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Long-term Deformation used as Indicator Representative of Highway Embankment on Soft Foundation

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Long-term settlement and deformation of highway embankment on soft foundation

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Relationship between indicators

Indicators of highway embankment

settlement
lateral displacement

Road performance Indicators

traffic delays/crashes
vehicle operating cost
etc

Performance-related Indicators

vertical alignment
faulting etc

Road asset management supported by Soil / Water coupled FE analysis

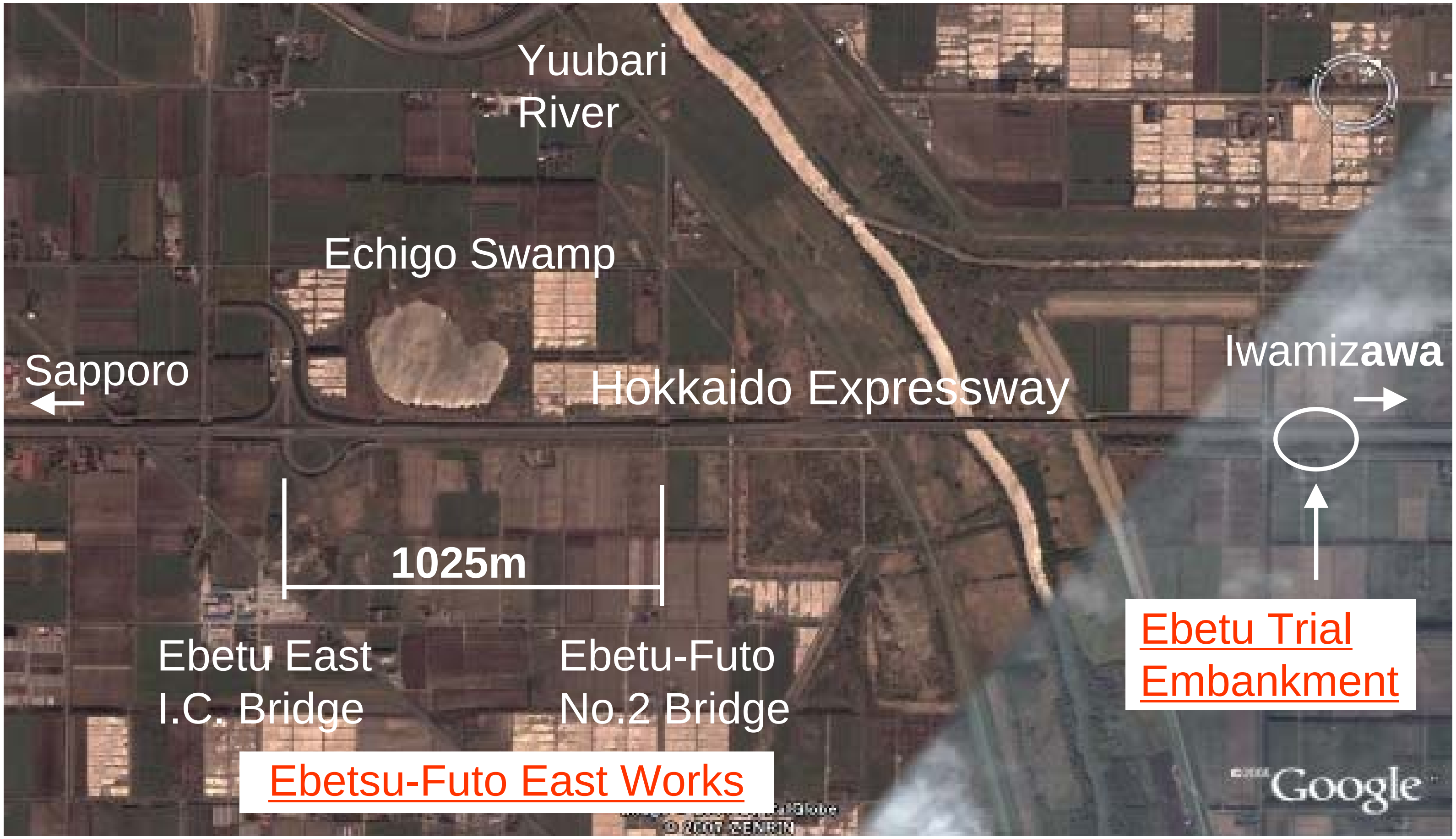
- Data collection
- ↓
- Soil / water coupled FE analysis
- ↓
- Performance modeling
- ↓
- Planning & Life cycle cost estimation

•Analysis can be conducted in one of the post mortem analysis during construction.

