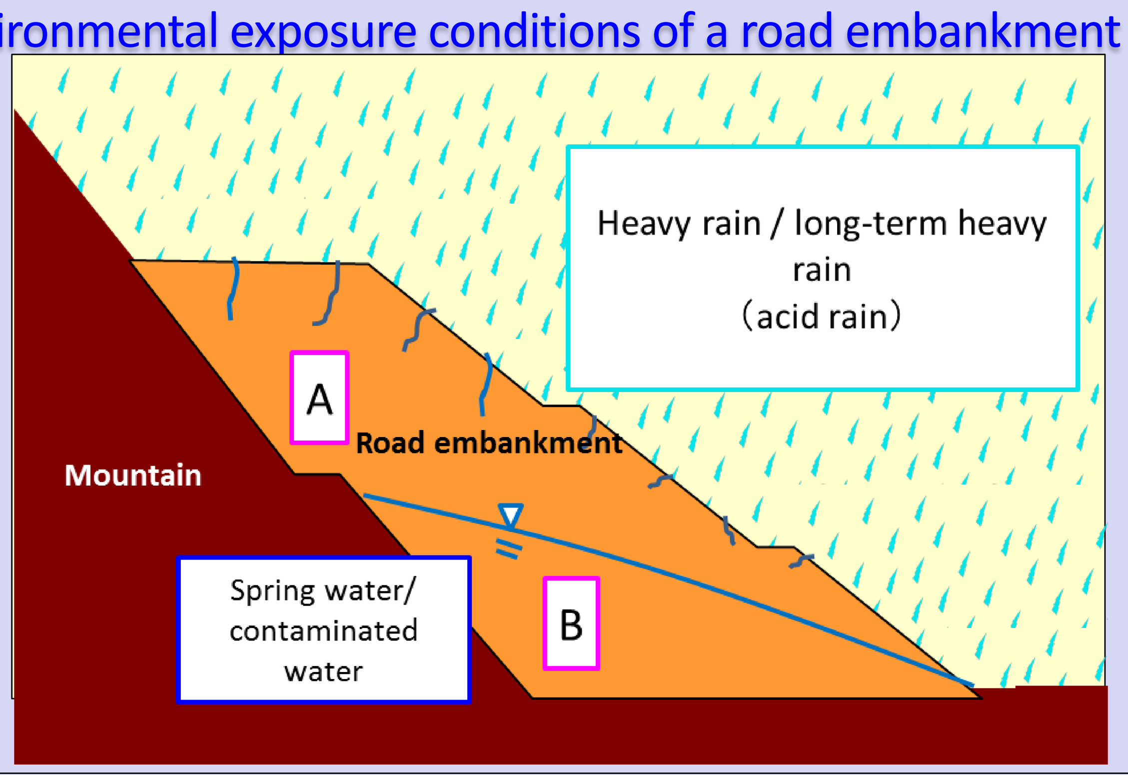
セメント/石灰改良土の長期挙動

Stabilization using lime or cement has been a widespread technique for soils with poor geotechnical performances. Various studies have been conducted on their physical and mechanical properties including strength and durability. However, the effect of curing conditions on the long term strength of lime and cement treated soils with lower binder contents are not well understood. In this study, therefore, unconfined compression tests were conducted on lime and cement treated surplus soil under two curing conditions called "sealed" and "soaked". It was inferred that the differences in strength were caused by the differences of physical and chemical properties of stabilized soils which changed due to curing conditions.

