8, June, 2020
iGrip Webinar

Development of Geosynthetics Reinforced-soil Structure for Japanese high-speed bullet train “Shinkansen”

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東京大学 THE UNIVERSITY OF TOKYO

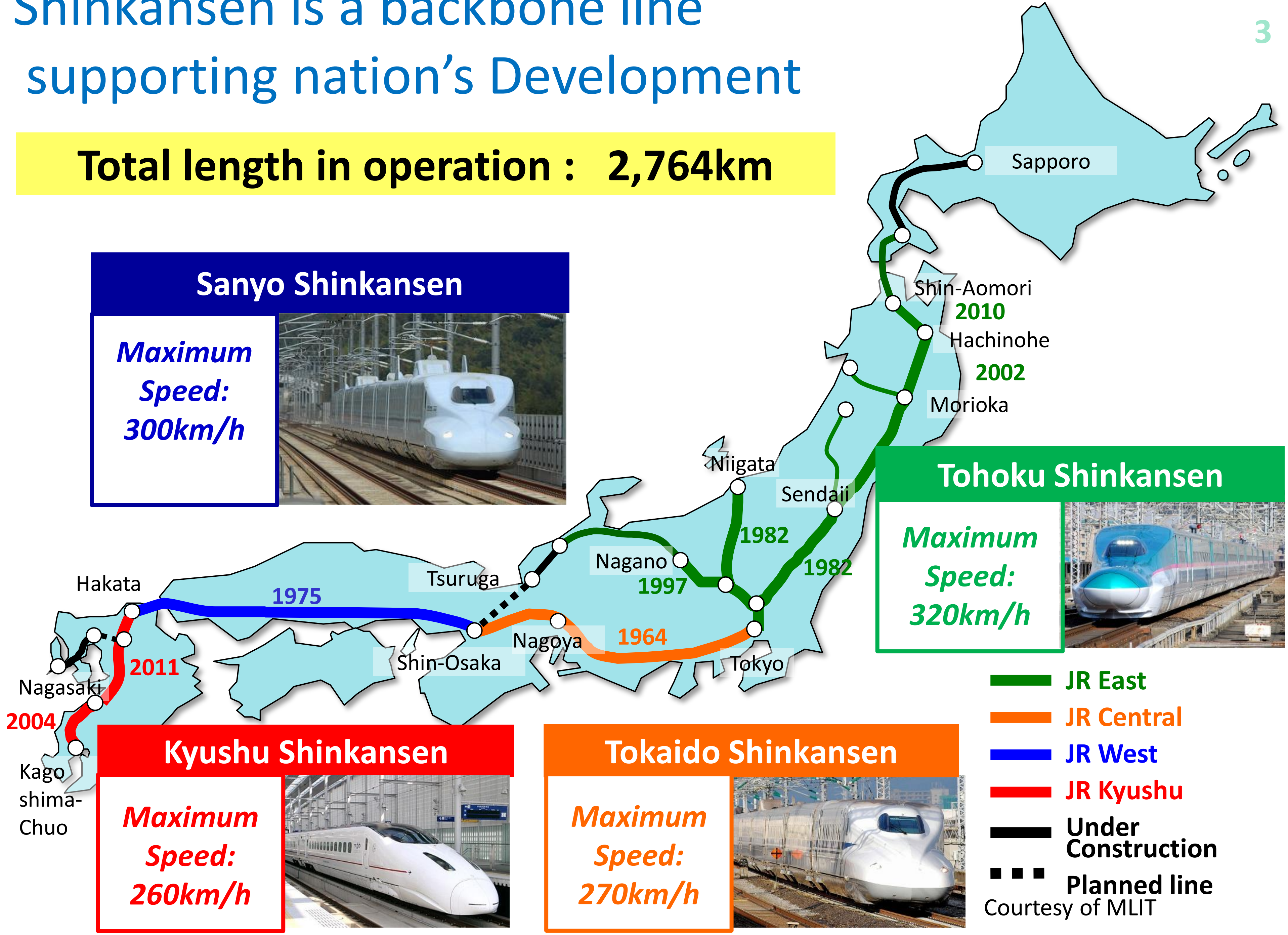
Railway Technical Research Institute

RRR スリーアール工法協会

Contents

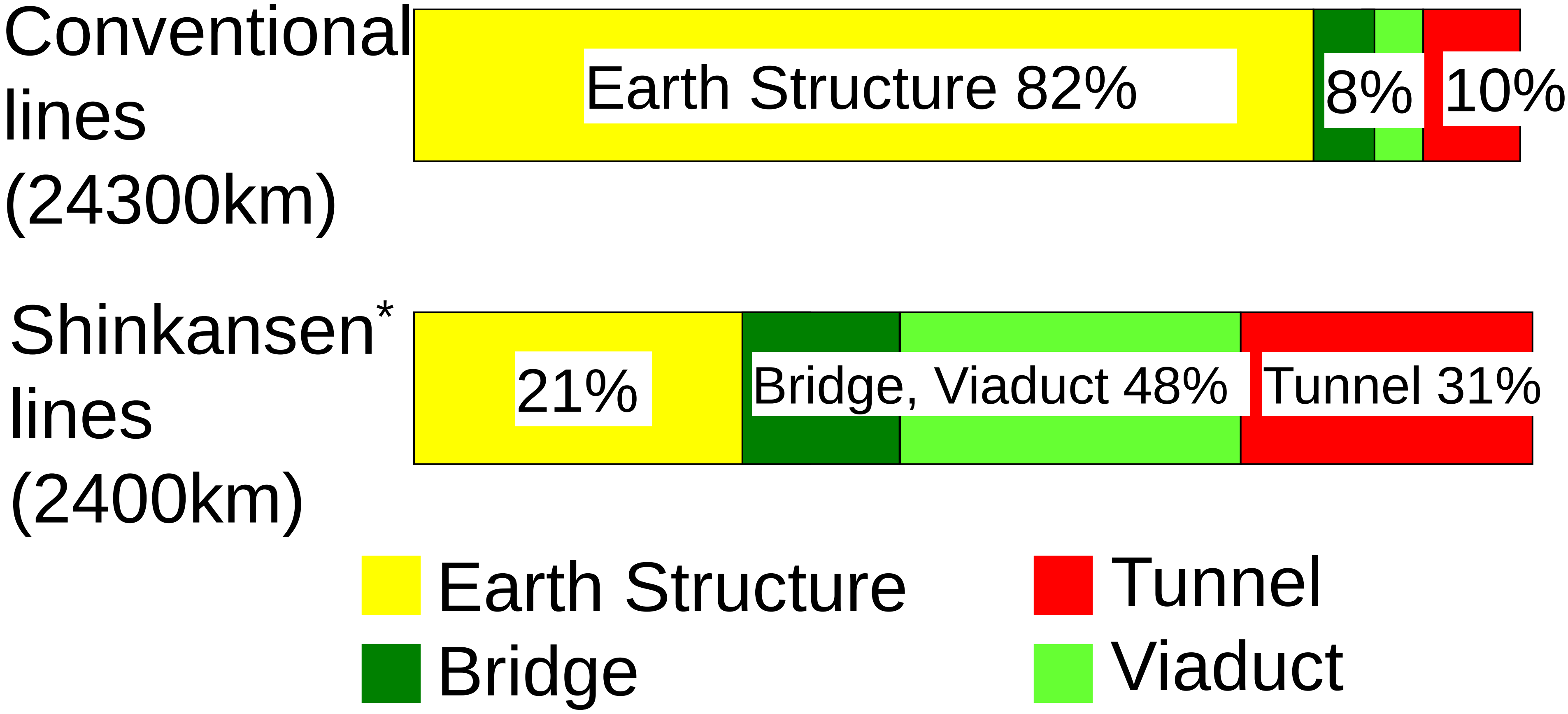
Shinkansen is a backbone line supporting nation's Development