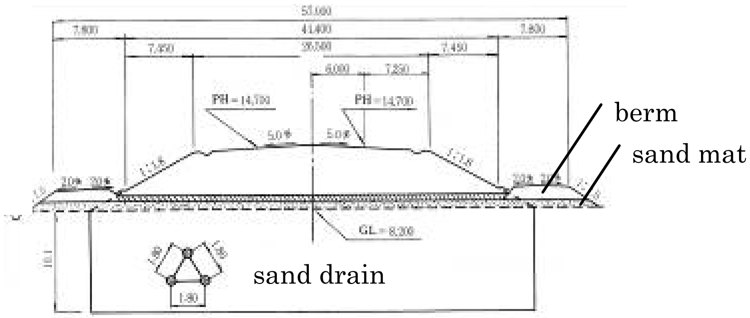
•If the analysis can successfully simulate the deformation behavior during construction, the analysis may successfully predict the long-term settlement and deformation by extending the boundary conditions to longer time period.

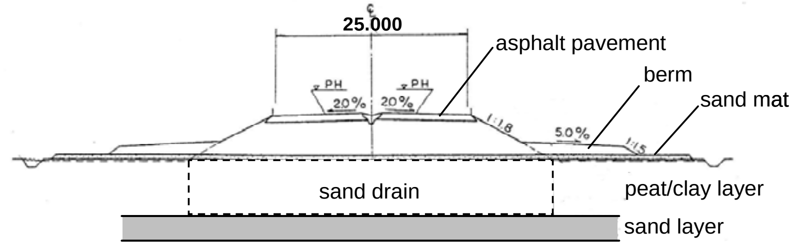
Predictability of long-term settlement and deformation by Soil / Water coupled FE analysis

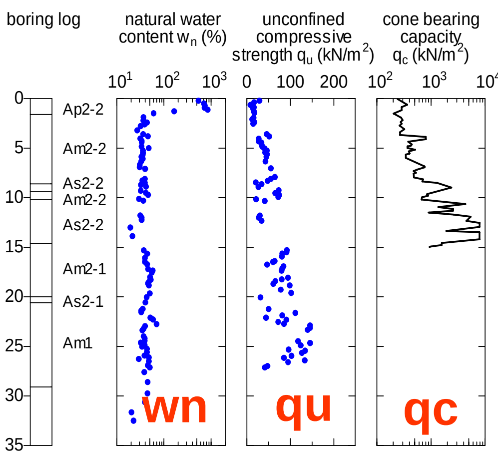
20 years old highway embankment of Hokkaido expressway between Sapporo and Iwamizawa in Japan



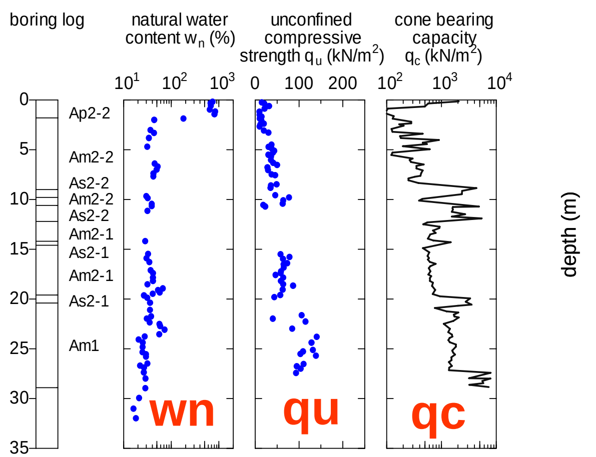
Ebetsu trial embankment & Ebetsu-Futo east works



