Emerging Technology

Construction of a man-made island for Central Japan International Airport by the pneumatic flow mixing method

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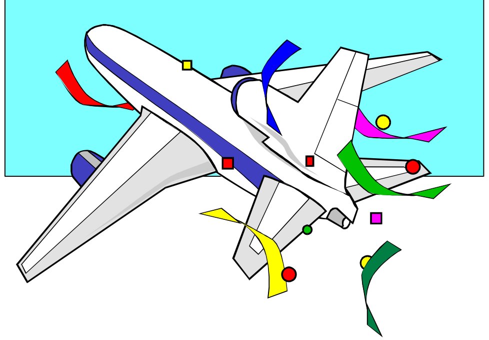
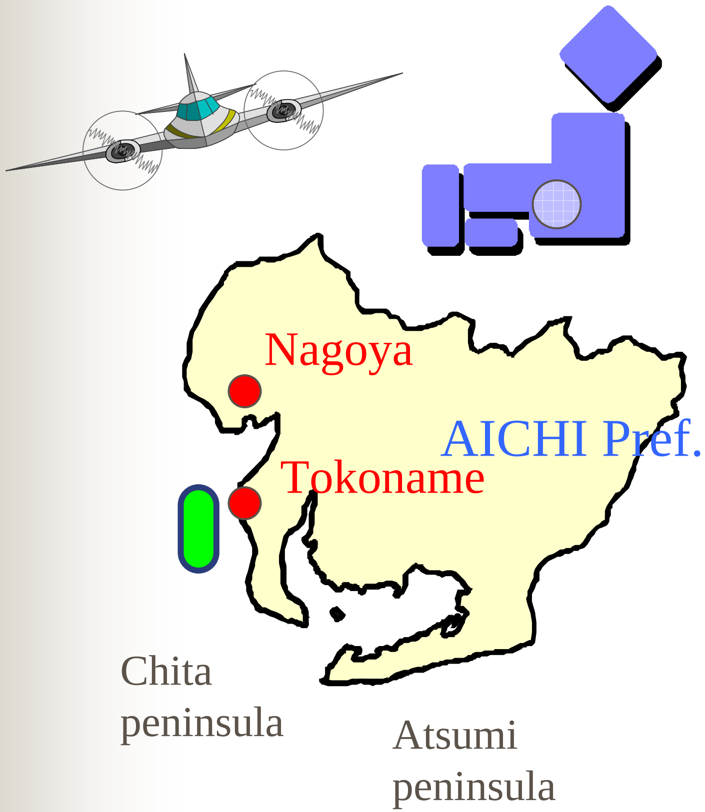


CENTRAL JAPAN INTERNATIONAL AIRPORT CONSTRUCTION



Airport area	
Phase Ⅰ	Runway：3,500 m Plane area：about 470 ha
Future	Runway：2 * 4,000 m Plane area：about 700 ha

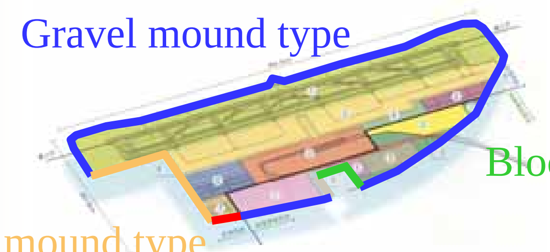
Estimated airport demand (per year)			
	passengers (million)	cargo (million tons)	take off (million)
Phase Ⅰ	8	0.43	0.13
Future	10	0.53	0.16

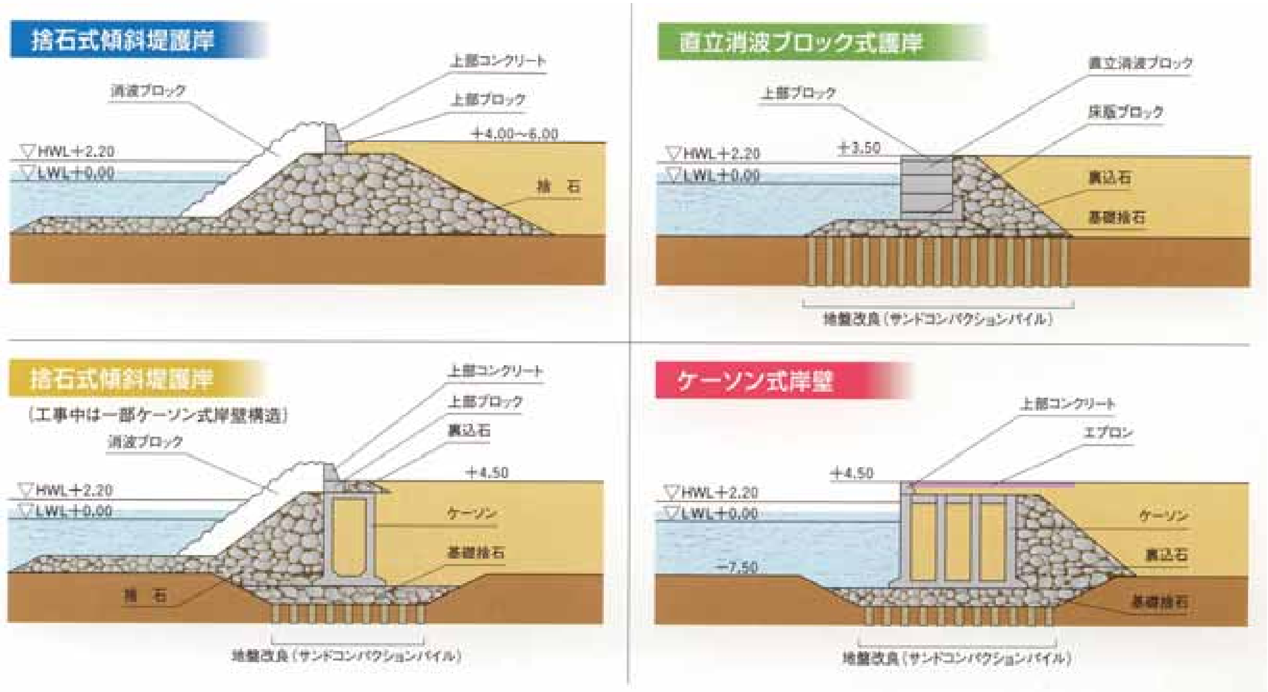
bird's - eye view of island

Airport island

	Airport island	
	airport facility site	regional development site
plane area	approx. 4.7 million m^2	approx. 1.1 million m^2
length of sea revetment	approx. 8 km	approx. 4 km
volume of reclamation soil	approx. 56 million m^3	approx. 13.7 million m^3
depth of water	-2.6 ～ -8.0 m	-2.6 ～ -10.0 m