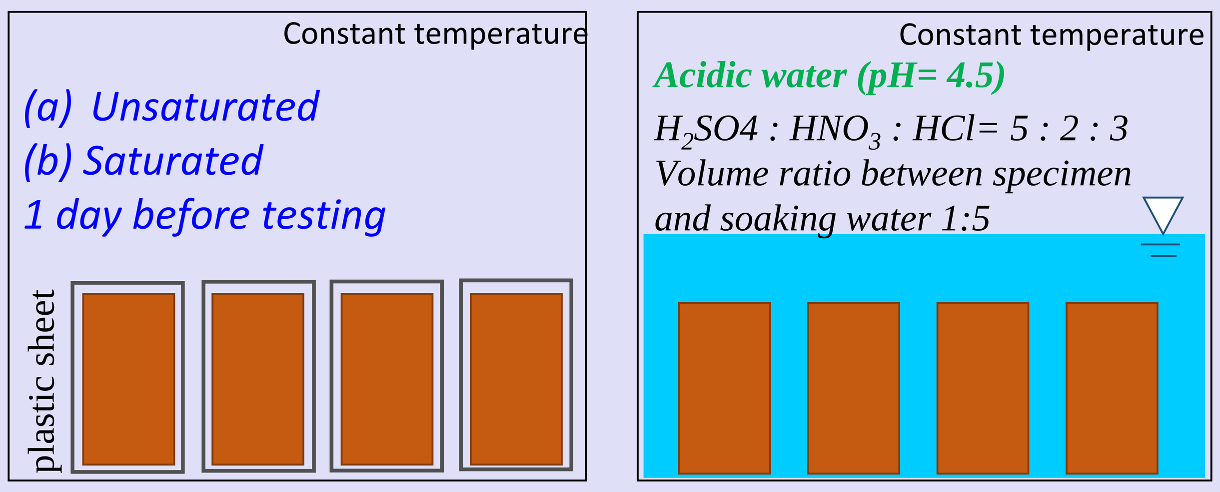
本研究は（国研）土木研究所と共同研究で実施しています。低改良率のセメント改良土と石灰改良土を種々の条件で168日間養生し、一軸圧縮試験により強度特性を調べました。水浸養生の供試体では高い飽和度と共にカルシウムの溶出等により強度低下がみられました。

(1) Introduction

Environmental exposure conditions of a road embankment



Simulation of curing conditions in laboratory



(2) Materials and testing method

Physical and mechanical properties of Miho sand

Soil classification (JGS 0051)	SF (sandy soil)
Soil particle density, ρ_s (g/cm³)	2.693
Optimum water content, w_{opt} (%)	21.6
Maximum dry density, ρ_{dmax} (g/cm³)	1.624
Sand (%)	52.9
Silt (%)	21.6
Clay (%)	24.7

Mix proportions

Binder type	Binder content	Curing type	Water type
Lime	2.5%	Sealed	_
		Soaked	Acid water
	3.8%	Sealed	_
		Soaked	Acid water
Cement	3.5%	Sealed	_
		Soaked	Acid water
	5.3%	Sealed	_
		Soaked	Acid water

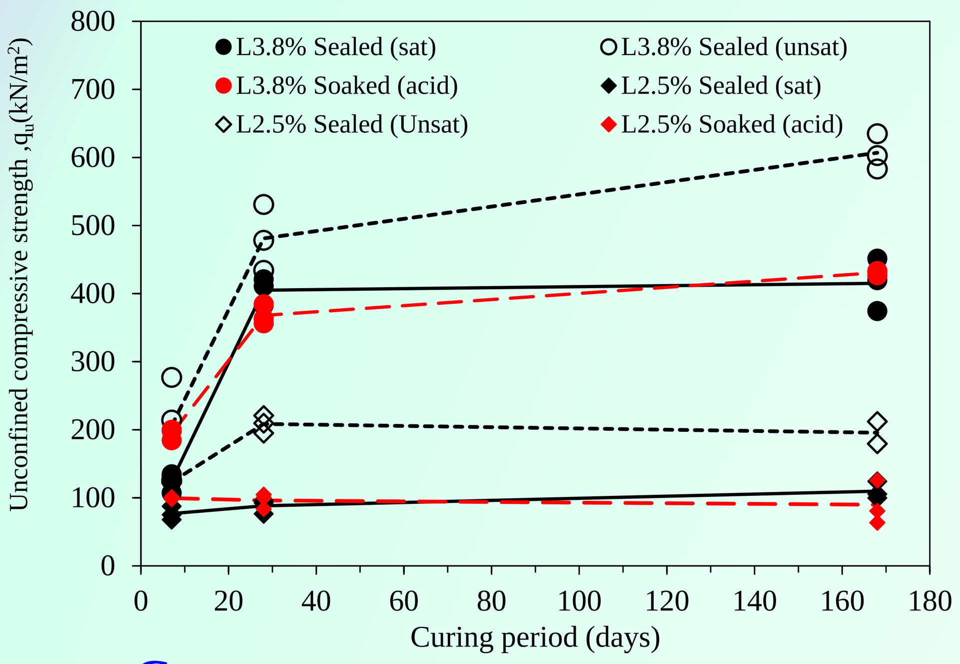
Chemical properties of Miho sand and binders