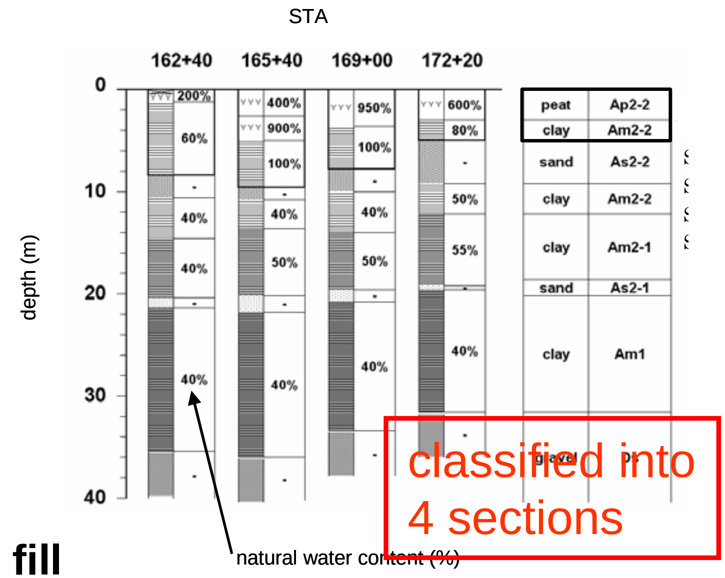




(a) Non-treated test fill



(b) Sand drain-treated test fill

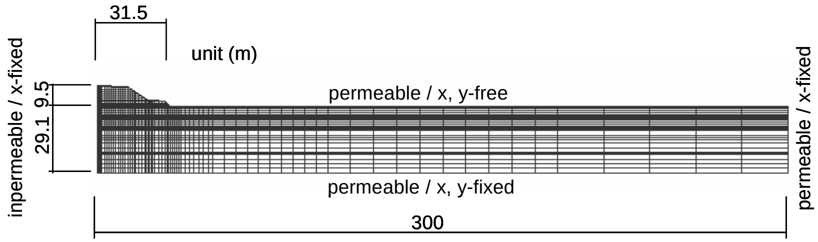


Ebetsu trial embankment **Ebetsu-Futo east works**

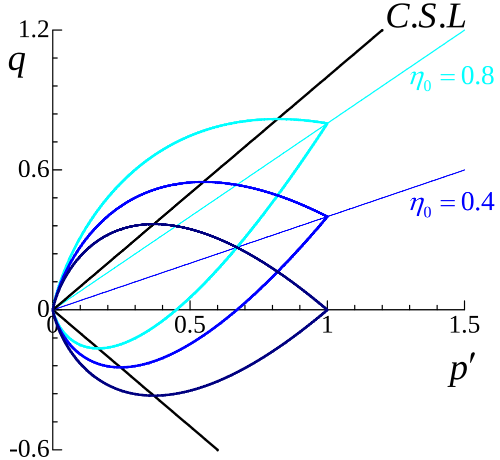
The area covered with highly compressive peat layer on alternation of soft clay layers and sand layers of 30 m thickness.

Soil / Water coupled FE analysis

The soil-water coupled FE code : DACSAR (Iizuka & Ohta, 1987)
(Deformation Analysis Considering Stress Anisotropy and Reorientation)



Sekiguchi-Ohta model
(Sekiguchi & Ohta, 1977)



Elasto-plastic model

$$f\left(\boldsymbol{\sigma}', \varepsilon_v^p\right) = MD \ln \frac{p'}{p'_0} + D\eta^* - \varepsilon_v^p = 0$$