Total length in operation : 2,764km



Courtesy of MLIT

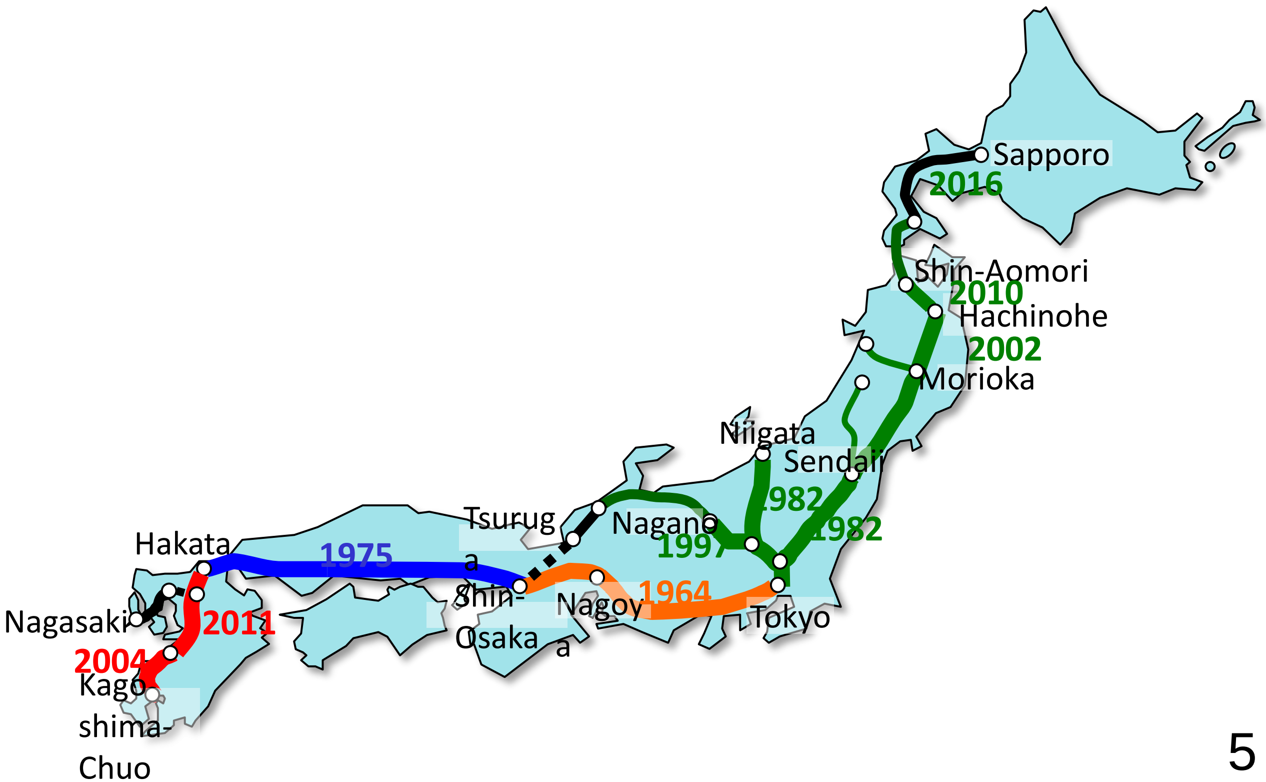
Type of Structure and Composition of Japanese Railway



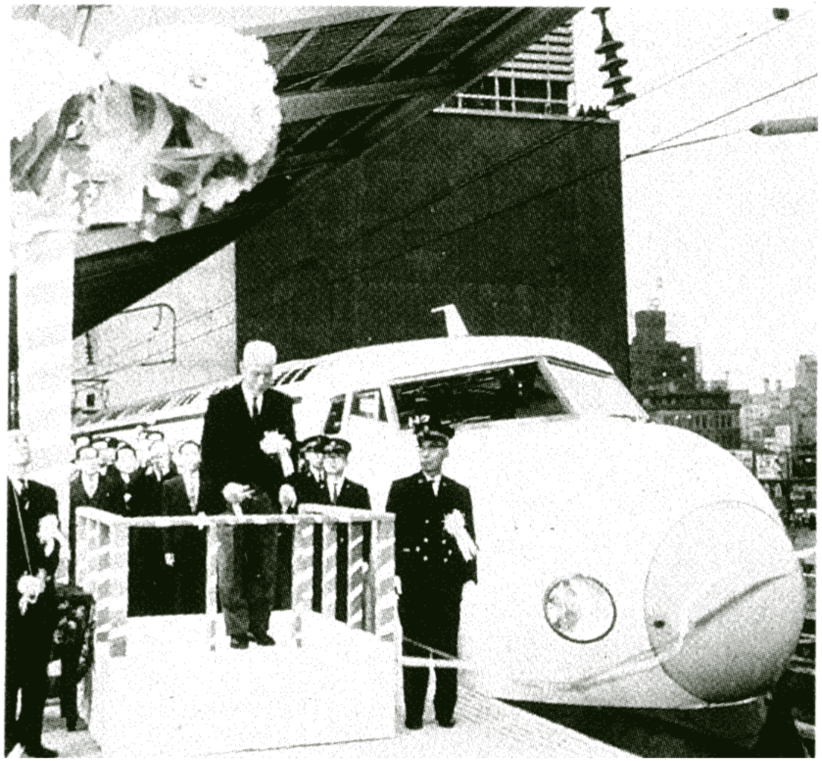
*Shinkansen : High speed bullet train in Japan