Type of sea revetment





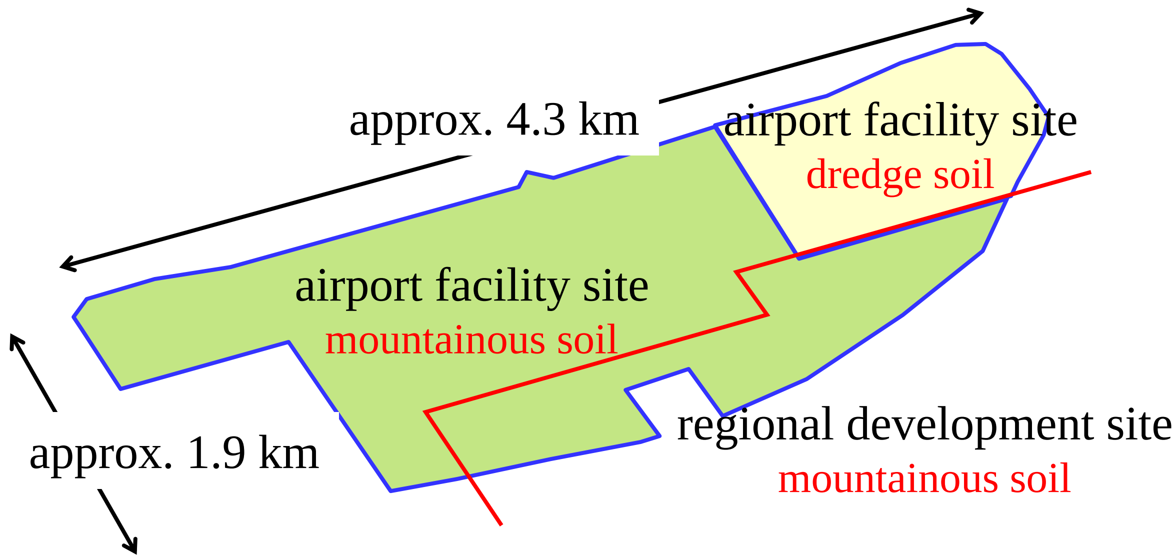
Sea reclamation

Reclamation by mountainous soil (approx. 61.8 million m^3)

by dumping, shooting

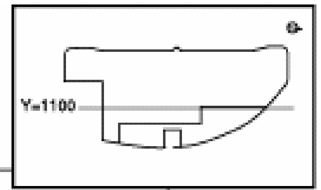
Reclamation of dredge soil (approx. 8.2 million m^3)

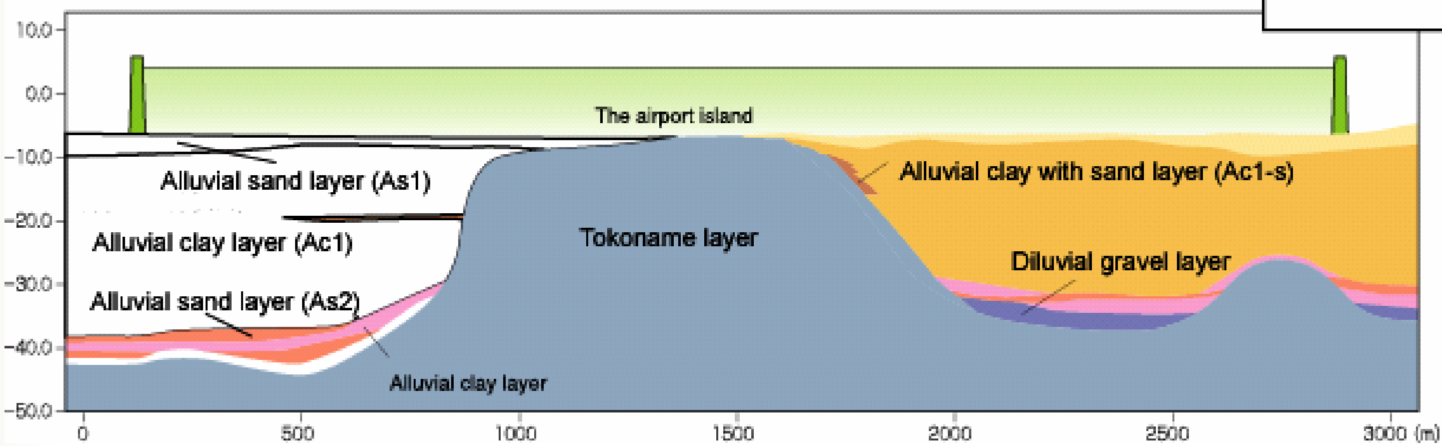
by PNEUMATIC FLOW MIXING METHOD



Geological condition at construction site

island is constructed on good foundation, Tokoname layer
sea depth : 3 to 10 meter, 6 meter in average
sand layer : 14 to 15 of SPT value
alluvial layer : about 70 kNm^2 of *qu*
diluvial clay : 13 to 43 of SPT value





Mixing design – required strength -

Required unconfined compressive strength : 120 kN/m^2

(1) no consolidation settlement allowed (Pc equal or larger than σv’)

σv’ at the bottom of treated soil ground:

148 kN/m^2 at runway, 98.8 kN/m^2 at taxi way

consolidation pressure of treated soil, Pc :

Pc = 1.25 * *qu*

required unconfined compressive strength:

qu ≧ 118 kN/m^2 120 kN/m^2

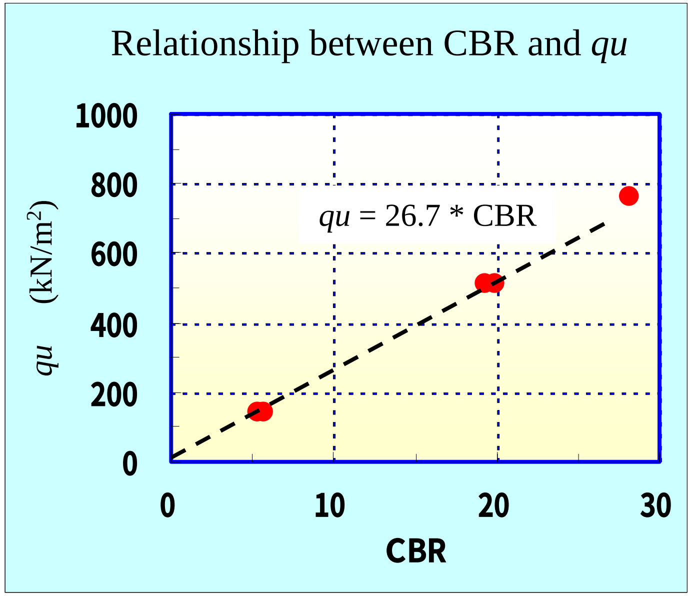
(2) required strength for base ground under pavement

regulation by Ministry of Transport

CBR ≧ 3

required unconfined compressive strength:

qu = 26.7 * CBR = 80.1 kN/m^2



design of mixing condition

- influence of strength variation -

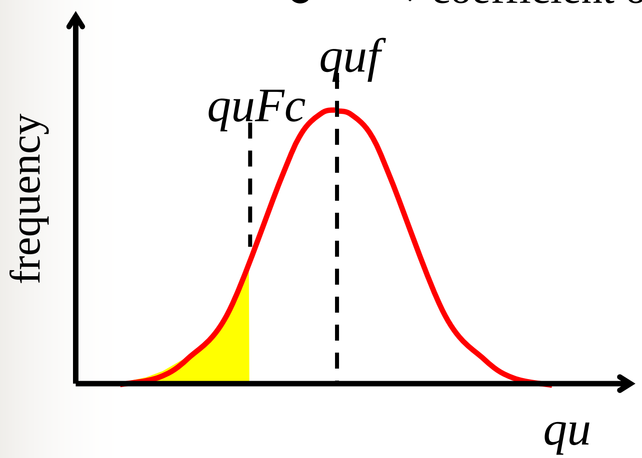
design strength

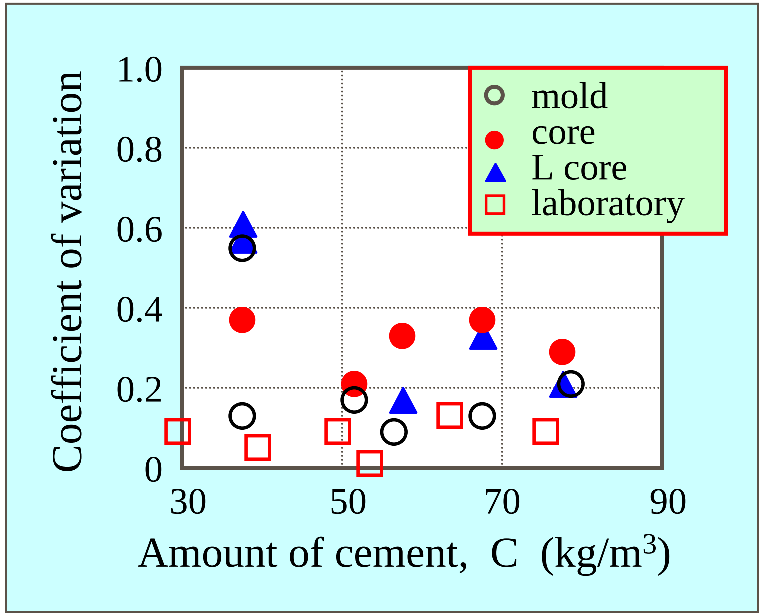
$$quFc = quf - \alpha * \sigma$$

α :1.2for current design

where

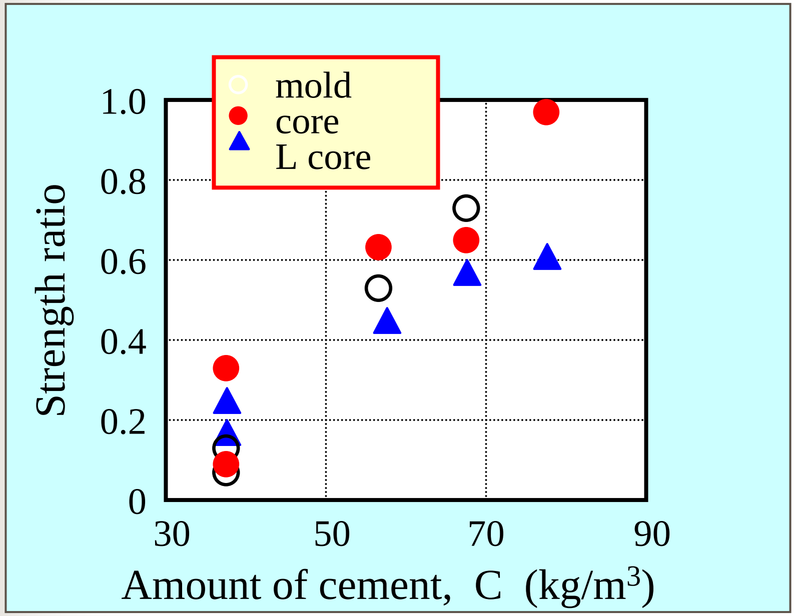
quFc ：design strength
α ：factor
σ ：coefficient of variation



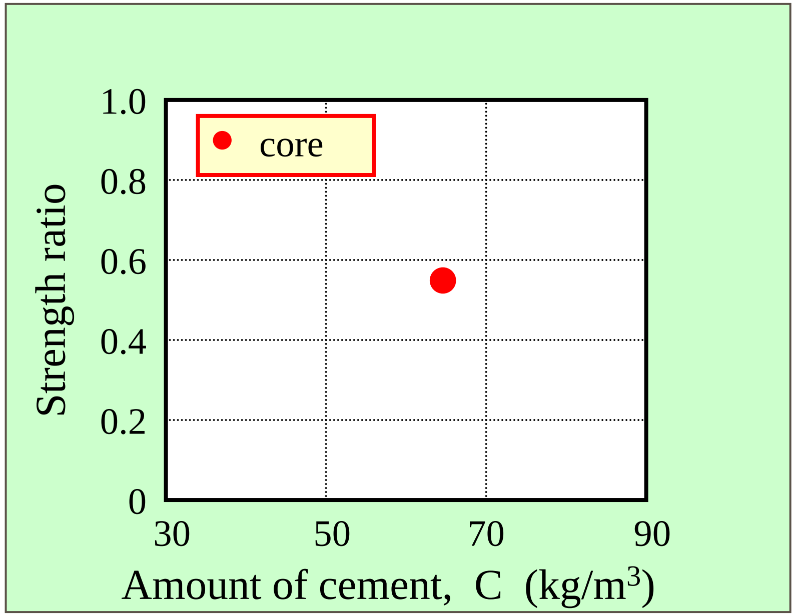


design of mixing condition
- influence of strength ratio, *quf*/*qu*l -

In the design, *quf*/*qu*l = 0.5 is adopted



placement on land



placement under seawater

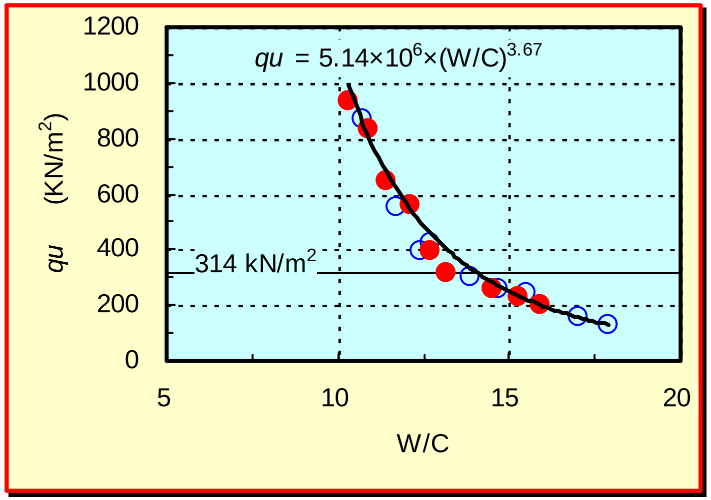
design of treated soil

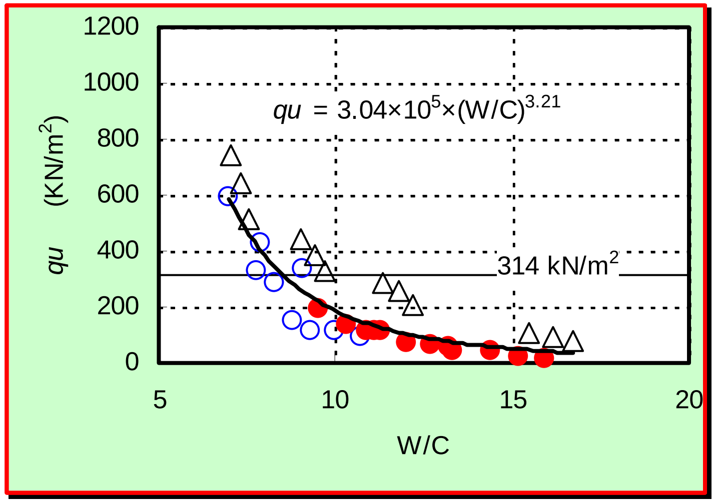
determination of design strength ①no consolidation settlement ②minimum CBR value of 3	quf = 120 kN/m^2
⇩	
determination of average field strength ①incorporating scatter of field strength	quf = 157 kN/m^2
⇩	
determination of laboratory target strength ①incorporating strength ratio	qul = 314 kN/m^2
⇩ flow characteristic	
determination of mixing condition	54 〜 60 kg/m^3

