Applications of PARI centrifuge Model tests

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Practical research having close relevance to specific prototype

- Haneda Offshore Expansion Project -

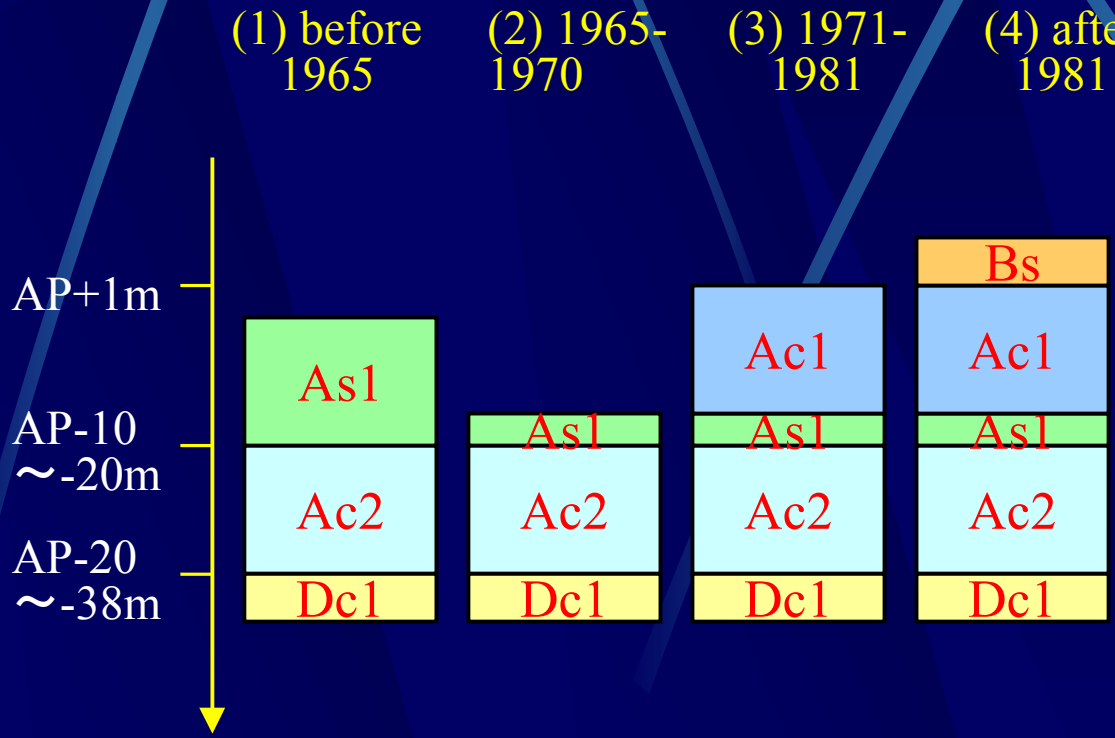


May, 1990



August, 1998

Reclamation and Dredging History of Haneda Site



application of fabri-packed sand drain



The clay layer at the construction site had high water content exceeding 150% (being metaphorically called as “Haneda Mayonnaise Layer”)

Sand piles was not able to stand and in soft clay and might fail to function as drainage path.