Track Type of Shinkansen

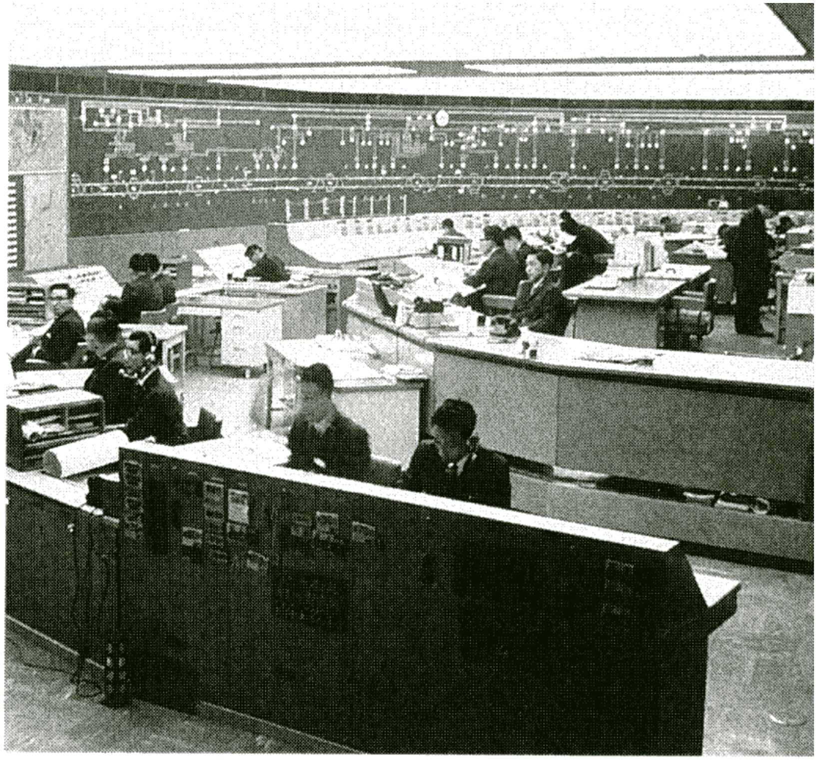
- Tokaido Shinkansen (1964)
  - Ballasted track on embankment
    - Bearing capacity of embankment was not very high.
    - (using clay, low compaction control etc)
    - Settlement of ballasted track became very large after opening.



Tokaido Shinkansen (1964.10.1)



Opening of Shinkansen



Shinkansen CTC Center

Service section: between Tokyo and Shin-osaka (Distance: 515.4 km)

Time: 3 hours 10 minutes

Maximum speed: 210 km/hr

Tokyo Olympic (1964.10.10 - 10.24)

Much infrastructure (Shinkansen, highway, Metropolitan Expressway) were constructed just before the Tokyo Olympic.

→ Construction period was too short !

<Metropolitan Expressway, Tokyo>

Maintenance cost of Tokai-do Shinkansen just after the opening (1965/4-1966/3)

Labor type	Total cost (1 year)	
	Japanese Million Yen	US Million $
Spot surfacing/ leveling of track	10,690	106.9
Compaction of ballast	1,350	13.5
Lining of track	3,210	32.1
Total	15,250	152.5

* Present values are estimated from consumer price index(CPI)

*1US$=100 JPY

So high!

It is better to consider the Life Cycle Cost (not only initial cost!!)

→ Quality control of earth structure (good material, sufficient compaction)

Application of slab track

Iwao Nisugi: Story of the maintenance work for Shinkansen (新幹線保線ものがたり）, Sankaido, 2006 (in Japanese)

Track Type of Japanese Railway

- Tokaido Shinkansen (1964)

  Ballasted track on embankment

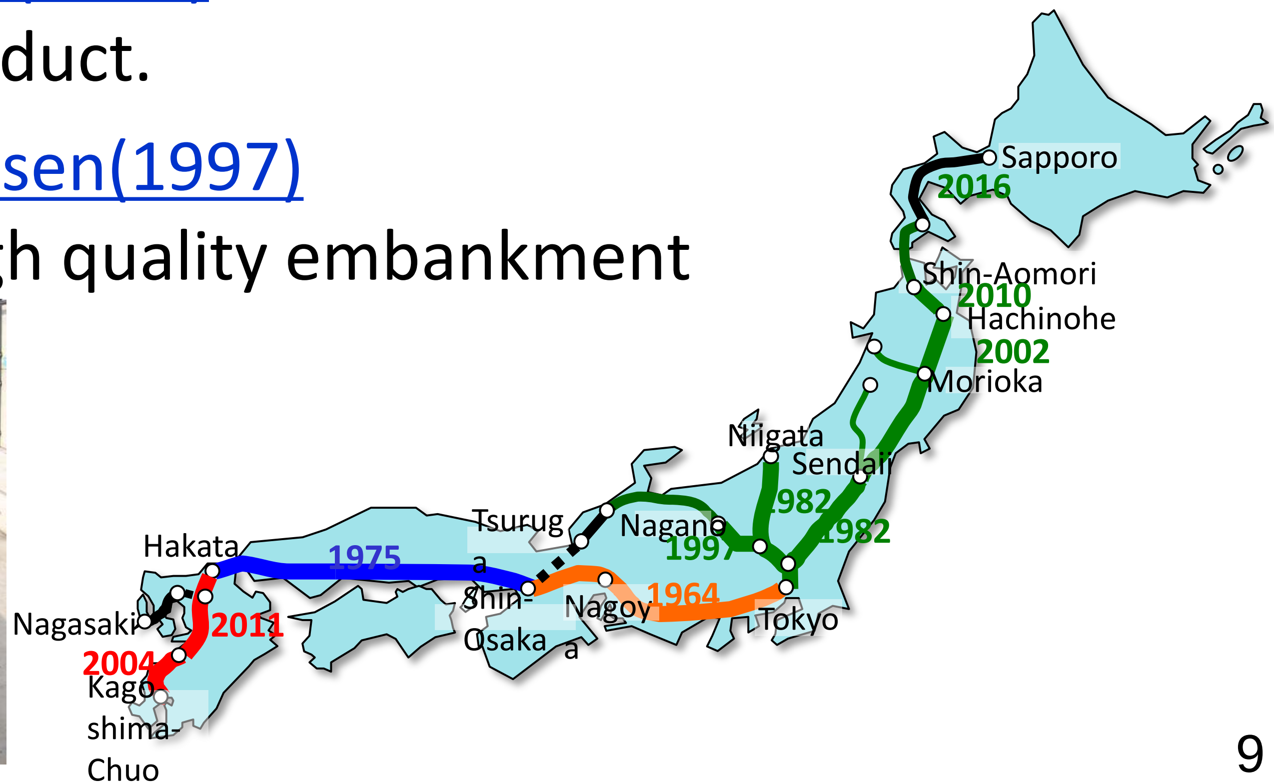
  Bearing capacity of embankment was not very high.
  (using clay, low compaction control etc)
  Settlement of ballasted track became very large after opening.