Unconfined compressive strength vs. Water/Cement ratio

qu is almost inversely proportional to the W/C,
and unique relation obtained for each dredge soil.

$$qu = a * (W/C)^{-n}$$



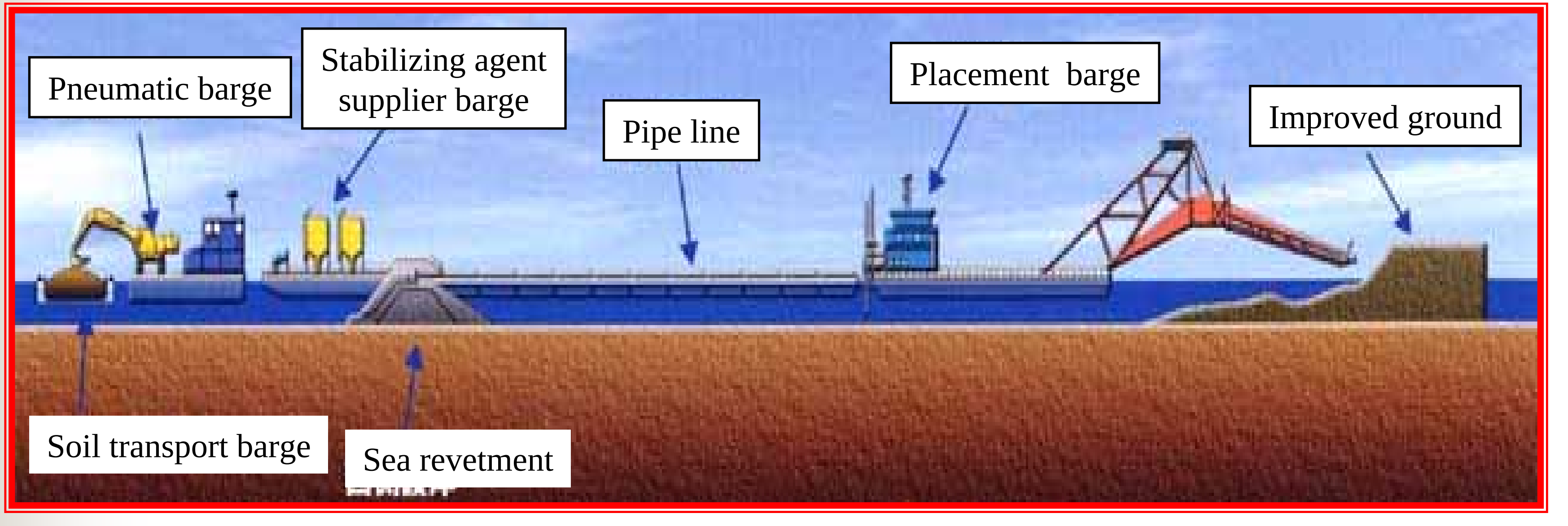


W/C ratio = all water contained soil and cement slurry / cement

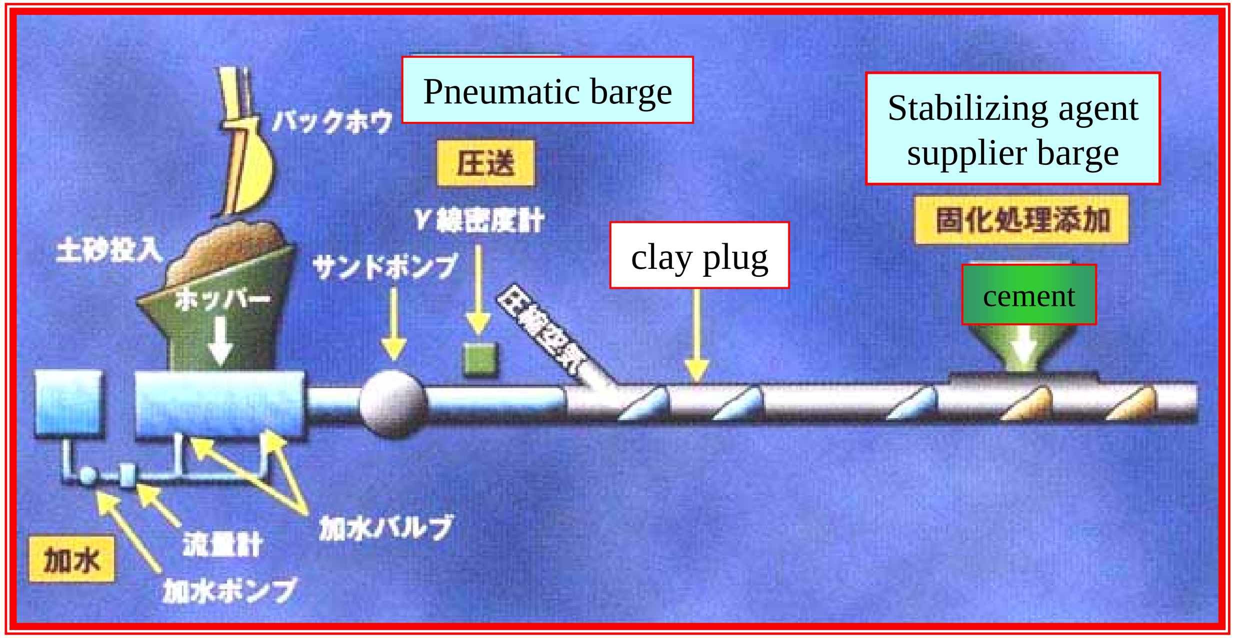
Soil property of expected dredge soils

excavation site no.	property of dredge soils						Mixing condition		
	Wi (%)	unit weight (g/cm^3)	particle size distribution: gravel (%)	sand (%)	clay (%)	liquid limit (%)	W/C ratio	W (%)	cement (kg/m^3)
A	74	1.57	0.0	6.8	93.2	75.6	14.0	105	54
B	81	1.58	0.0	8.0	92.0	74.3	13.4	97	55
C	75	1.56	0.0	5.6	94.4	85.5	13.8	113	56
D	84	1.51	0.0	2.4	97.6	88.3	13.8	116	56
E	68	1.57	0.1	8.7	91.2	72.7	13.8	101	54
F	75	1.56	0.0	2.7	97.3	78.3	14.1	100	53
G	67	1.65	0.0	18.0	82.0	55.3	8.5	64	87
H	62	1.67	0.0	5.0	95.0	67.1	13.8	88	52
I	54	1.72	2.3	29.3	68.4	59.3	13.2	80	53
J	48	1.79	0.0	19.3	80.7	49.2	11.4	65	57