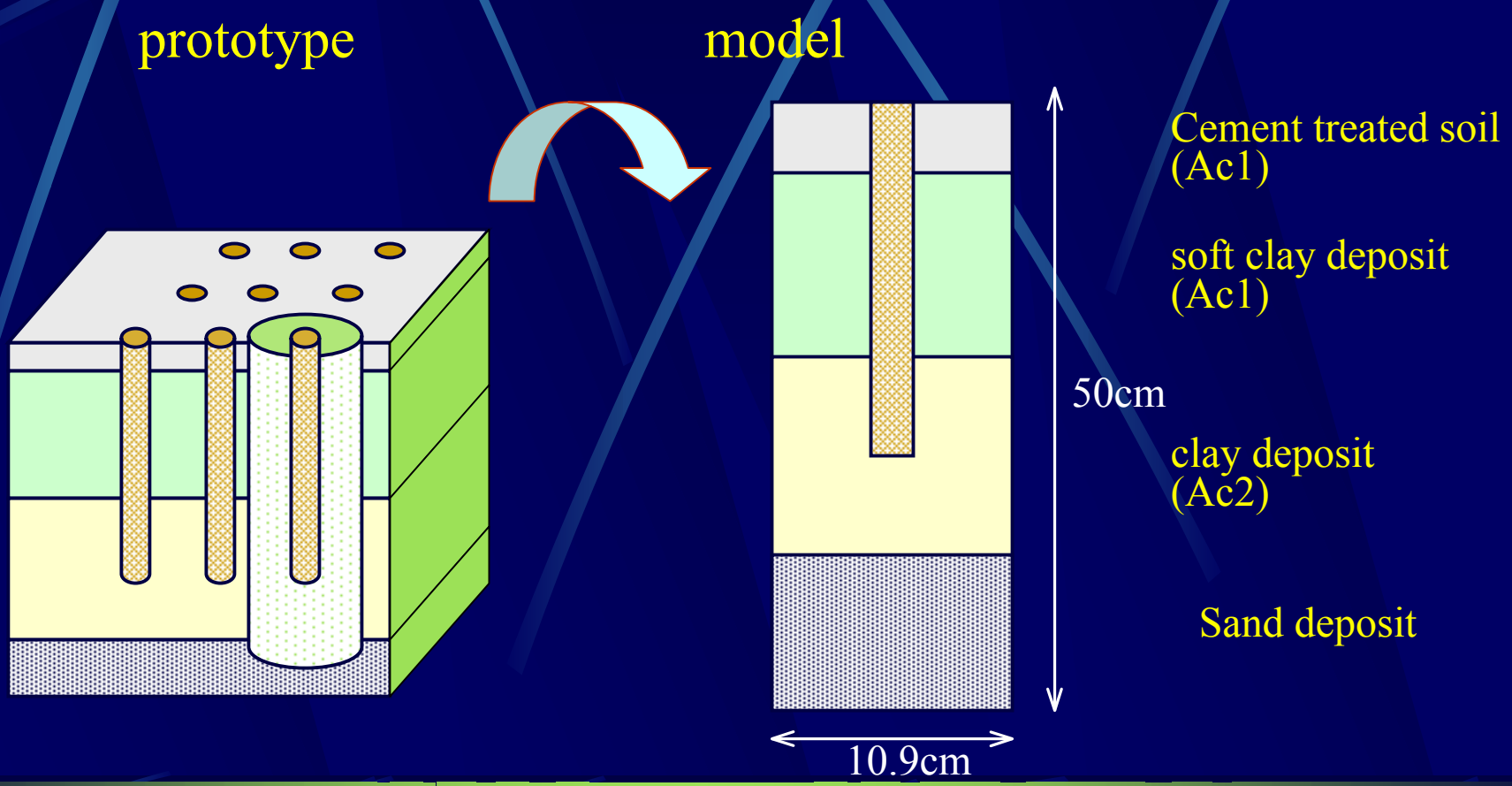
fabri-packed drain





Fabri-packed sand drain
- sand drain wrapped by an envelope made of geotextile
- expected to stabilize the sand pile to function as a drainage path in soft ground.

modeling in centrifuge



preparation of model sand pile



control density by vibration





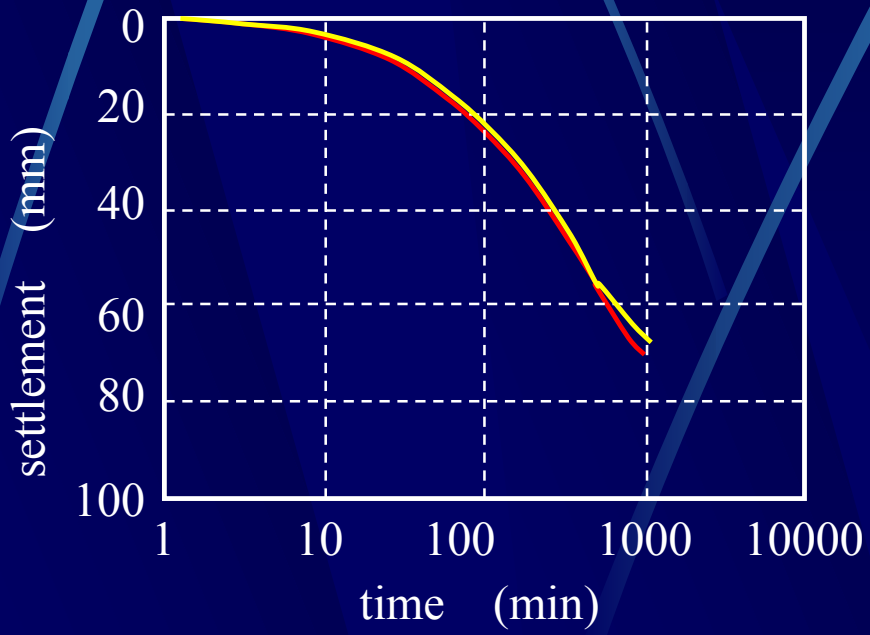
frozen and extract by motor jack

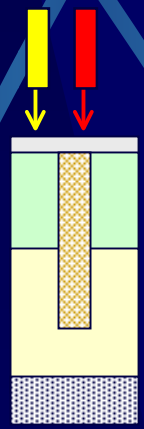
preparation of model ground



- preparing the bottom sand layer
- preparing the lower clay layer compressed one dimensionally to a vertical effective stress of 30 kN/m^2.
- install fabri-packed sand drain in frozen condition on the lower clay layer.
- pore saturated clay slurry at a water content of 150%.
- place a perspex doughnut plate at clay surface to simulate cement-treated soil.
- place Toyoura sand and lead shot as fill materials.

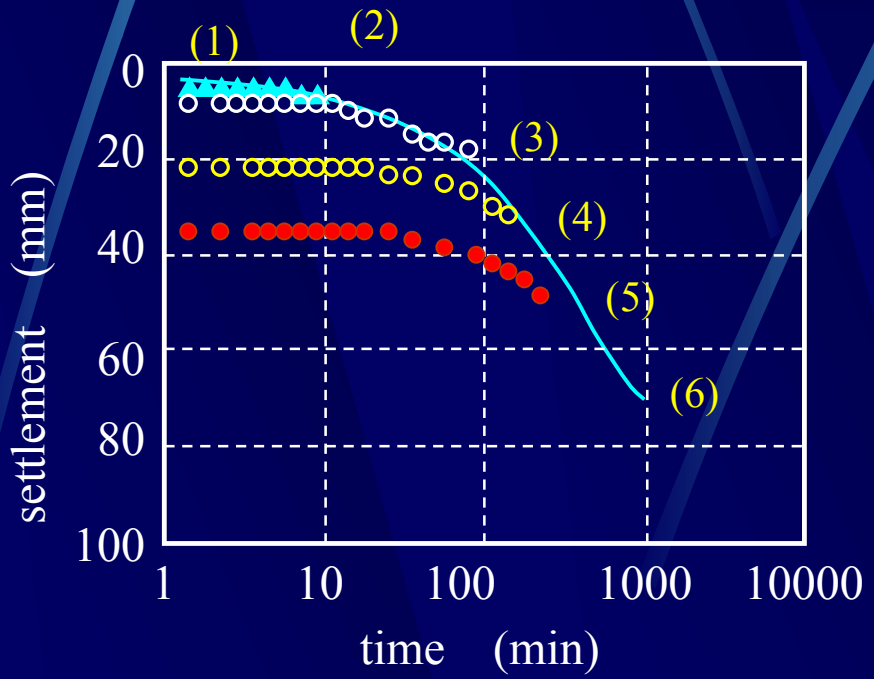
time – settlement curves





The two curves obtained at the top of sand pile and at the clay surface coincide during the consolidation, which shows no differential settlement took place in the composite ground consisting soft clay and a sand pile.