- Sanyo Shinkansen(1975)

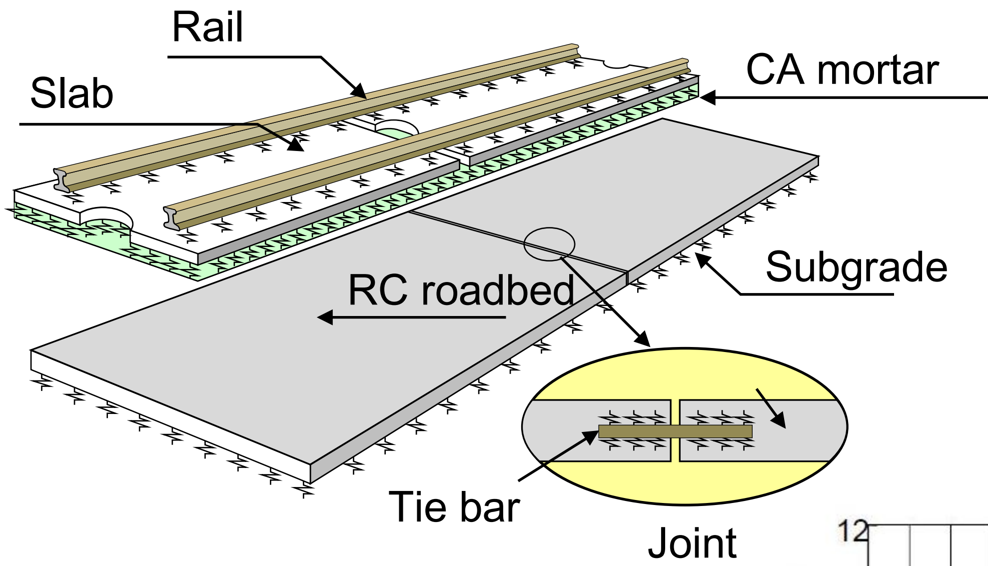
  Slab track on viaduct.

- Hokuriku Shinkansen(1997)

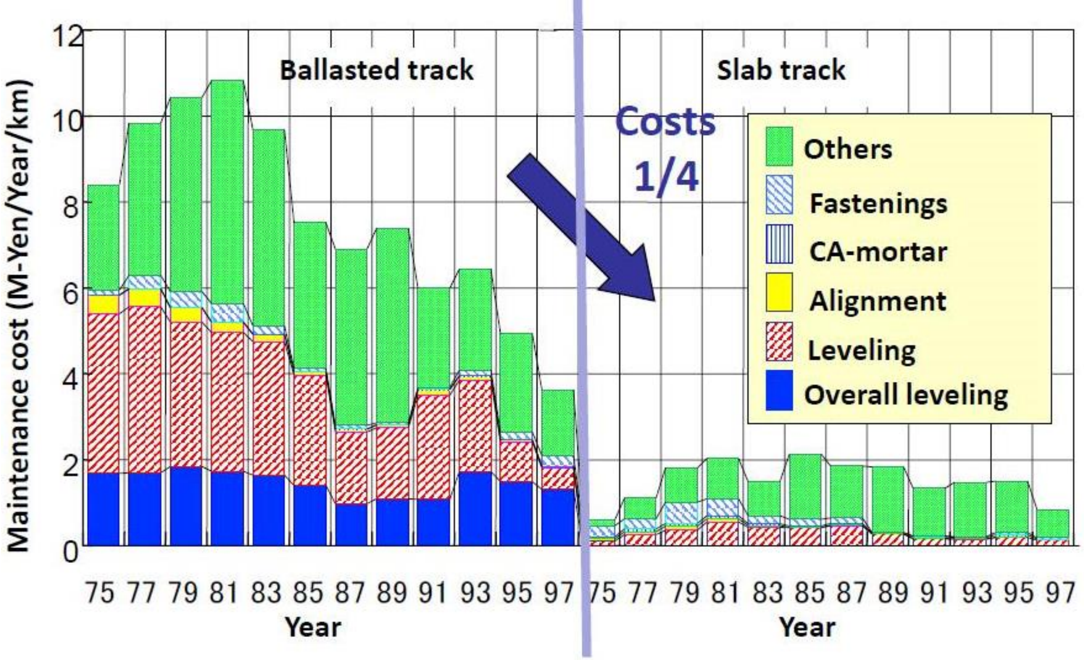
  Slab track on high quality embankment



Continuous RC slab track



- Relatively high construction cost
- Large reduction of maintenance cost
- Very small allowable settlement of subsoil



Ando, K., Sunaga, M., Aoki, H. & Haga, O.:Development of Slab Tracks for Hokuriku Shinkansen Line, QR of RTRI, Vol.42, No.1 Mar, 2001

Technical issues around 1990

How can we construct earth structure,
which does not require,

- Much maintenance work ?
- Much land for construction ? → Retaining structure

<Slab track on earth structure, Shinkansen>

Allowable settlement for slab track

- 10mm/10years (Serviceability)
- Less than 5cm(Level 1 EQ)
  Less than 15cm(Level 2 EQ)
  (Restorability)

Terre-Armée method

Terre-Armée method was introduced to Japan around 1967

Terre-Armée was applied around 1970's for Japanese Railway, but there were some technical problems.

(This problem have already been solved)