	SiO_2 (wt %)	TiO_2 (wt %)	Al_2O_3 (wt %)	Fe_2O_3 (wt %)	MnO (wt %)	MgO (wt %)	CaO (wt %)	Na_2O (wt %)	K_2O (wt %)	P_2O_5 (wt %)	S_{total} (wt %)
Miho sand	61.69	0.73	19.92	6.86	0.11	1.29	1.48	1.18	1.54	0.10	0.03
Cement	24.36	0.28	8.65	1.85	0.13	1.98	61.87	0.31	0.46	0.16	3.13
Lime	2.21	0.10	0.75	0.74	<0.01	1.02	102.2	0.16	<0.03	0.03	<0.02

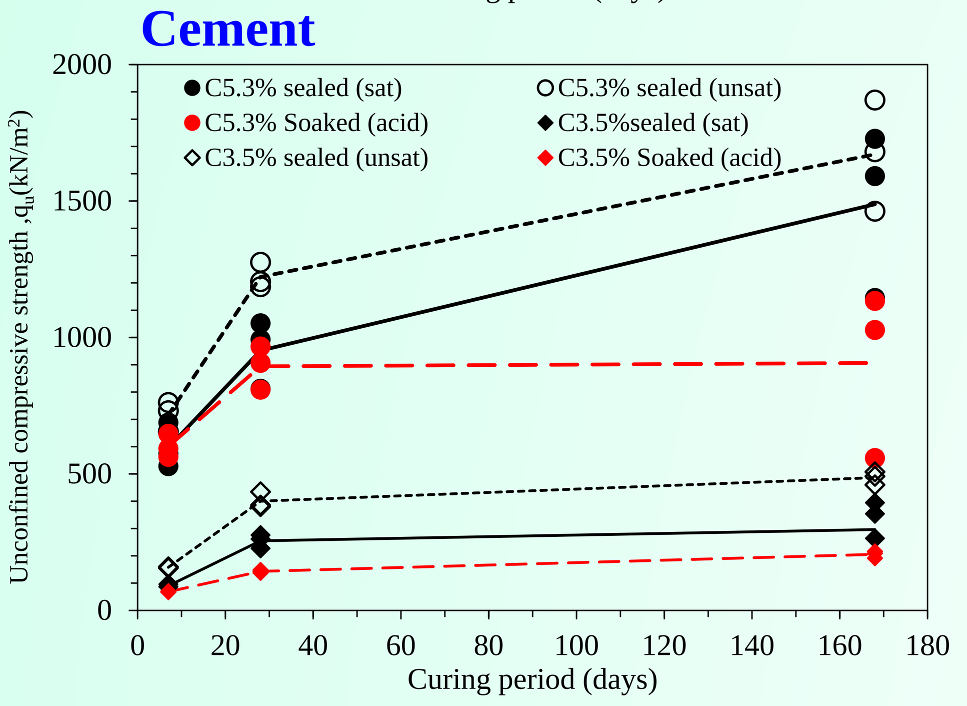
- Specimen size: Diameter 50 mm, Height 100 mm
- Degree of compaction, Dc= 90 %
- Unconfined compression test (JIS A 1216) conducted after 7, 28 and 168 days.
- The amount of calcium and sulfate ions and pH in the soaked water measured at each time water exchanged.