deformation of sand pile



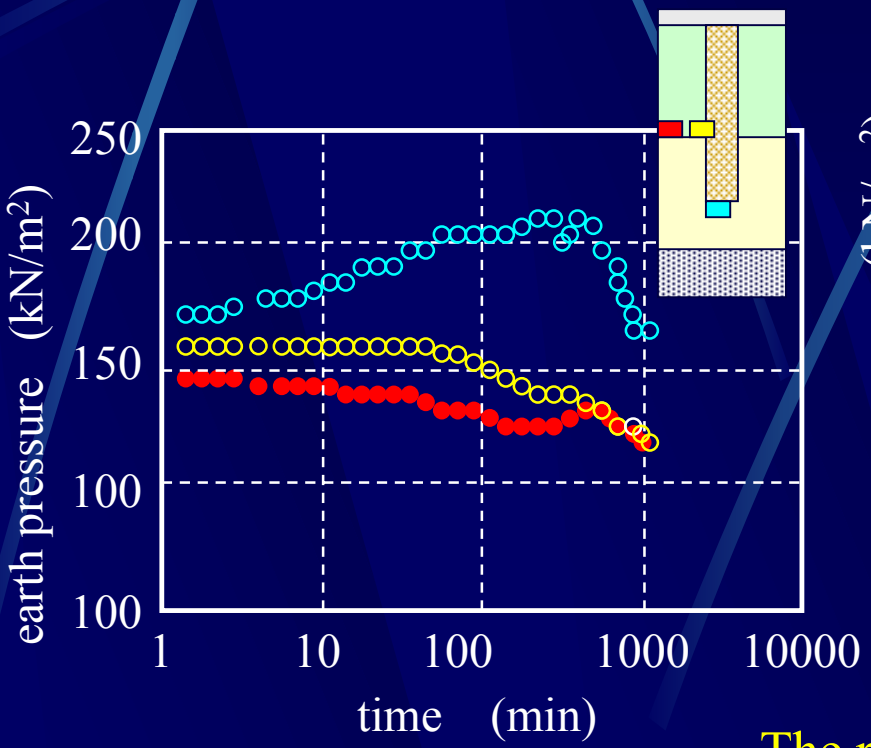
(6)

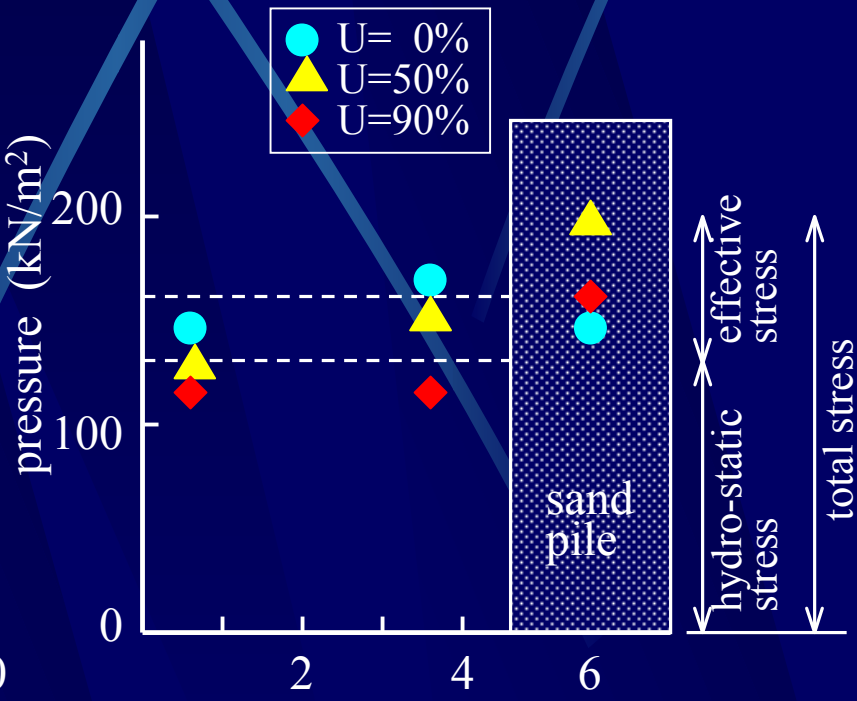




(1) (2) (3) (4) (5)