Corrosion of metal strip caused by electric current

There is no design method against large earthquake

➡ Only a few kilometers was used for Japanese railway

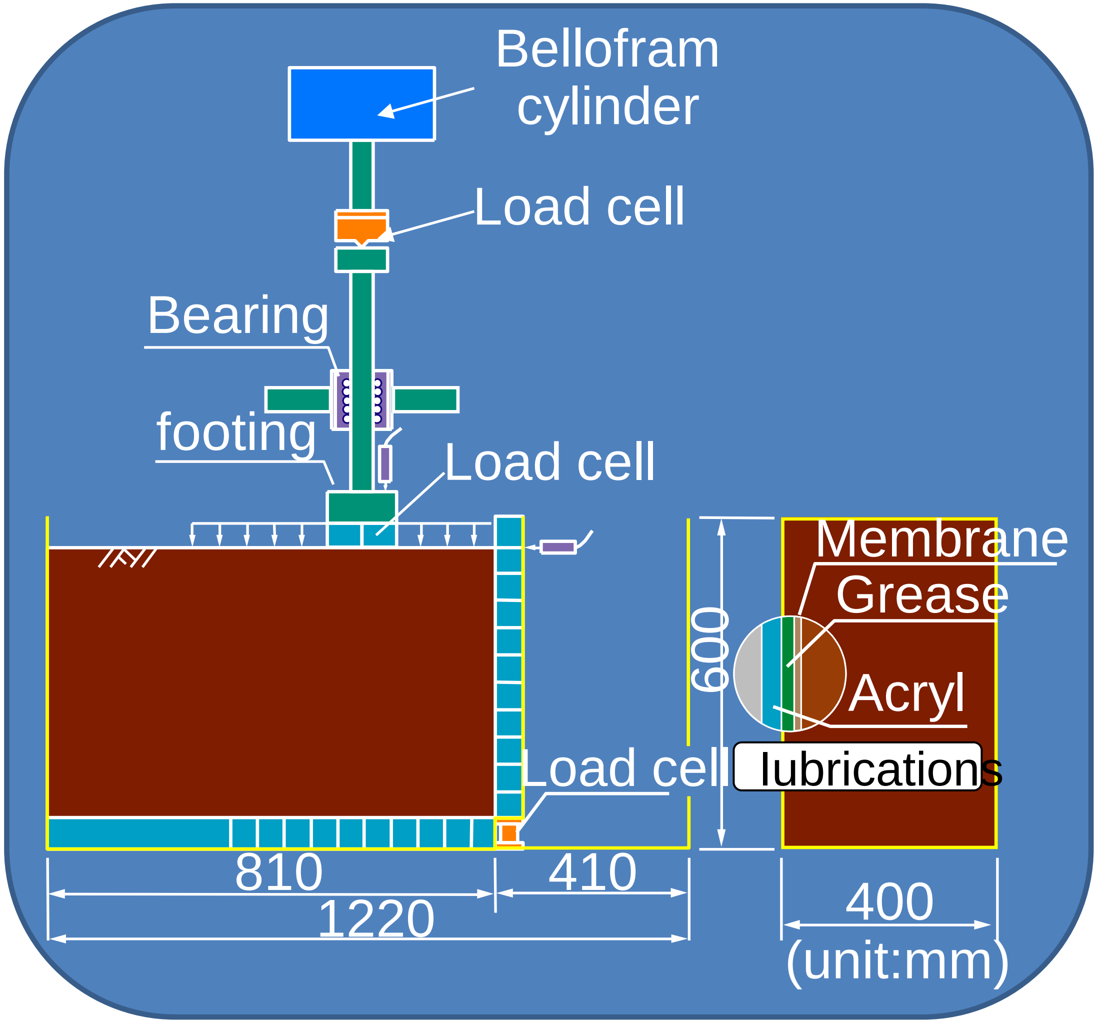
Failure of Terre-Armée method

➡ Japan Railway tried to develop other reinforced-soil structure using Geosynthetics from 1988
（Collaborative research between Univ. of Tokyo and Railway Technical Research Institute, Japan)

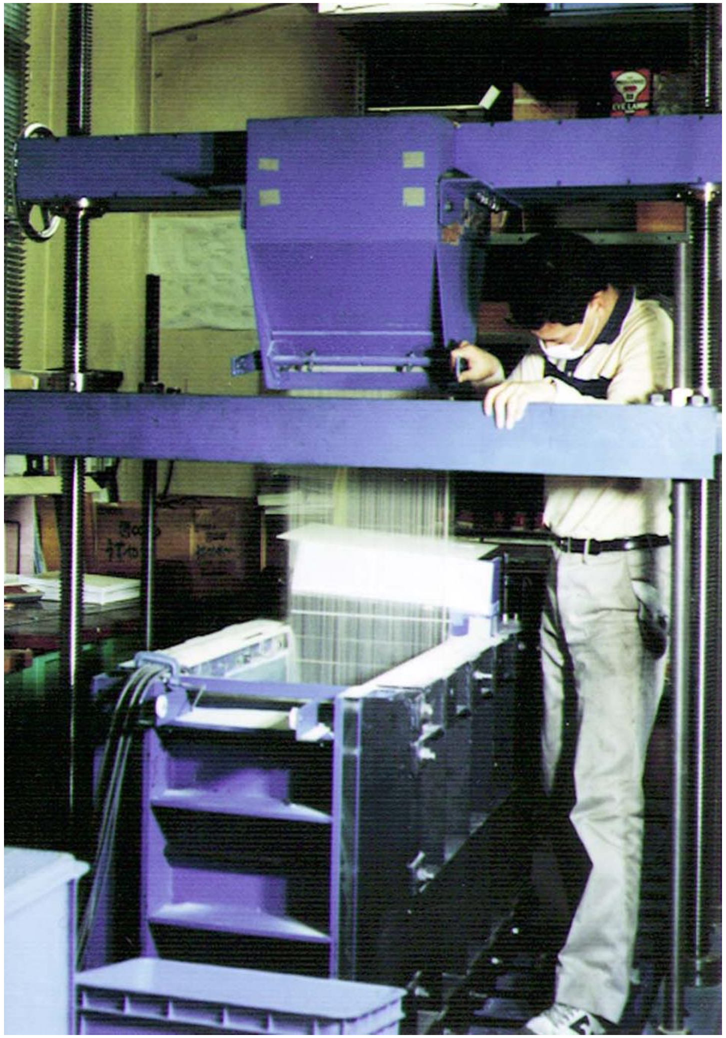
Contents

1. Background (Technical issues around 1990)
2. Development of GRS retaining wall (1990's)
3. What are functions of facing?
4. Advantages of GRS RWs
5. Application of GRS to bridge abutment (2000's - 2010's)
6. Overview of recent application
7. Other examples of GRS structure