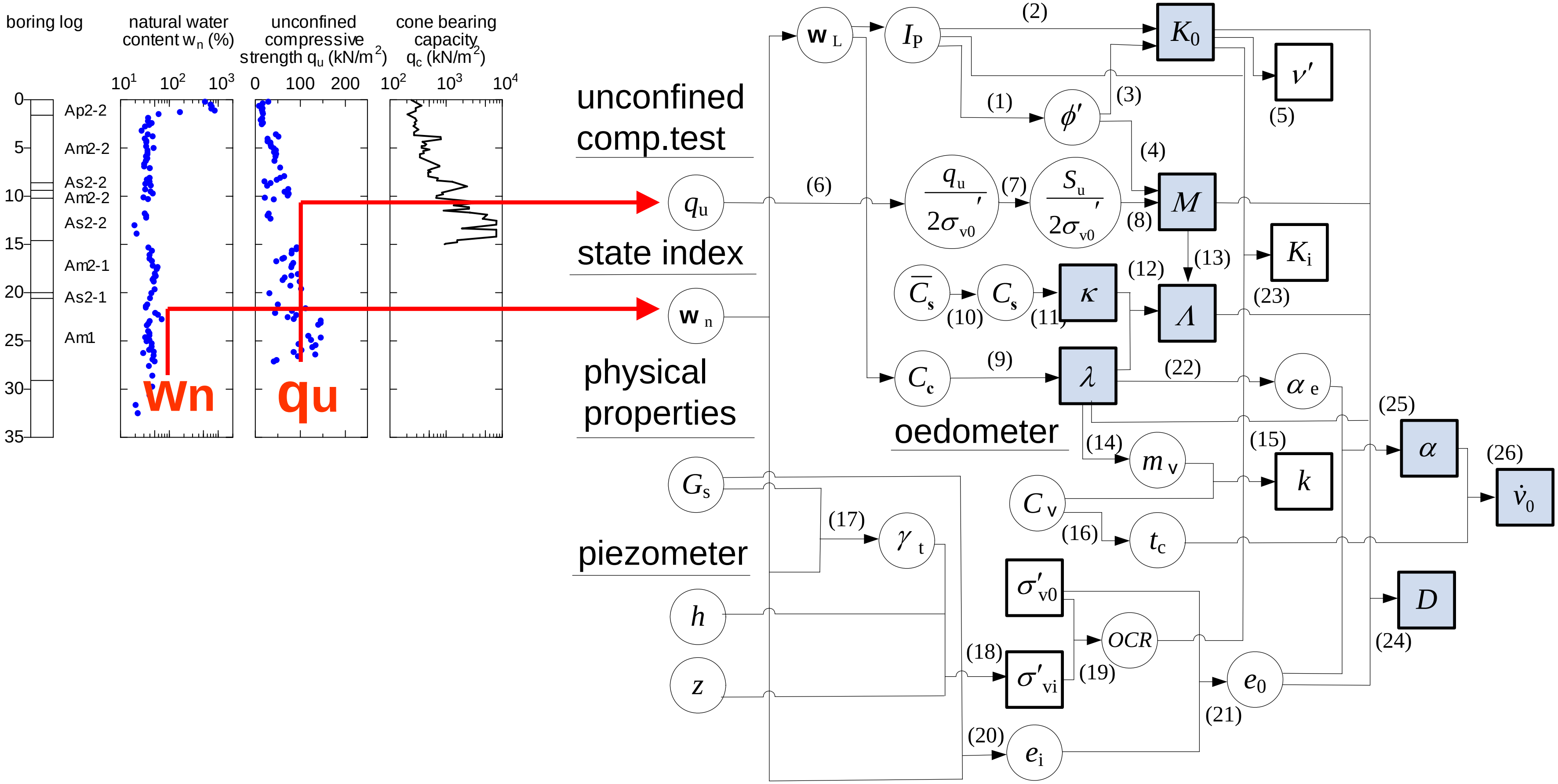
Elasto-visco-plastic model

$$F = \alpha \ln \left\{ 1 + \frac{\dot{v}_0 t}{\alpha} \exp\left(\frac{f\left(\boldsymbol{\sigma}'\right)}{\alpha} \right) \right\} - \varepsilon_v^{vp} = 0$$

$$f\left(\boldsymbol{\sigma}'\right) = MD \ln \frac{p'}{p'_0} + D\eta^*$$

Sekiguchi-Ohta model can describe the induced anisotropy, creep and relaxation characteristics of soils by 6-8 material parameters.