(3) Results and discussion

Lime



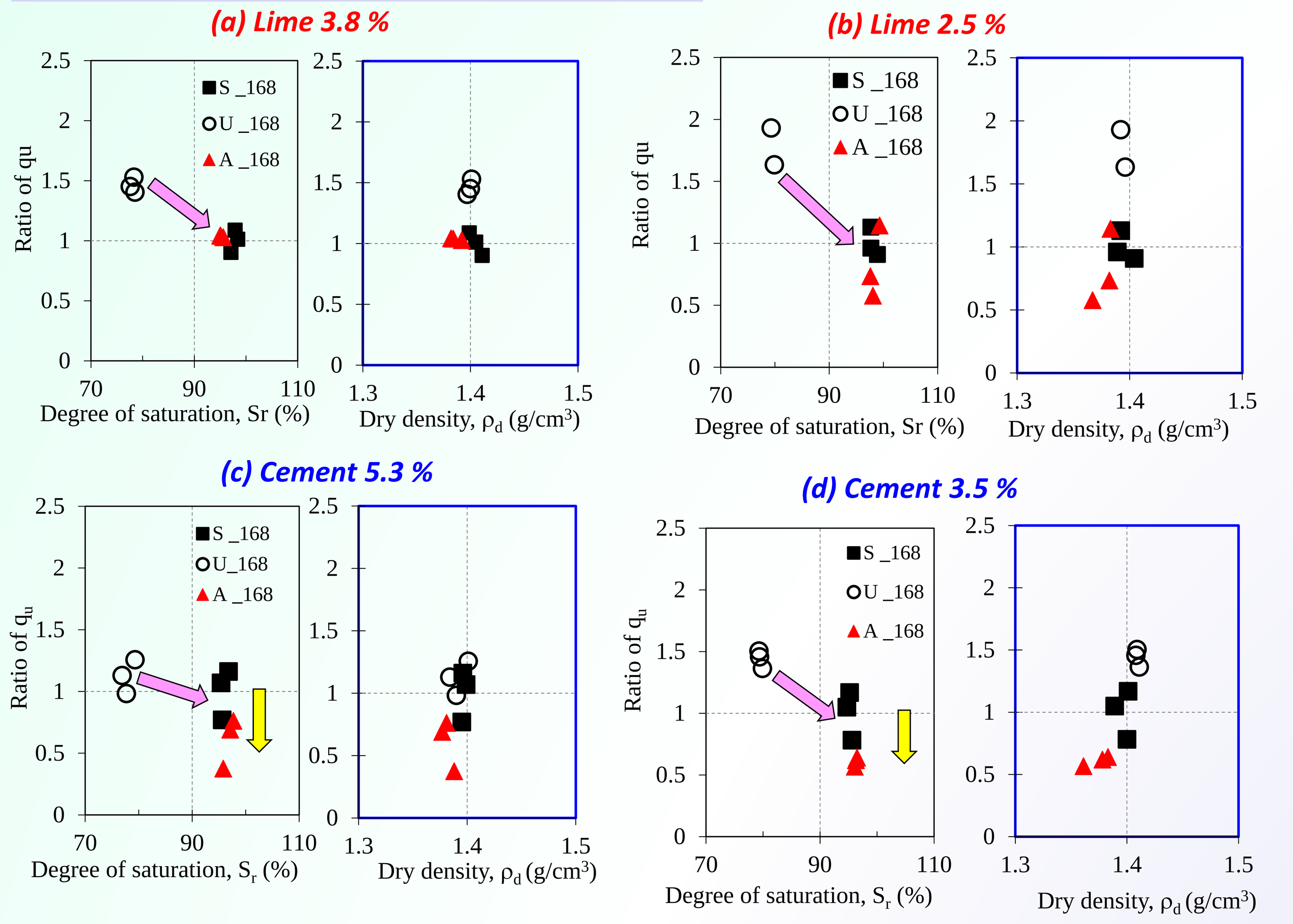
Cement



- Under sealed curing strength increased with curing period.
- For all cases Higher strength in particular curing age is in sealed-unsaturated condition.
- It was observed almost the same strengths in saturated and soaked specimens of lime treated soils.
- In cement treated soils, soaked specimens showed the smaller strengths after 168 days.