Laboratory Test @University of Tokyo

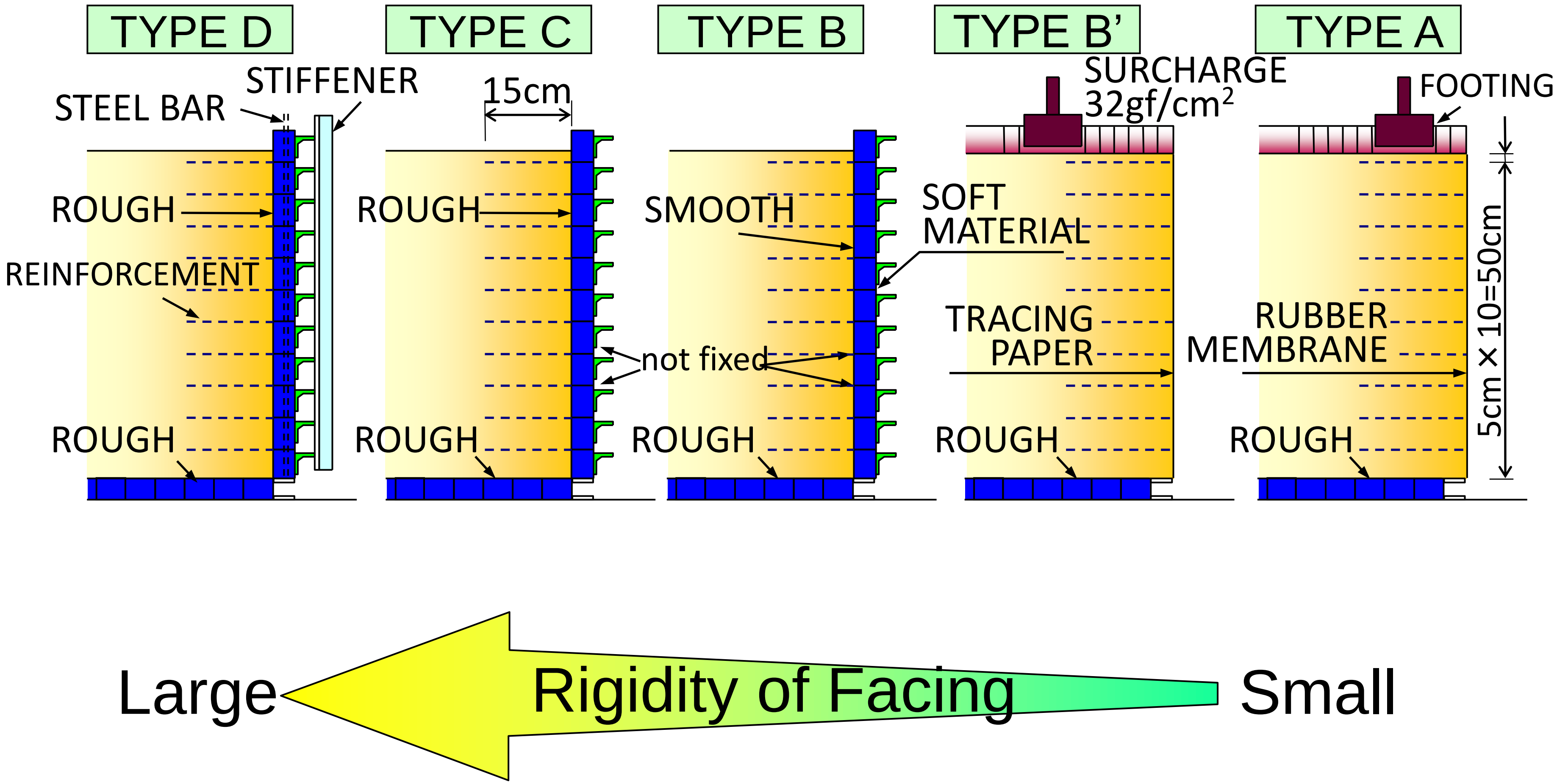


Loading set-up

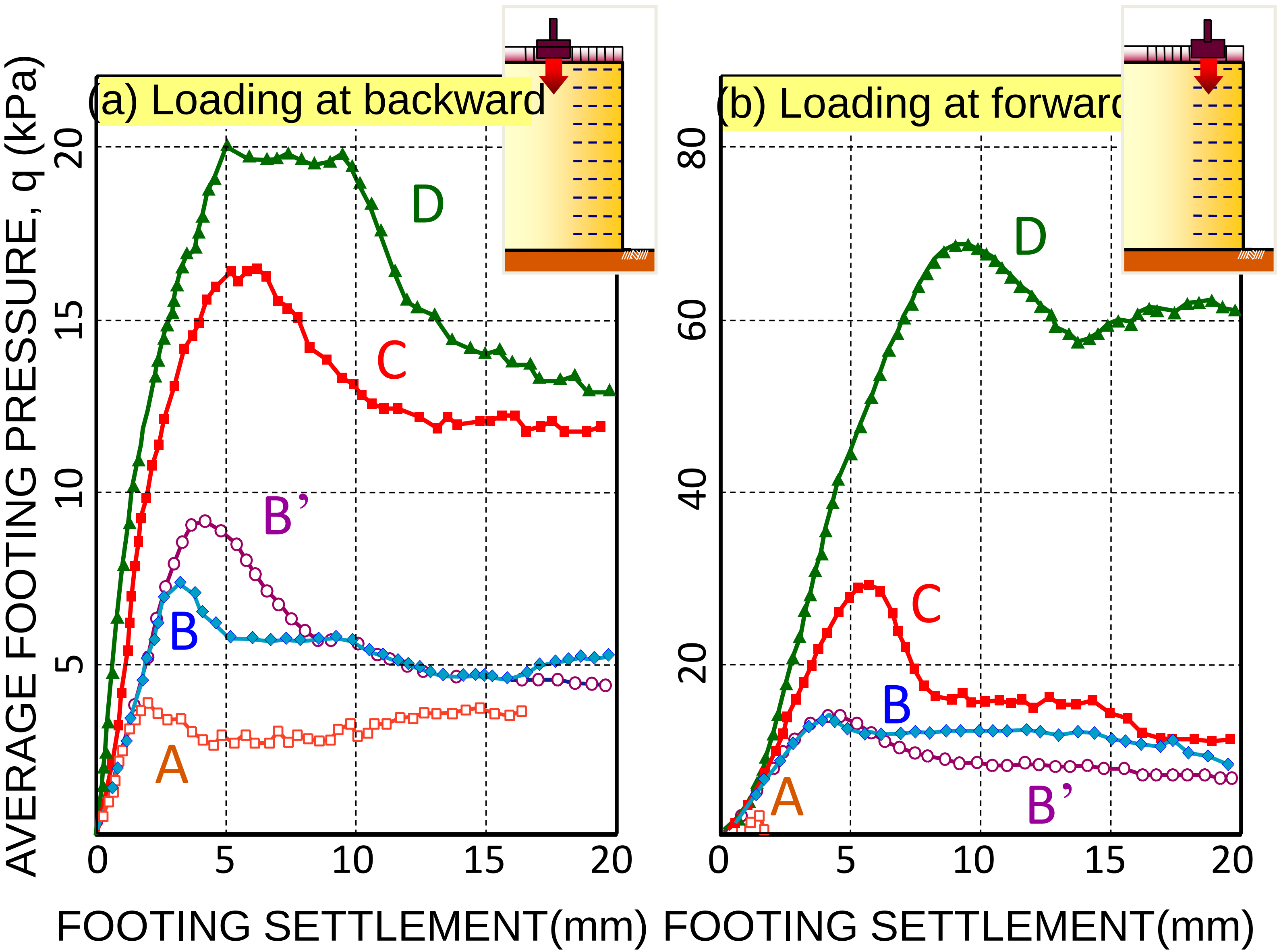


Molding specimen

Types of Facing



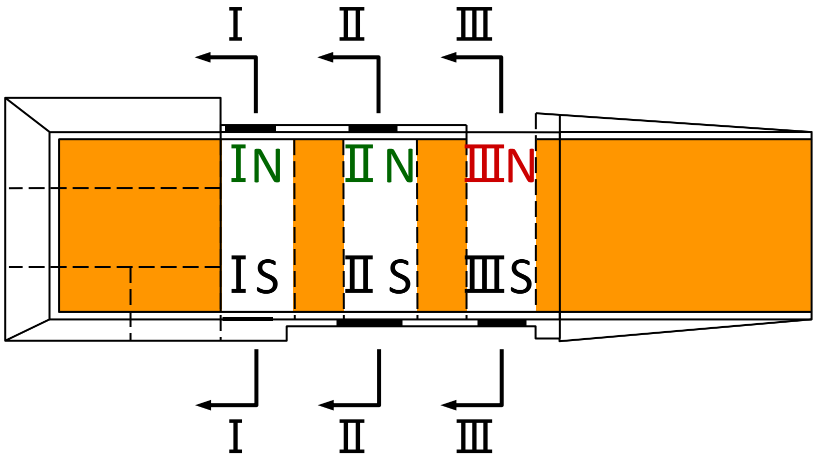
Load-Bearing Behaviors



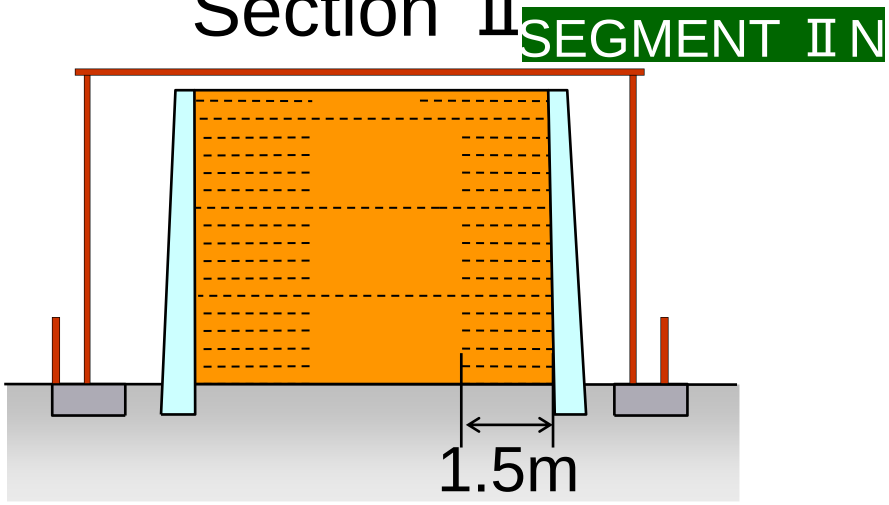
Construction of Full-Scale Test Embankment