Input parameter determination

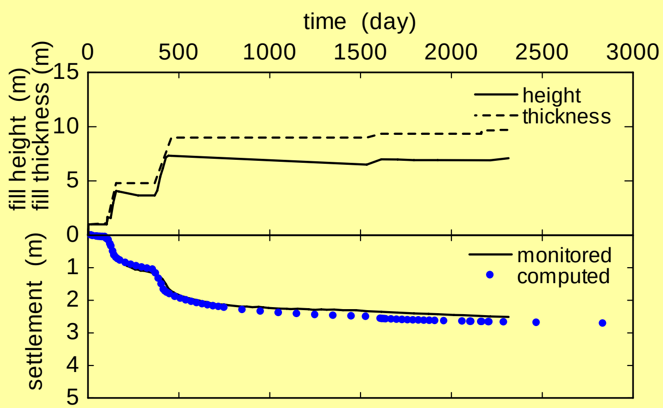


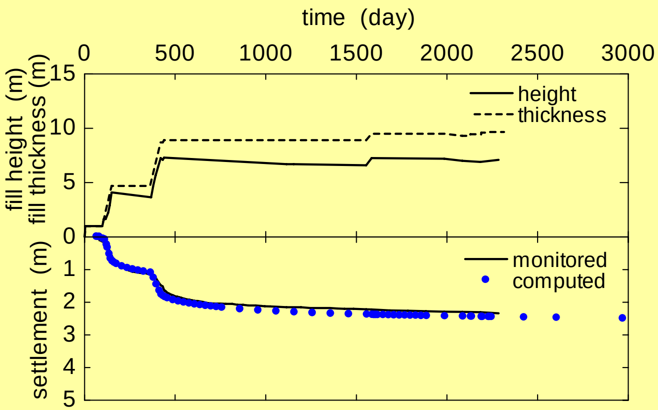
The procedure of input parameter determination follow the charts which is based on laboratory and field tests together with a set of correlations proposed by many research workers.

Computed results in Ebetsu Trial Embankment

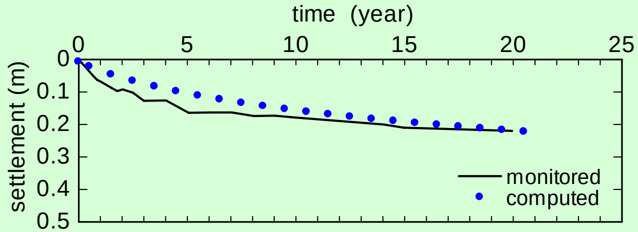
(a) Non-treated test fill **(b) Sand drain-treated test fill**