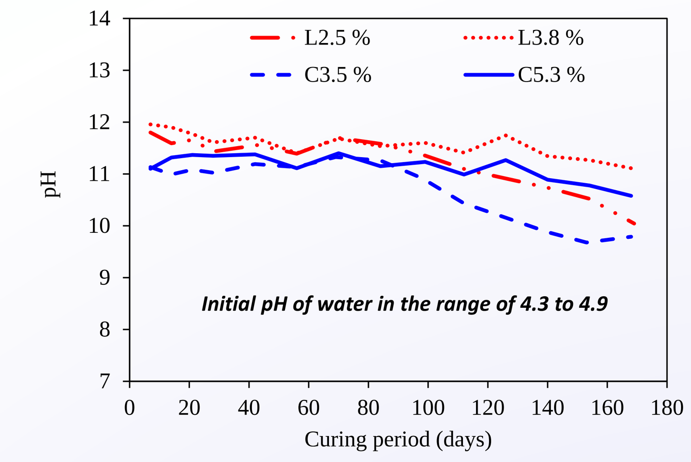
Effect of physical properties

Strength ratio at 168 days = $\frac{q_{u(soaked,unsat)}}{q_{u(average\ saturated)}}$

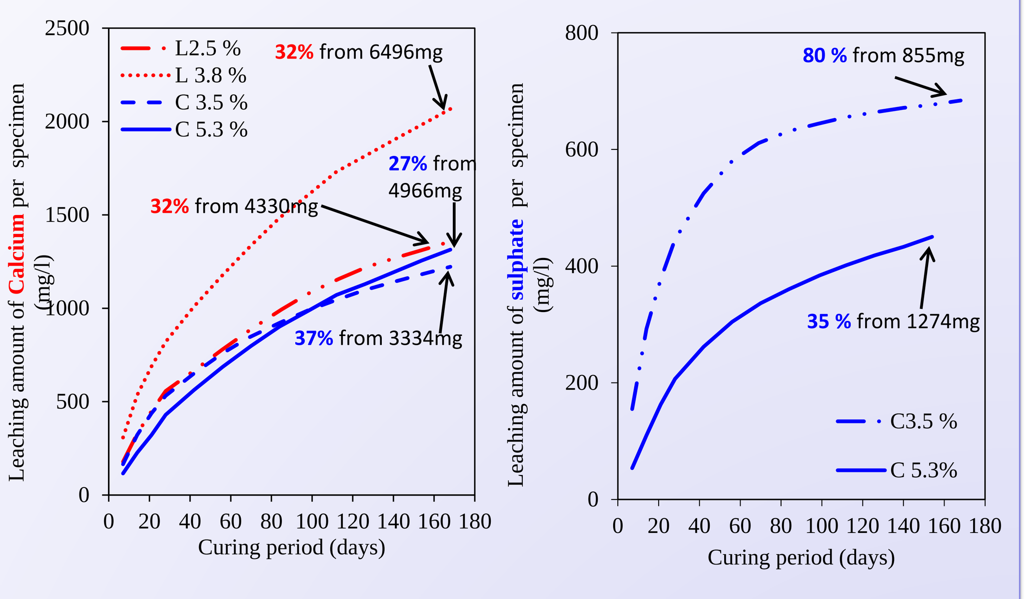


- In almost all the cases, the dry densities of specimens were maintained around 1.4 g/cm³
- The degree of saturation of sealed (unsaturated) condition is the lowest.
- Degree of saturation of soaked curing and sealed (saturated) curing is same.
- Strength ratio of sealed (unsaturated) curing of lime treated soil is 1.5 or more. The strength ratios under soaked curing and sealed (saturated) curing was similar and always lower than sealed (unsaturated) curing due to the affection by the degree of saturation.
- In cement treated soil, strength ratio of soaked curing is less than 1. Difference in strength between sealed (saturated) curing and soaked curing is not only due to difference in physical properties but due to difference in chemical properties.

Effect of chemical properties



pH values of soaking acid water had increased up to 12 in lime treated soils and 11 in cement treated soils initially, while those values started to decrease gradually with the curing period.



- Leaching of hydration products containing Ca and sulfate ions may affect the uniaxial compressive strength under soaked curing in cement treated soil.
- In lime treated soil, leaching of Ca ions did not affect the uniaxial compressive strength under soaked curing until the age of 168 days .

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