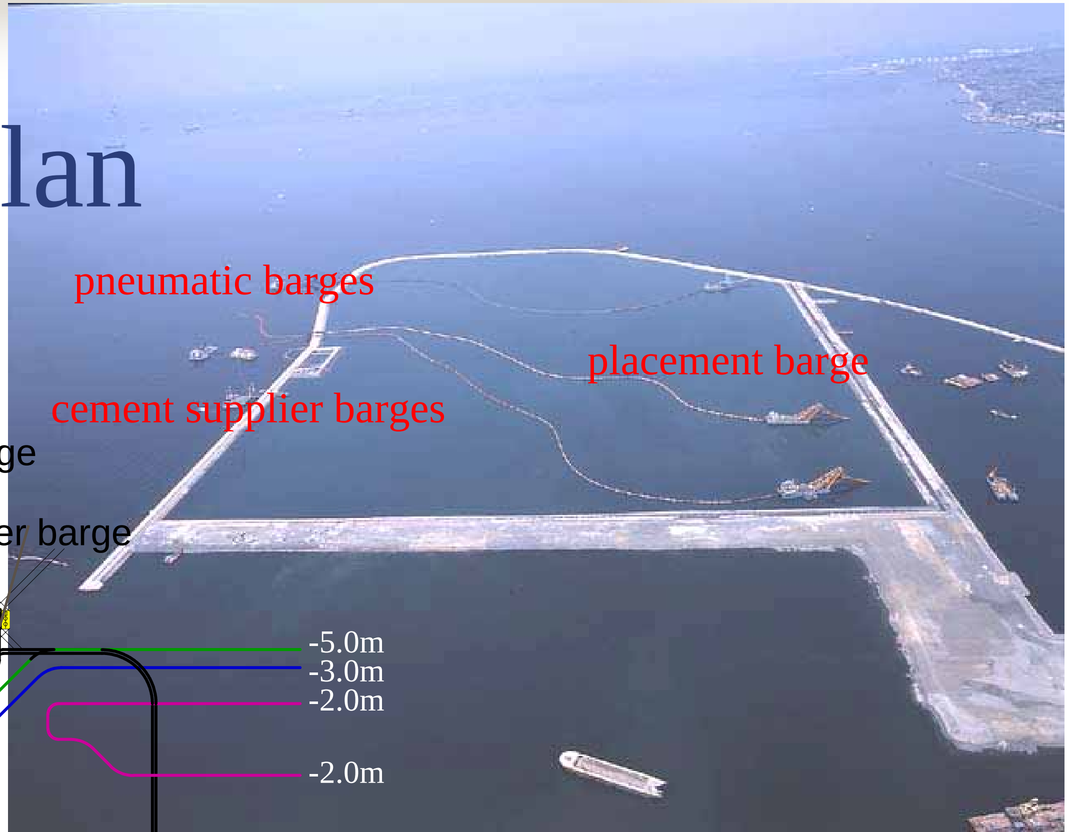
execution facility

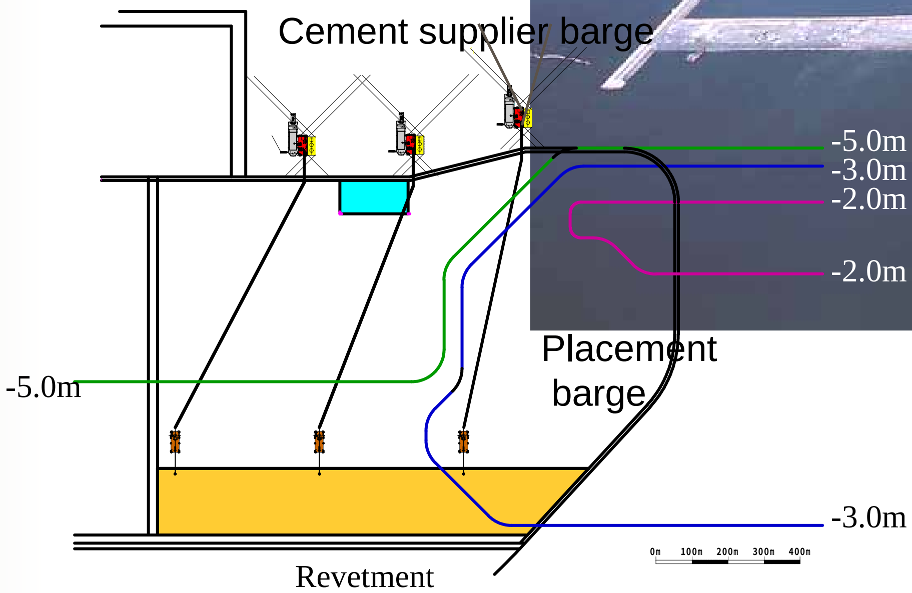


execution facility



Execution plan





facility

soil transport barge, pneumatic barge & cement supplier barge

soil transport barge

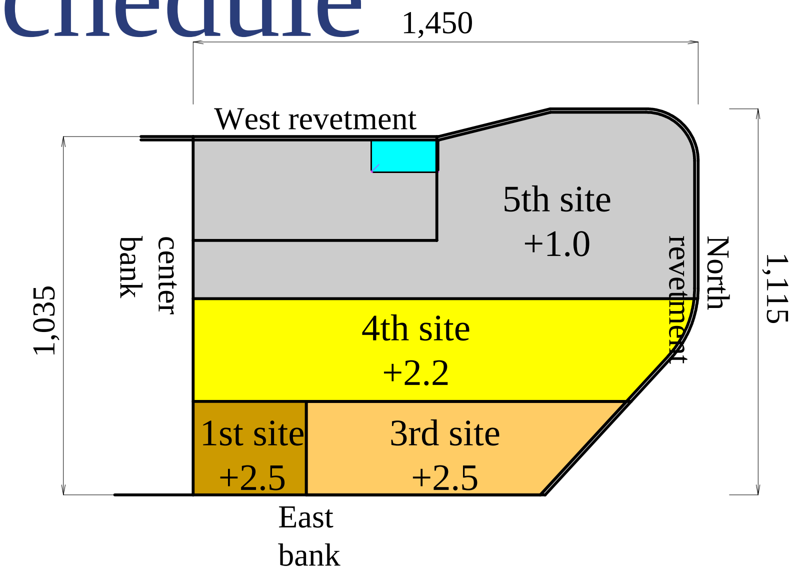
facility

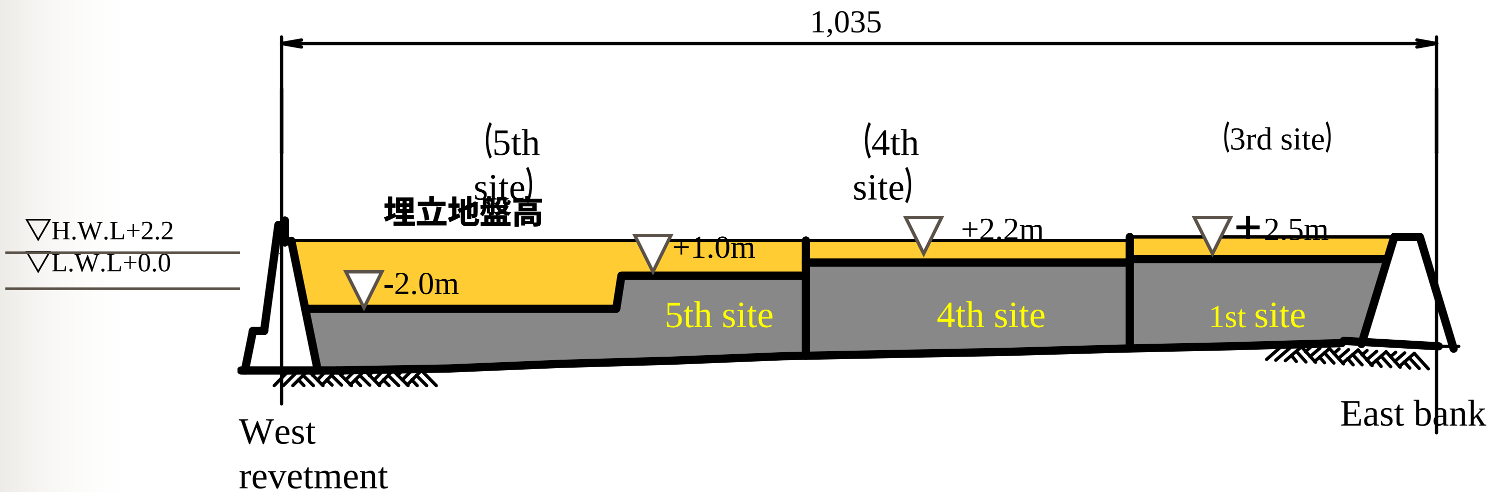
placement barge

placement barge

construction schedule

construction period	
1st site	end of Oct. 2001
3rd site	end of Jun. 2002
4th site	end of Dec. 2002
5th site	end of Apr. 2003