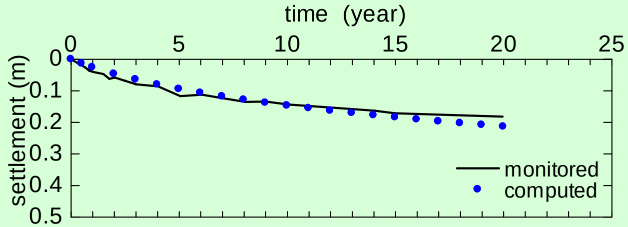
Settlement during construction





Settlement during operation

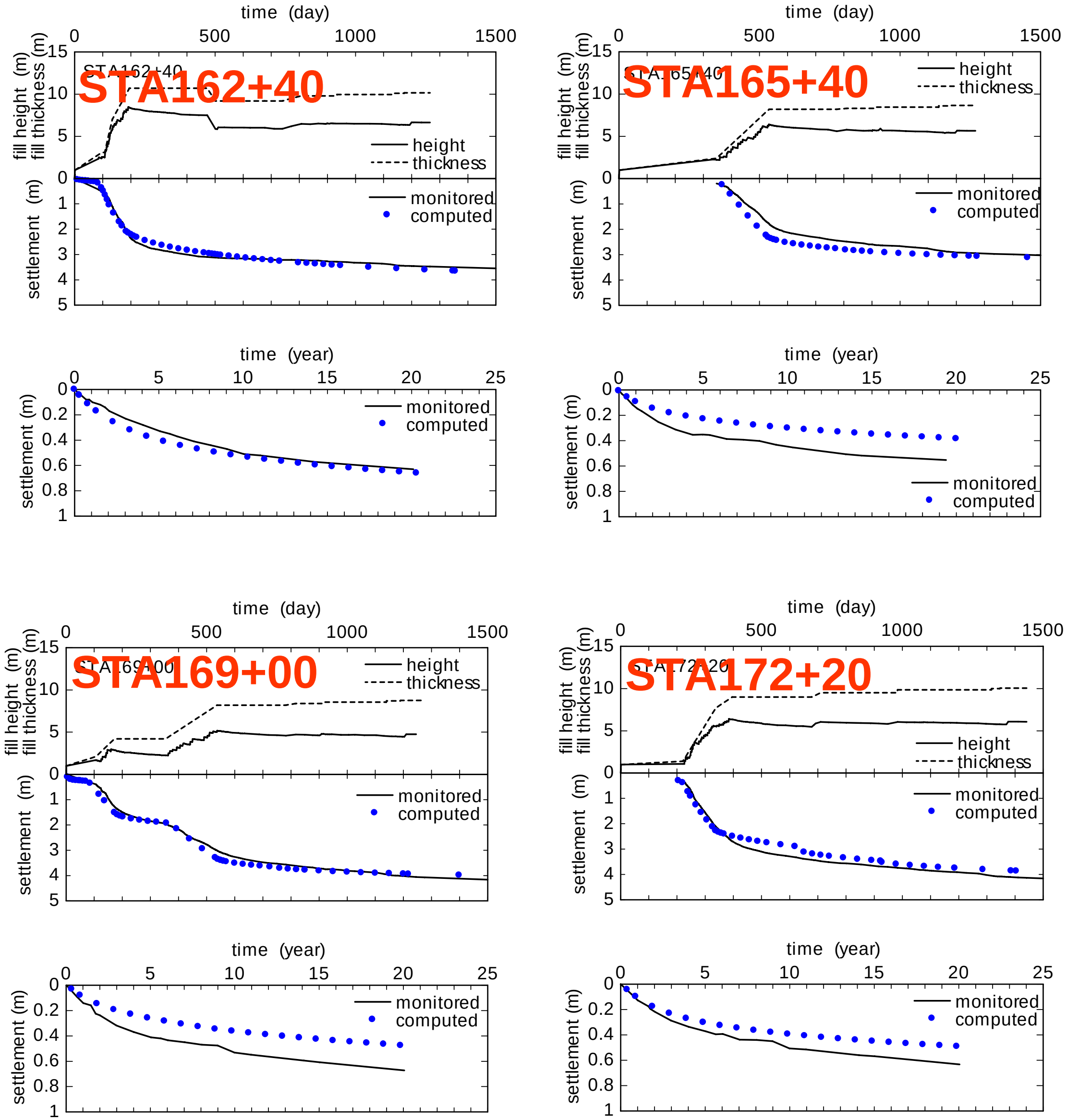




The computed long-term settlements for past 20 years are found to be with the sufficient predictive accuracy.