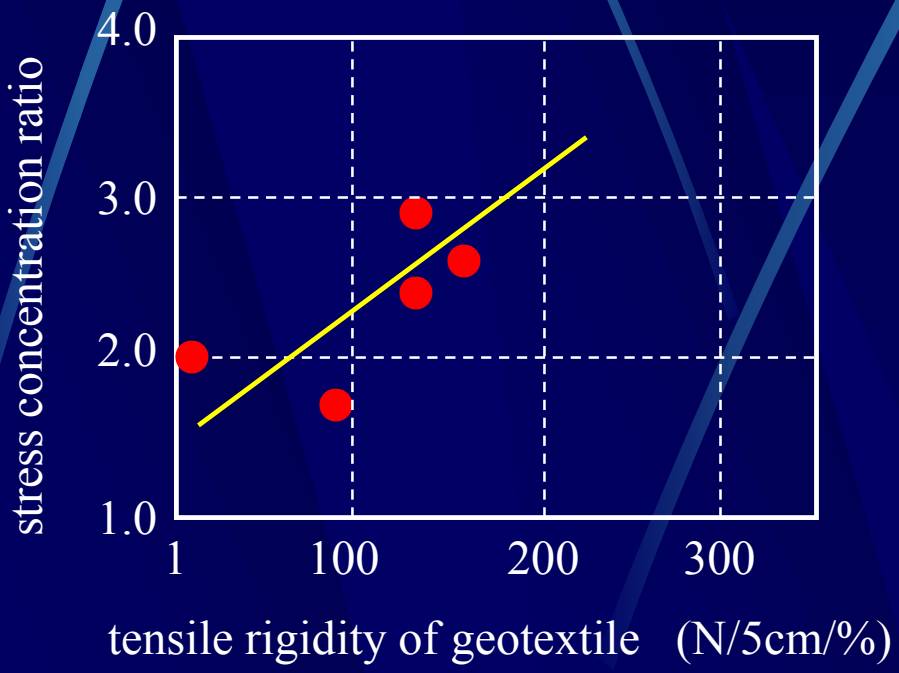
time – earth pressure curves





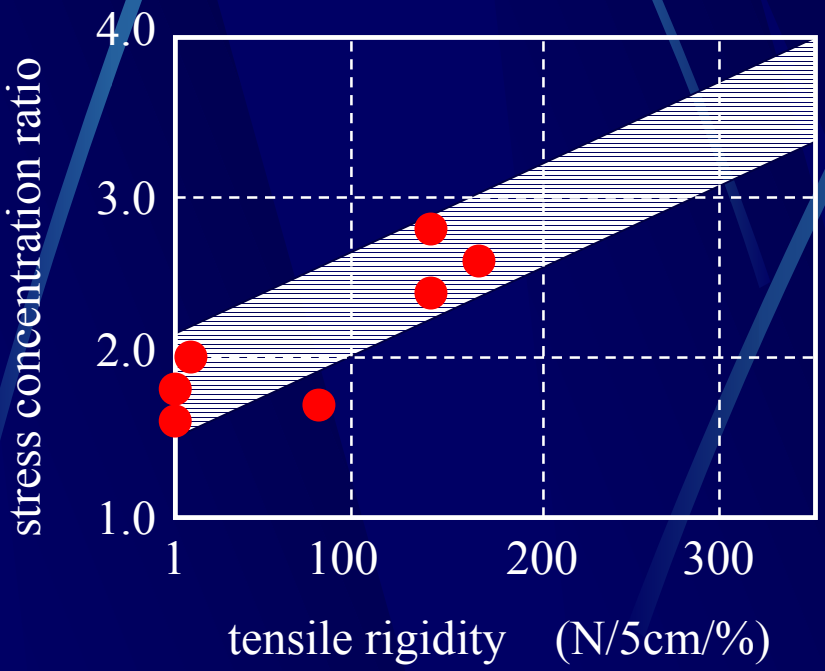
The pressure distribution changes during consolidation process.

tensile rigidity – stress concentration ratio



Stress concentration ratio increased almost linearly with the tensile rigidity of geotextile

tensile rigidity – stress concentration ratio



The influence of the stress concentration on the consolidation settlement:

$\beta = 1 / (As * n + (1 - As))$

where:

β : ratio of the settlement of an improved ground against that of un-improved ground

n : stress concentration ratio

As : replacement area ratio

The decrease of the settlement remained within 5 % as long as the tensile rigidity was lower than about 200N/5cm/%.

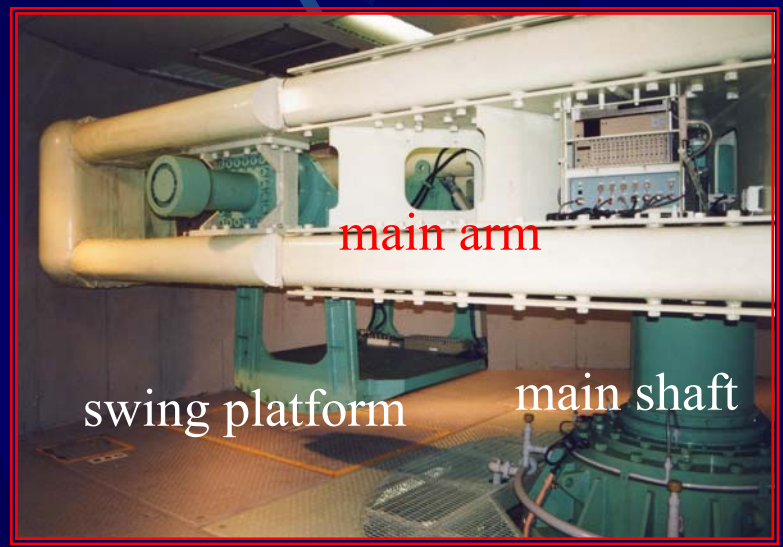
conclusion of model test

- The study revealed that the geotextile functions well to stabilize the sand pile in the extremely soft clay ground. The stress concentration resulting from the tensile rigidity of the geotextiles evaluated was smaller than anticipated and might not cause undesirable settlement.
- As the applicability of the fabri-packed sand drain was con-firmed by the centrifuge model study, the method was employed in the Haneda Project.



Conclusions

- PARI centrifuge has been employed extensively to investigate not only on basic research topics but also on practical topics. The research results have been applied to constructions of various port and airport facilities.
- Challenging but fairly difficult field on centrifuge application will be one to the major subjects of the PARI centrifuge.



research subjects (1)

- curiosity oriented and fundamental research
  - bearing capacity of sand and clay
  - reinforcement by geotextile
  - pile foundation
  - sand drain method
  - sand compaction pile method
  - deep mixing method
  - development of earthquake simulator

Curiosity oriented and fundamental research

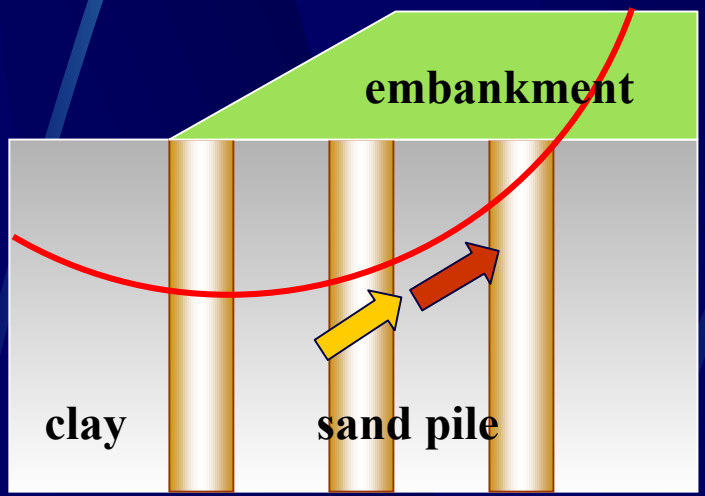
- Development of design formula for SCP improved ground -