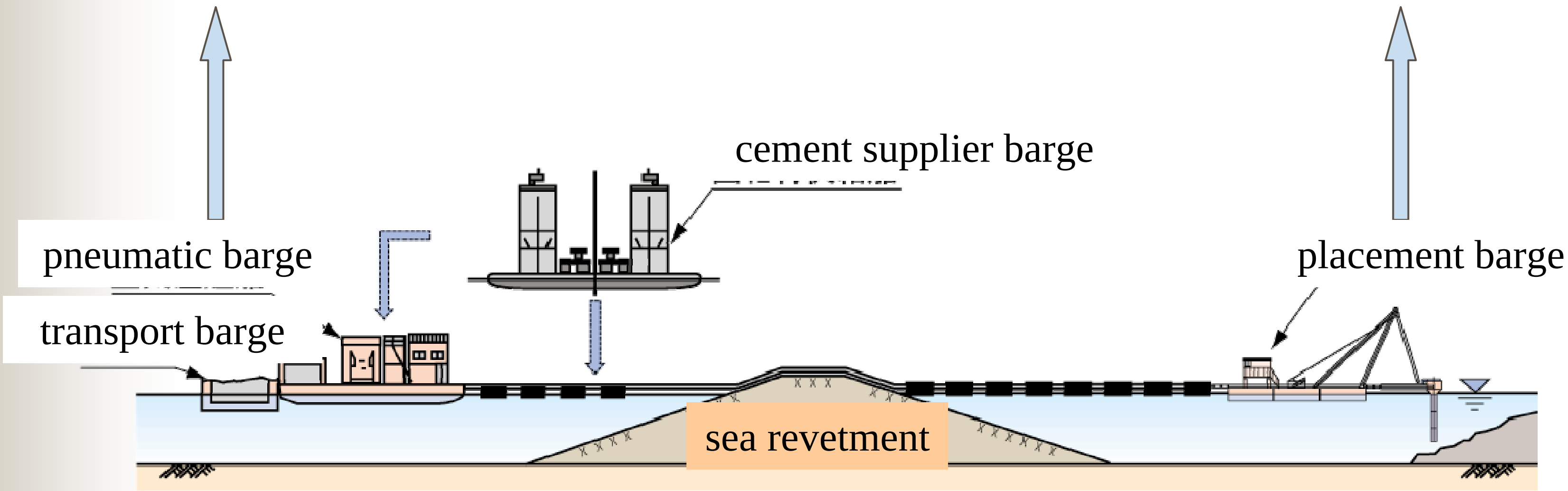




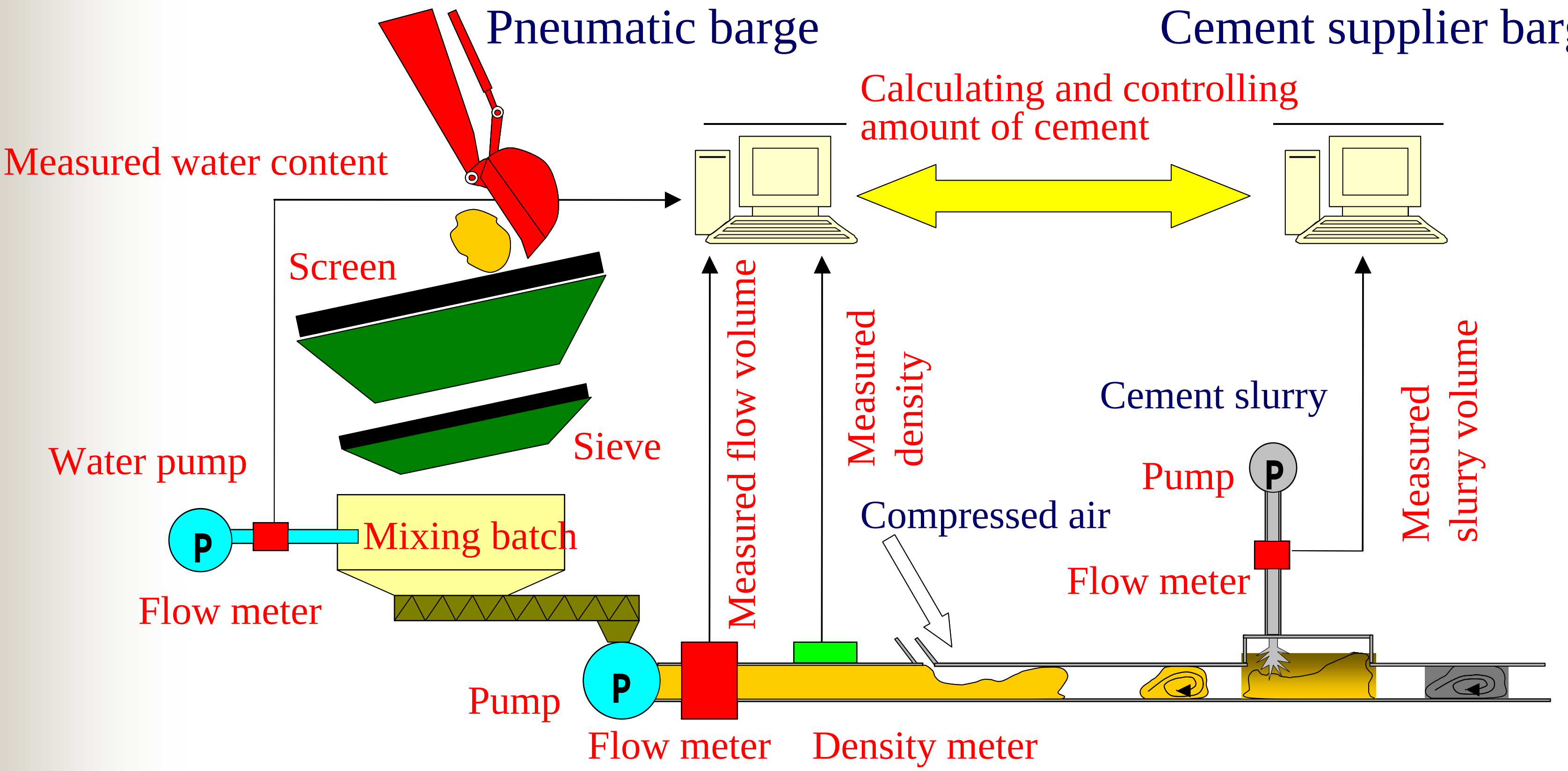
quality control and assurance

Water content measurement of dredge soil
feed back to mixing condition

unconfined compression tests
every 40 thousand m^3



Mixing control system

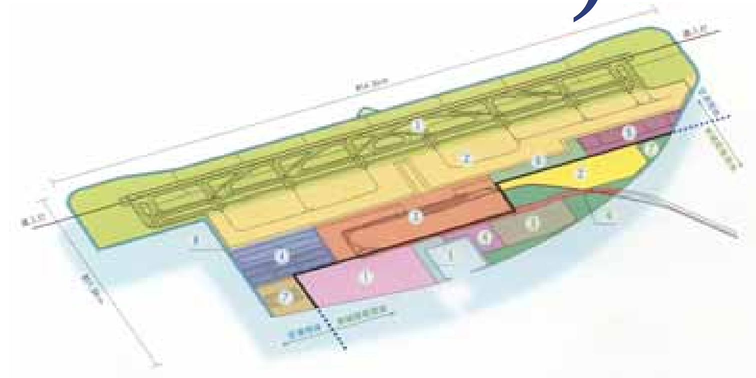


quality control

control item	testing method	frequency
strength of treated soil	in-situ cone penetration tests (JGS 1435)	every 2,500 m^2
	unconfined compression tests on core sample (JGS T511)	every 40,000 m^2

in construction contact:
strength under allowable strength shall be within 25%