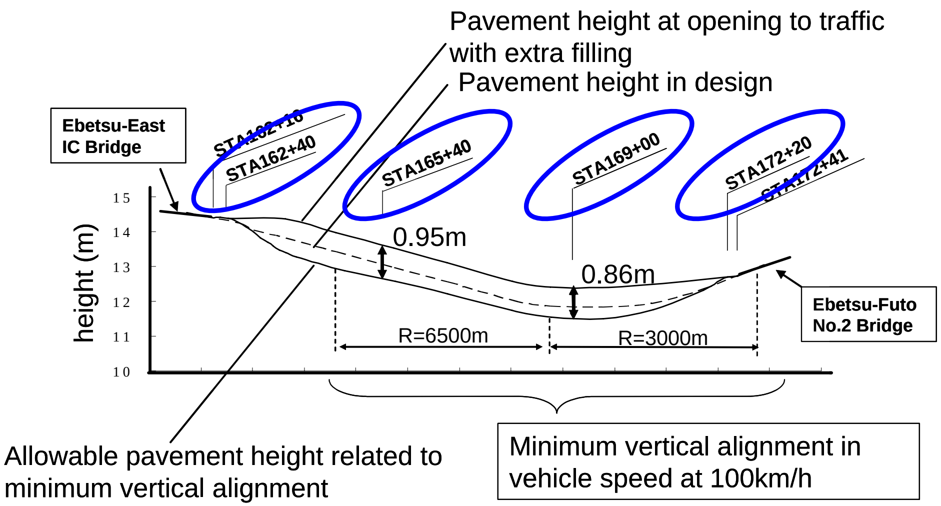
Case study of life-cycle planning supported by soil / water coupled analysis

Computed results in Ebetsu-Futo East works

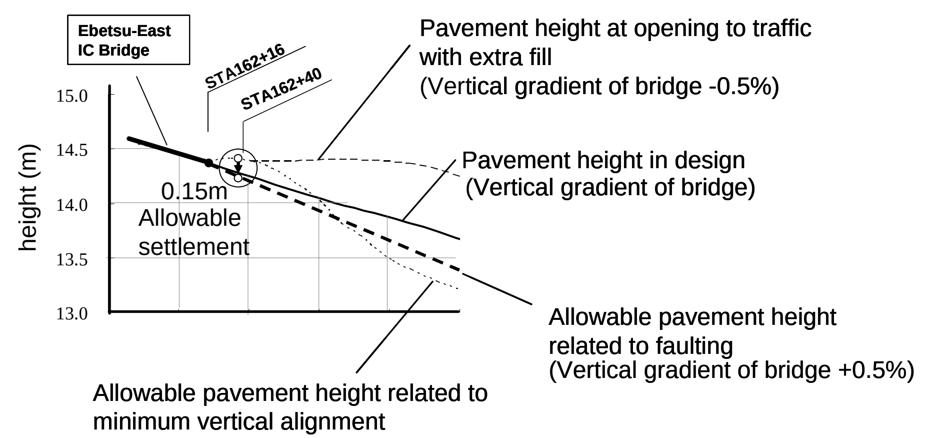


Maintenance criteria to service level

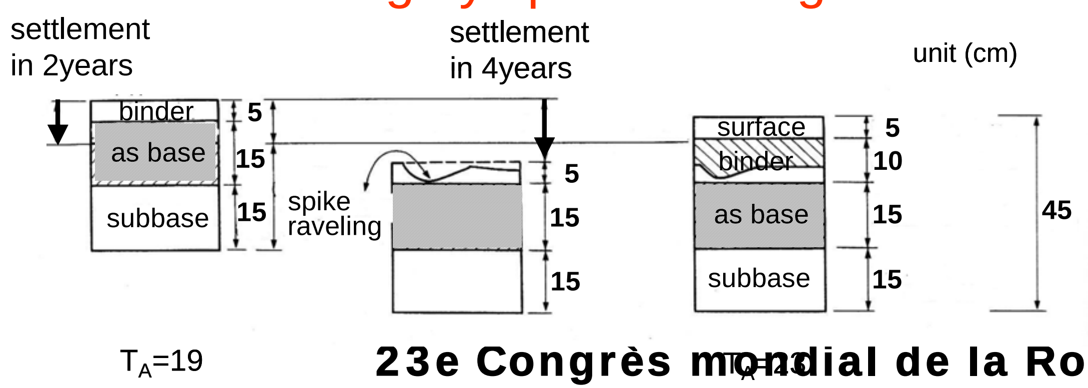
1) Settlement as indicator related to road vertical alignment