Bearing capacity

shear strength of SCP improved ground:

$$\tau = (1-as)\,(C_0 + k\cdot z + \mu c\cdot \Delta\sigma z\cdot Cu/p\cdot U) + (\gamma s\cdot z + \mu s\cdot \Delta\sigma z)\cdot as\cdot \tan\phi s\cdot \cos 2\theta$$



where

τ : shear strength

as : improvement area ratio

$C_0 + kz$: undrained shear strength of clay

μs : coefficient of stress concentration

$\Delta\sigma z$: increment of vertical stress due to external load

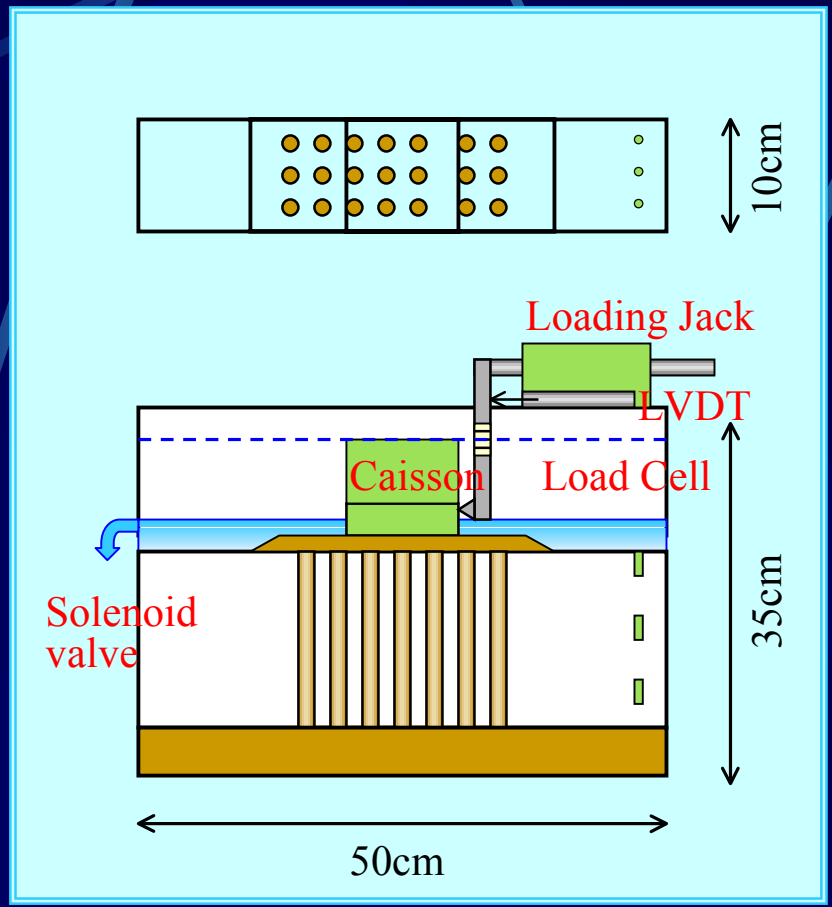
n : stress concentration ratio

U : average degree of consolidation of clay in between sand piles

ϕs : friction angle of sand pile

γs : unit weight of sand pile

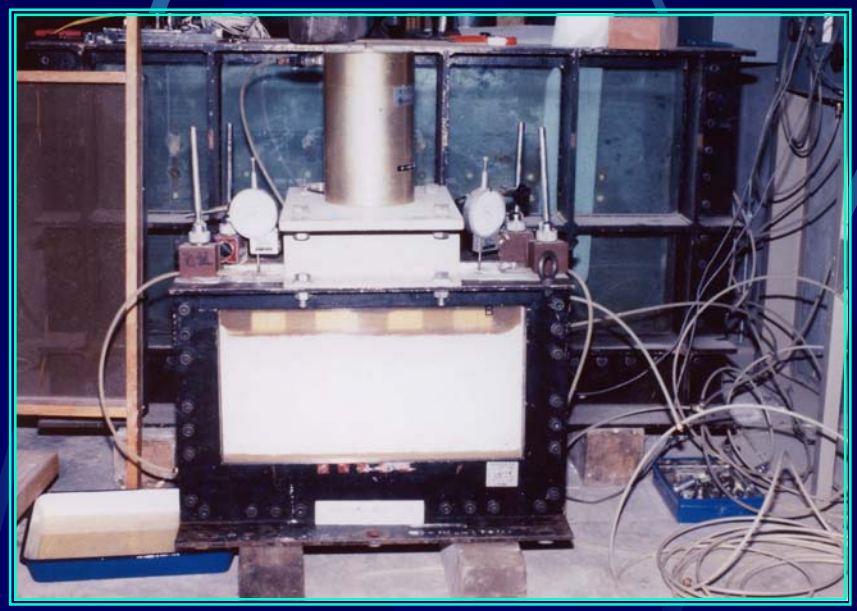
preparation of model ground



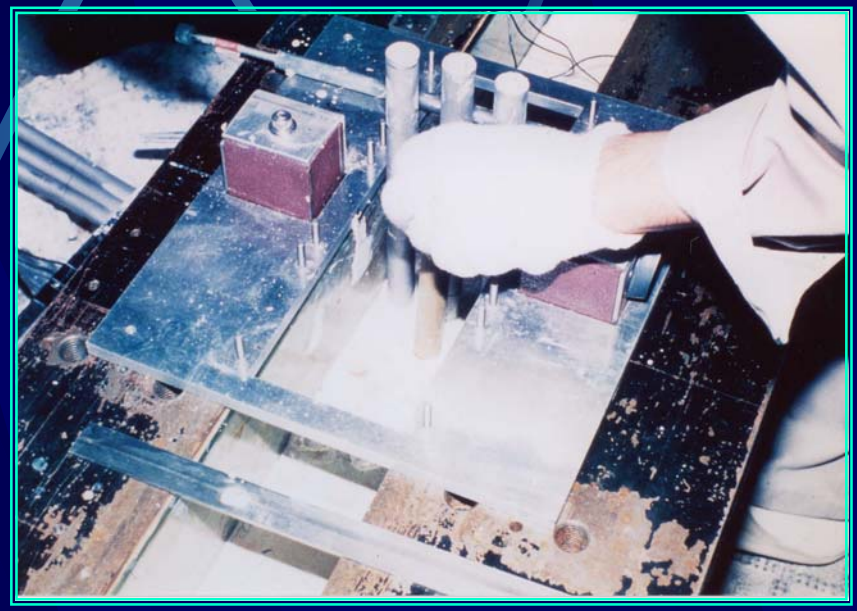
loading procedure

- **Vertical load was applied by quick lowering of the water level.**
- **Horizontal load was applied immediately after that by means of the horizontal loading jack.**