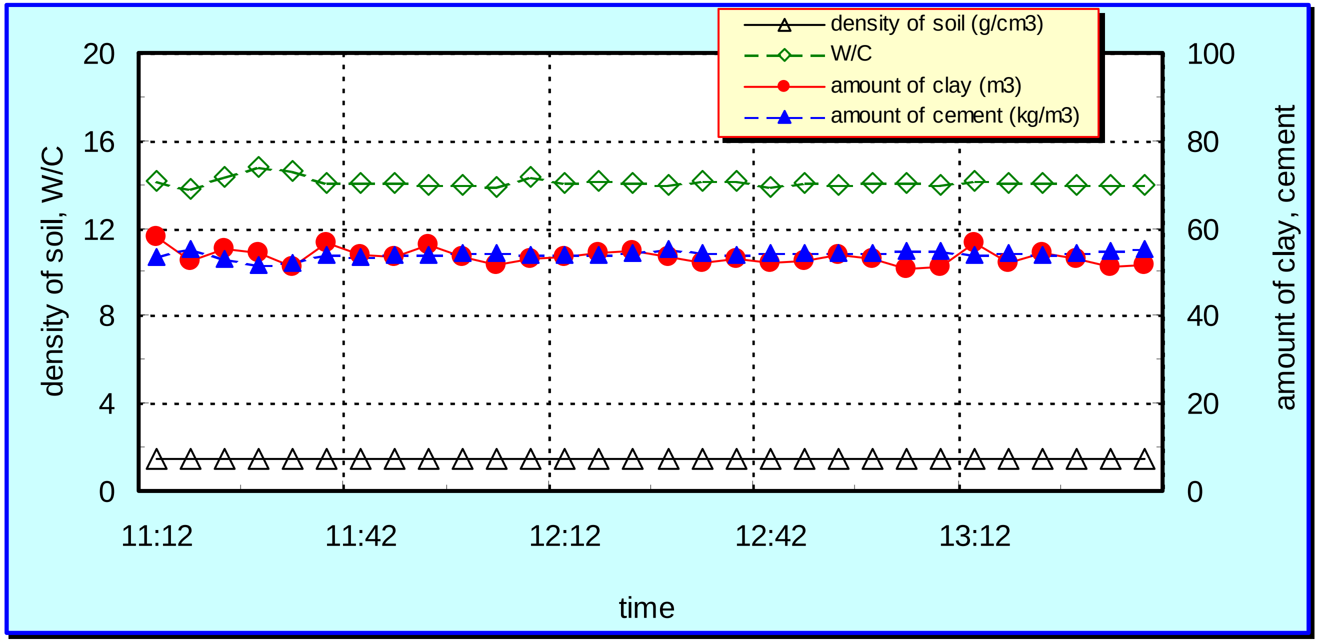
quality control (level of island)



ground level	allowable value	frequency
runway, taxi way and apron	-50cm、+20cm	every 50m distance
the others	±50cm	every 50m distance

Execution chart of soil properties and amount of cement

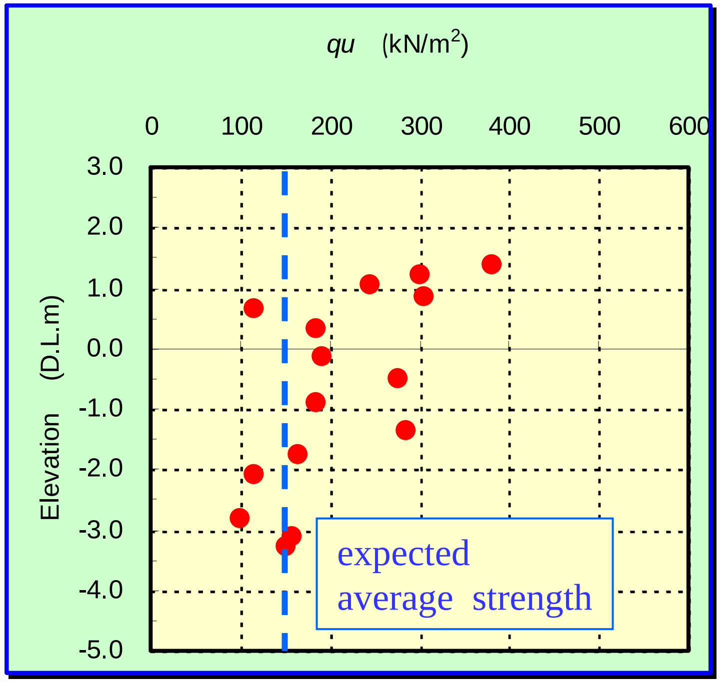
During the execution, the density of soil and amount of soil are measured every 20 seconds in order to determine the water and cement ratio (W/C) and amount of cement to be mixed, which can be feed back for quality control of the mixture.