2) Settlement as indicator related to faulting

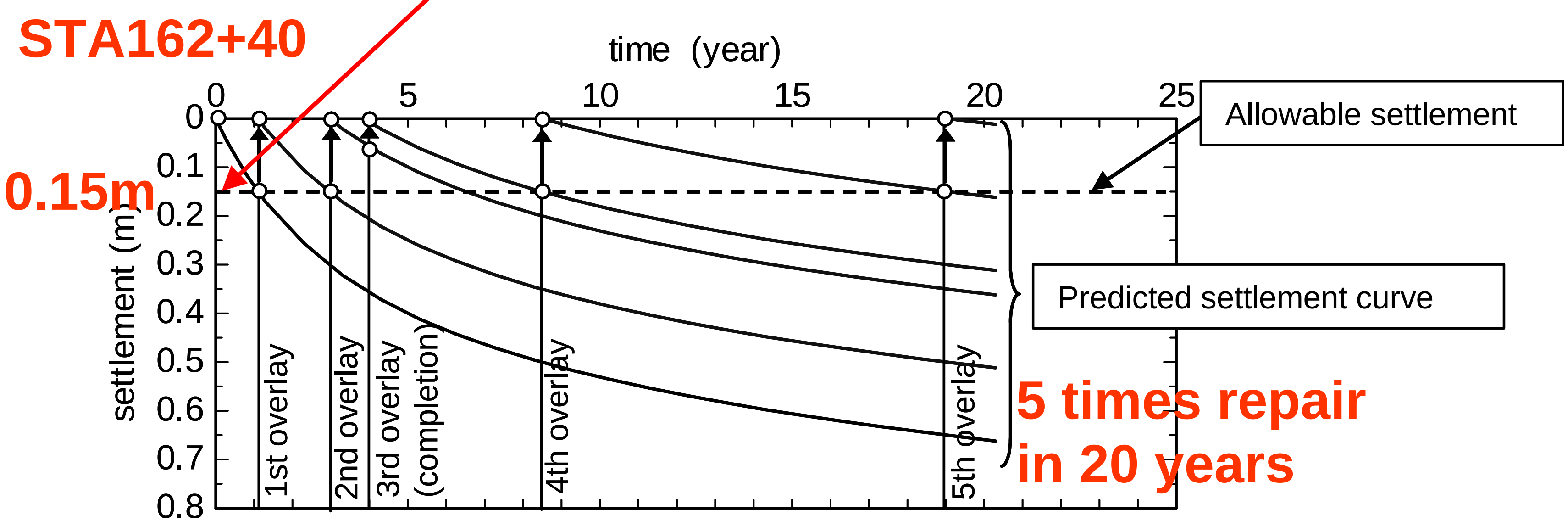


3) Pavement structure as countermeasure which took settlement and rutting by spike raveling



Performance modeling of Asphalt Overlay

STA	162+40	165+40	169+00	172+20
Performance related indicators	faulting	minimum vertical alignment	minimum vertical alignment	faulting
Indicators of highway embankment	allowable settlement			
Maintenance criteria	settlement >0.15m	settlement >0.95m	settlement >0.86m	settlement >0.16m



Predicted and actual life-cycle of asphalt pavement for 20years

STA	Predicted		Actual	
	Times of overlay	Timing of overlay (year)	Times of overlay	Timing of overlay (year)
162+40	5	1st,3rd,4th,8th,19th	5	1st,2nd,4th,6th,9th
165+40	1	4th	1	6th
169+00	1	4th	1	6th
172+20	4	1st,3rd,4th,15th	6	1st,2nd,3rd,4th,6th,11th

Life-cycle cost

Discount rate	(a) Predicted LCC (yen)	(b) Actual LCC (yen)	(a)/(b) (%)
3%	129,000,000	140,000,000	92.1
5%	118,000,000	126,000,000	93.6
7%	109,000,000	113,000,000	96.4
9%	101,000,000	102,000,000	99.0

Life-cycle cost based on this analysis successfully agrees with actual one.

Thank you for your kind attention