preparation of model ground

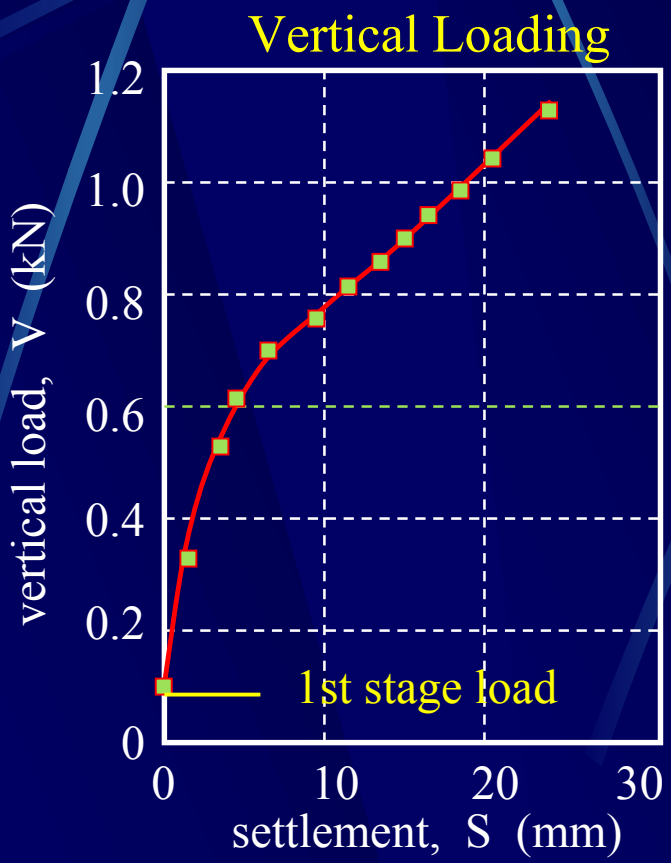


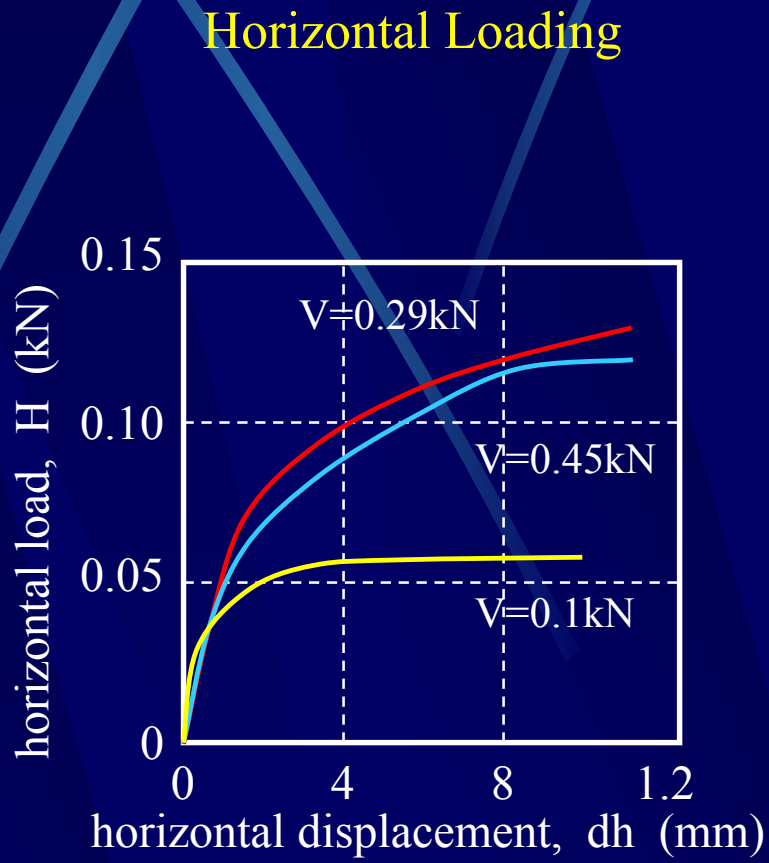
pre-consolidation in laboratory



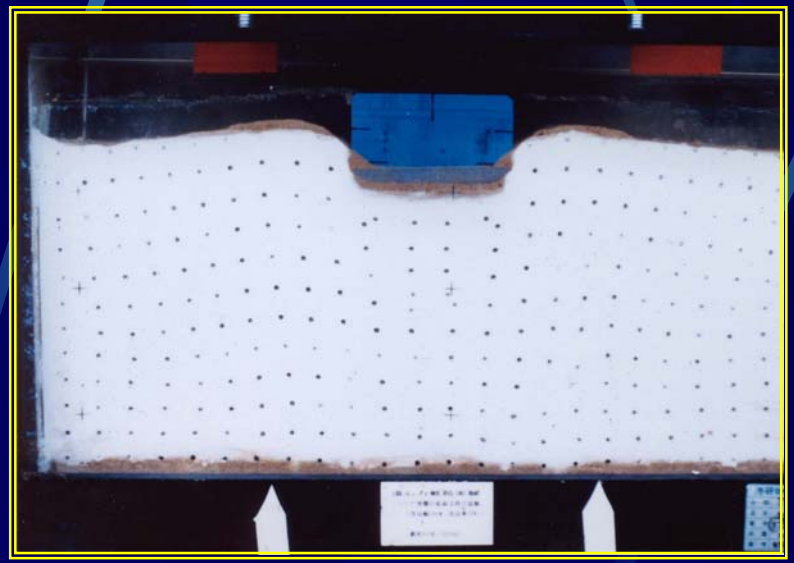
installation of sand piles

load – displacement carves

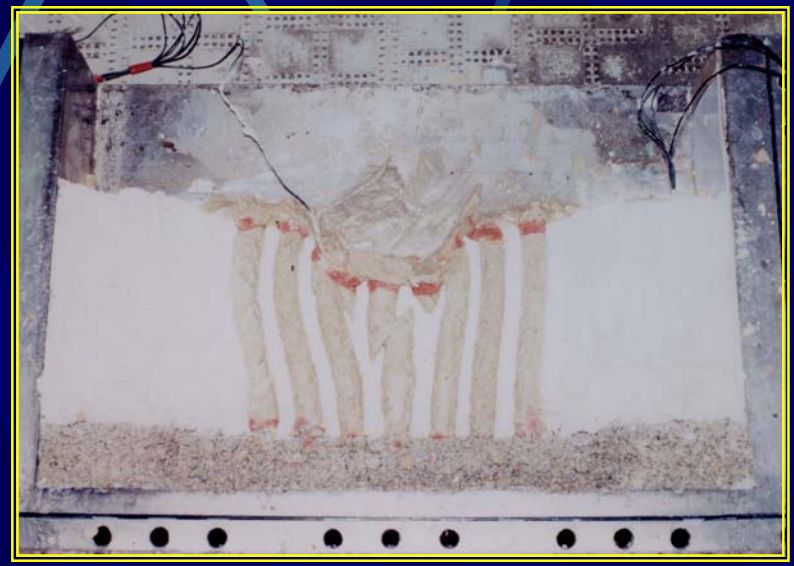




ground failure in vertical loading

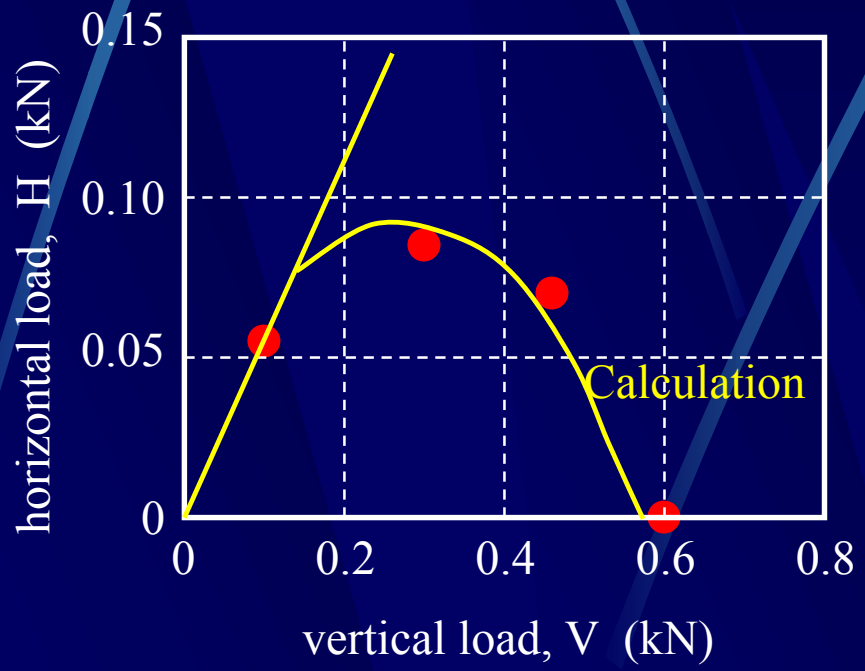


ground deformation



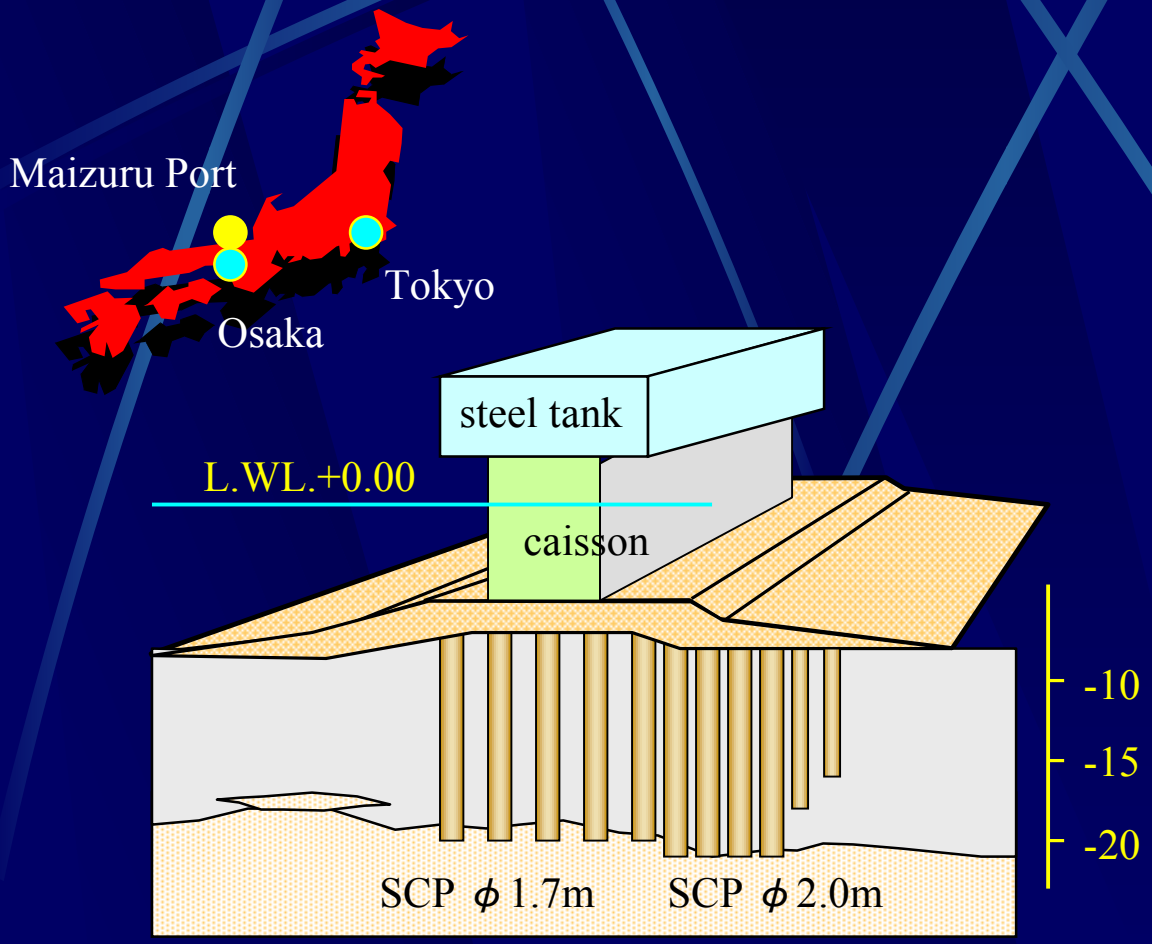
failure pattern of sand piles

failure envelope



Bearing capacity of the improved ground can be estimated by a simple clip circle method combined with the practical formula for the shear strength of composite ground.