Three Tested Sections of Embankment

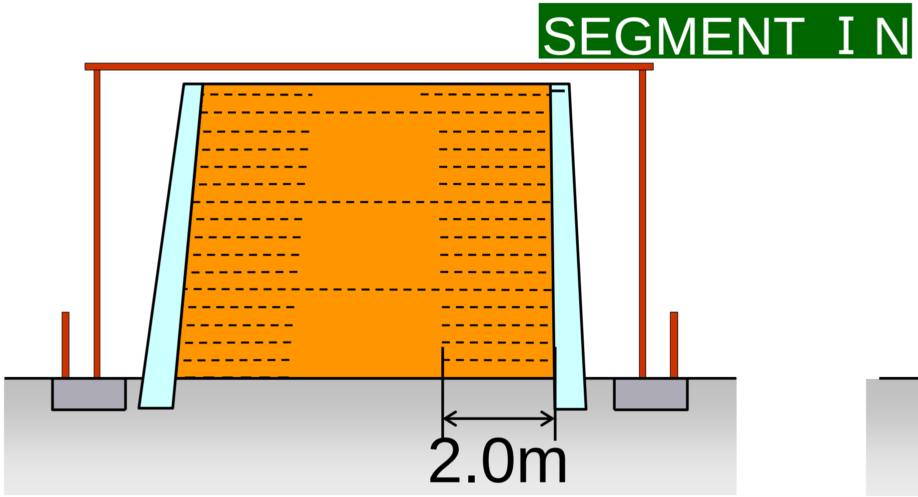
Plan



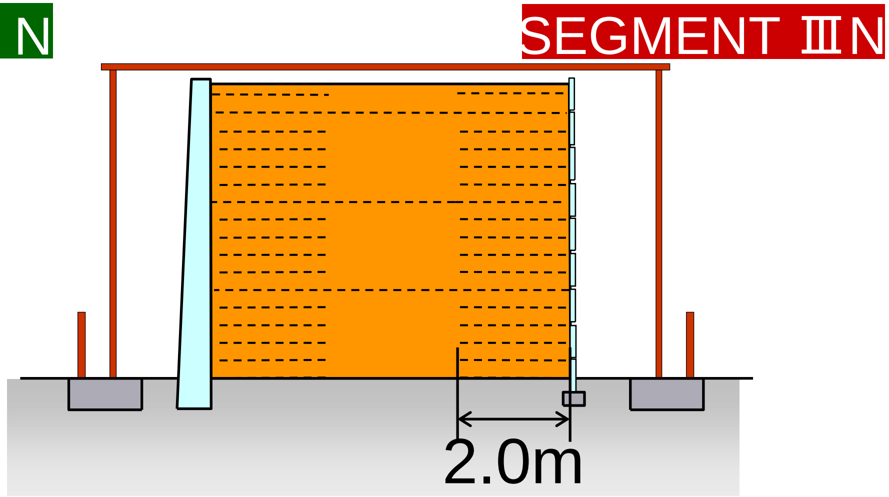
Section Ⅱ



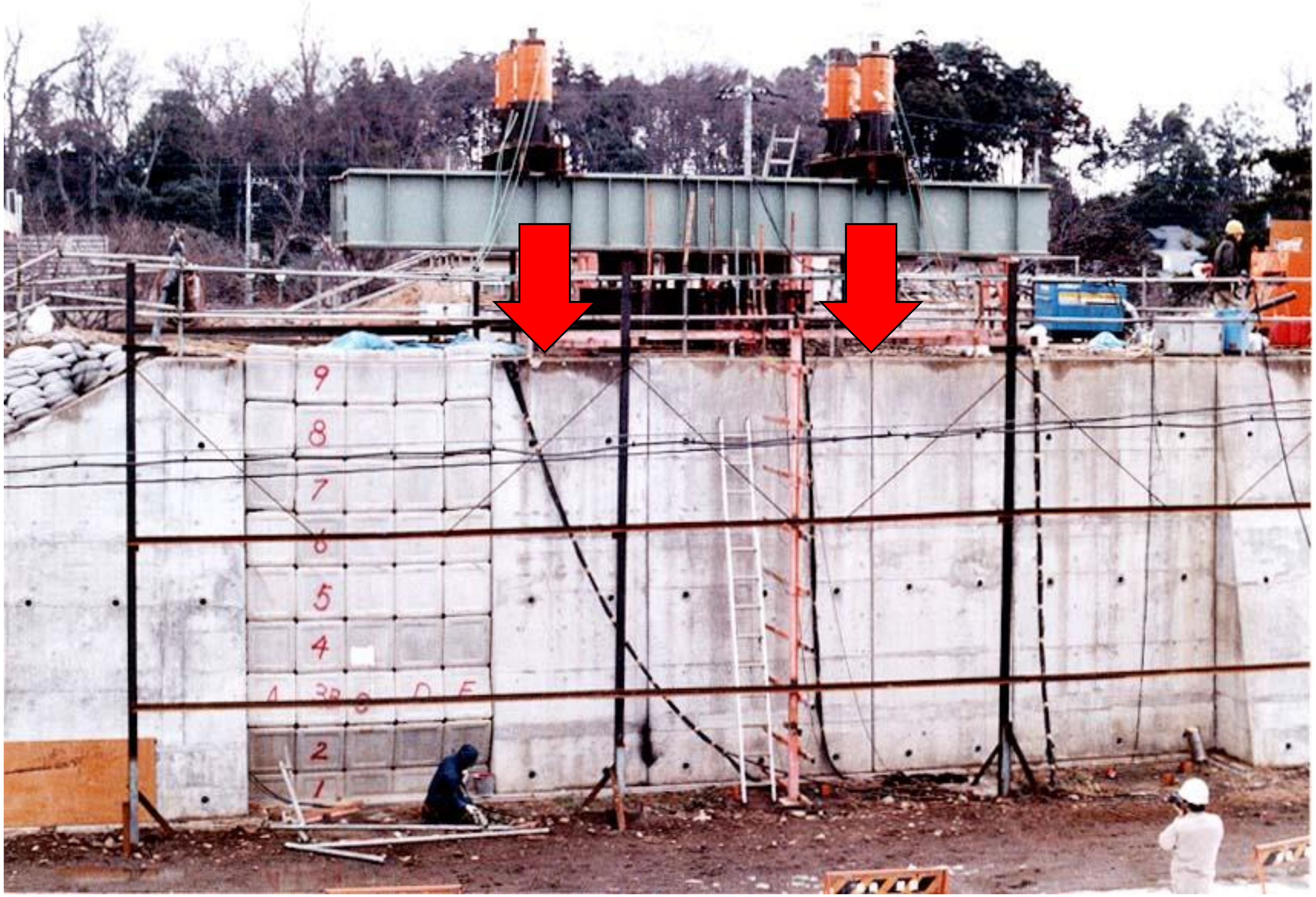