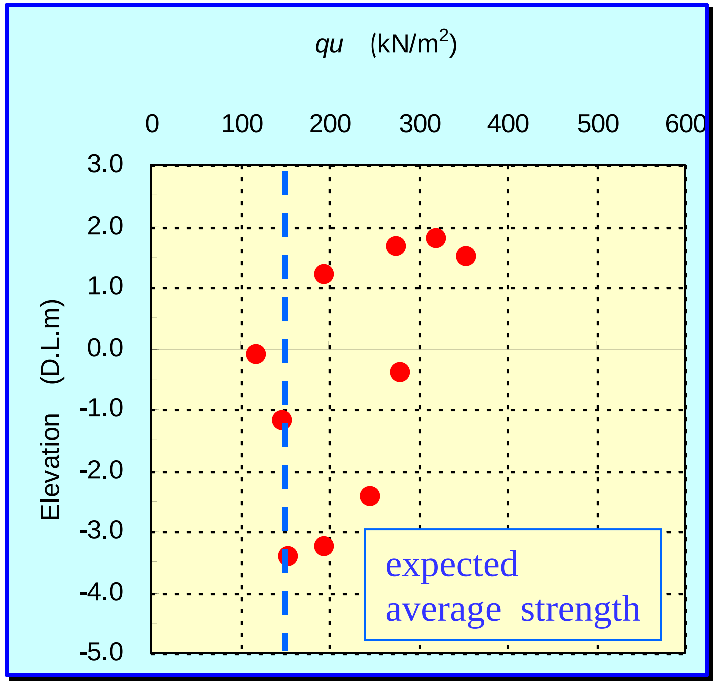


Unconfined compressive strength in field

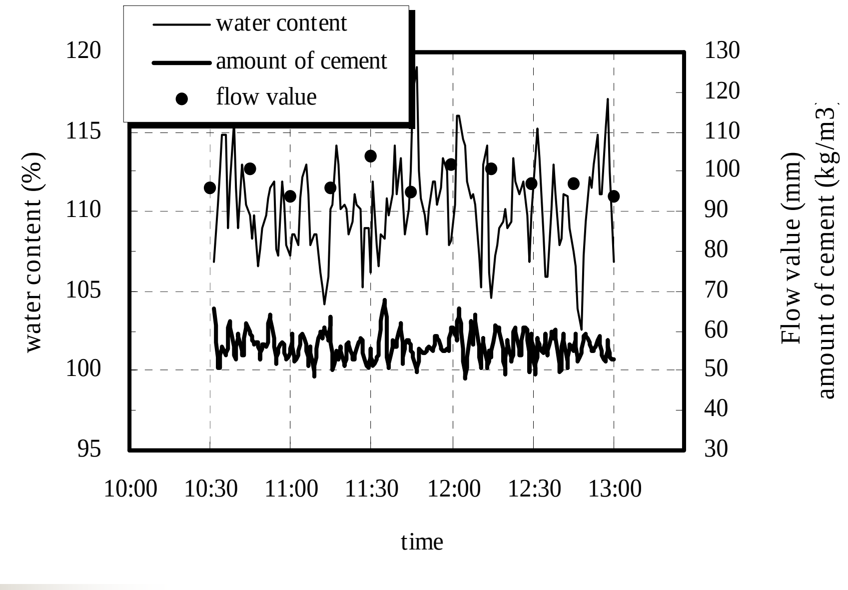
The measured data is relatively higher than the expected average strength.

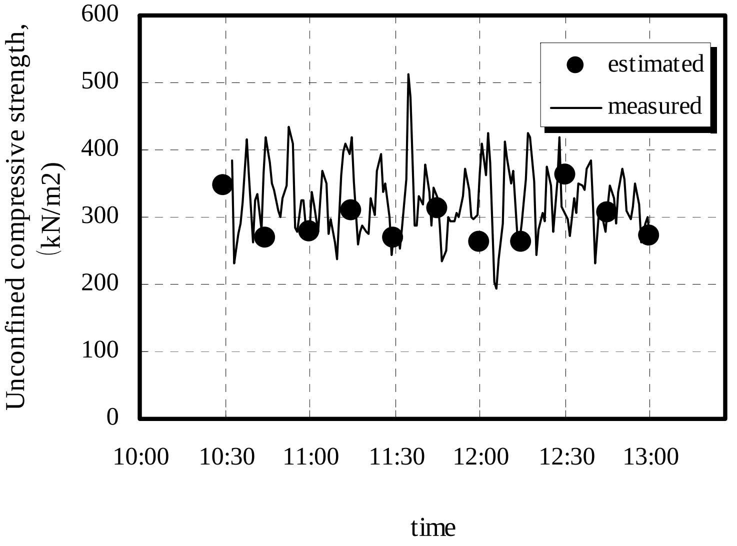
⇨ The reduction factor of *quf*/*qul* (0.5) is found to conservative.



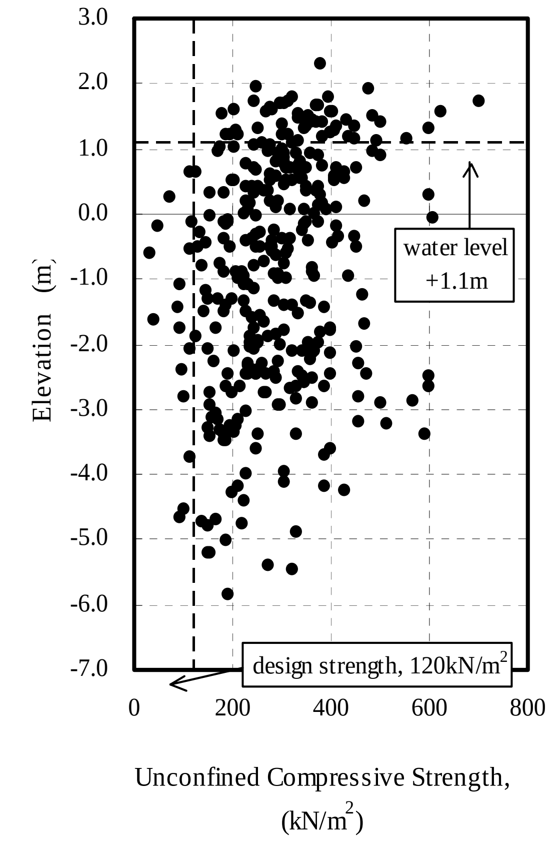


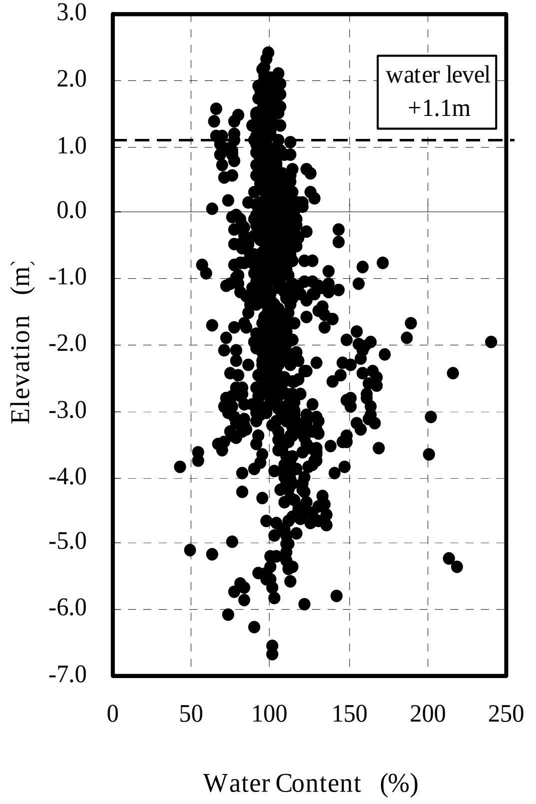
Quality control





Property of improved ground





Average and coefficient of variation of treated soil strength

testing method	number of testing points	whole treated soils (kN/m^2)	treated soils placed below water level (kN/m^2)	treated soils placed above water level (kN/m^2)
CPT	10	280	376	268
UCT	25	296	364	202

strength ratio

	q_u on field treated soil (kN/m^2)	q_u on laboratory treated soil (kN/m^2)	strength ratio
whole treated soils	280-296	430	0.65-0.69
treated soils placed above water level	364-401		0.85-0.93
treated soils placed below water level	268-282		0.62-0.65

CONCLUDING REMARKS

Pneumatic Flow Mixing Method has relatively high applicability for construction of man-made island, sea reclamation and back filling.

The man-made island construction of Central Japan International Airport was completed successfully and efficiently.

A lot of experiences and know-how in execution technique and quality control and assurance accumulated in the construction are published to promote further development of the method.