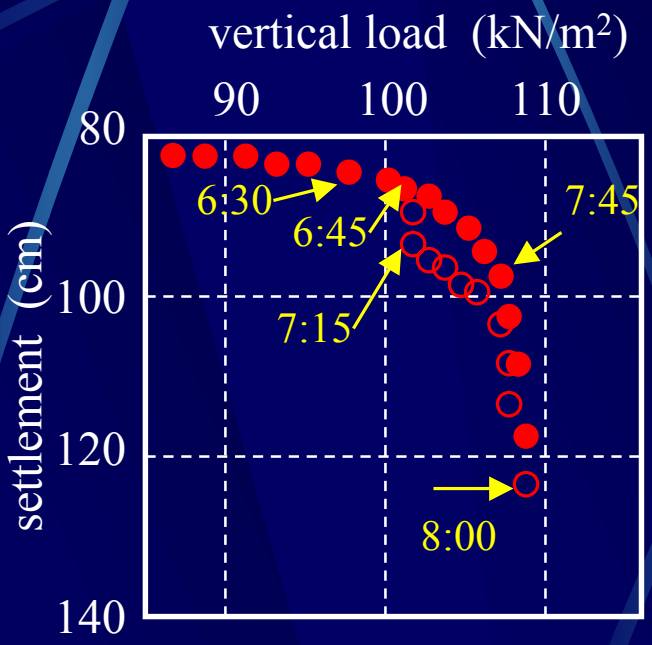
field test at Maizuru Port



Purpose:
to establish design method for low as improvement.

Procedure:
SCP improved ground is subjected to vertical load to fail

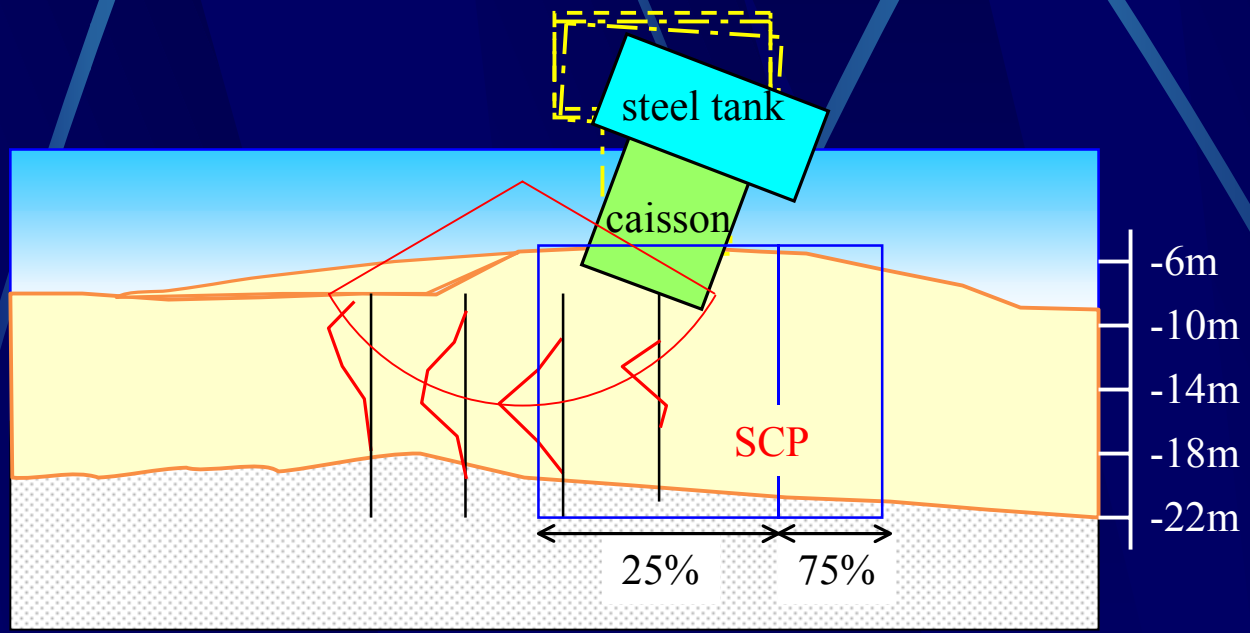
load – settlement curve



At 6:45 the concrete caisson is filled up with water and the loading is once interrupted for changing pipelines from the caisson to the tank.

The yield load of ground is determined as 106 kNm^2.

failure pattern



Conclusion of the test

- Bearing capacity of the improved ground can be estimated by a simple slip circle method of stability analysis combined with the practical formula for the shear strength of composite ground.

research subjects (2)

- practical research having close relevance to specific prototype
  - Niigata Port (application of DMM to retaining wall)
  - Haneda Airport (Stability of retaining wall during excavation, application of fabri-packed sand drain, influence of embedded sheet pile wall to deformation of ground surface)
  - Wakayama Shimotsu Port (effect of local soil DMM improvement)
  - Osaka Port (effect of SCP improvement on slope stability)
  - Kumamoto Port (Deformation of soft ground under placement of soft-loading breakwater)