Section Ⅰ



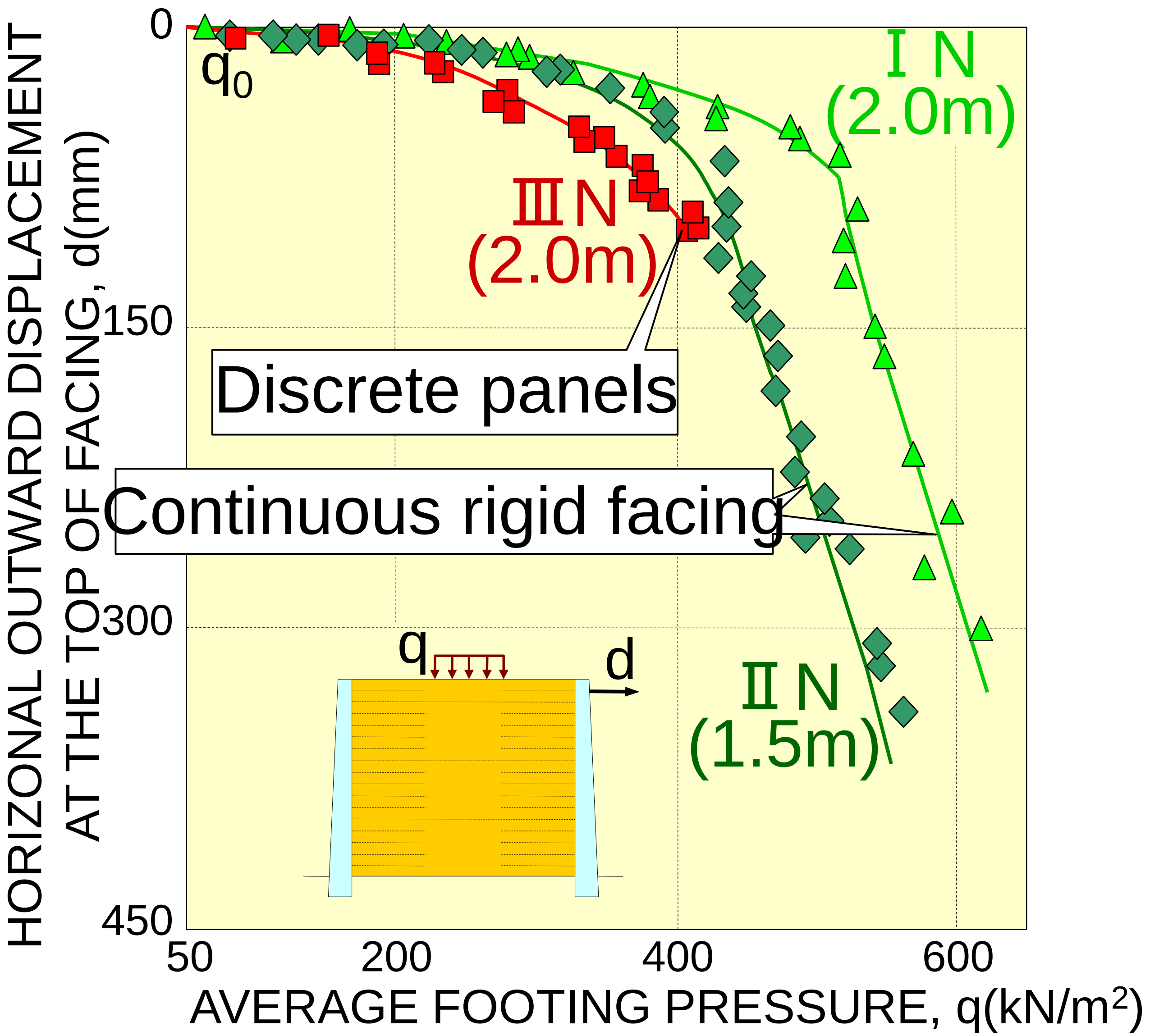
Section Ⅲ



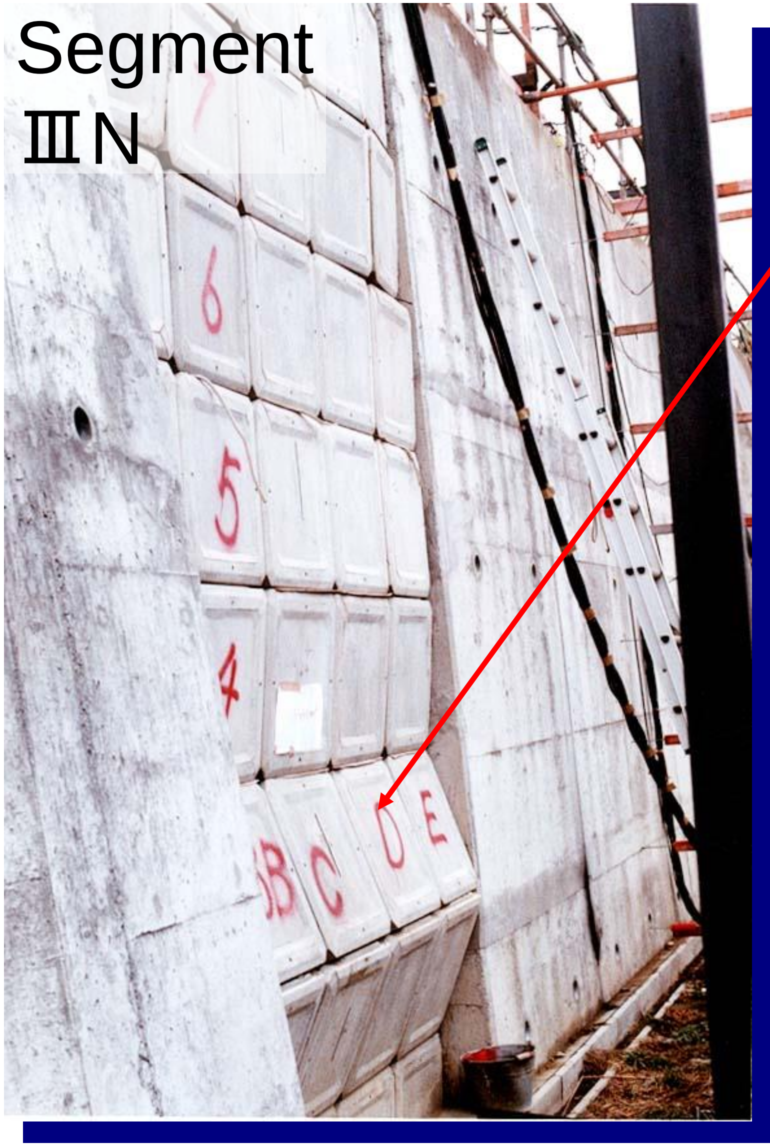
Loading Test Set-up



Load-Displacement Relations

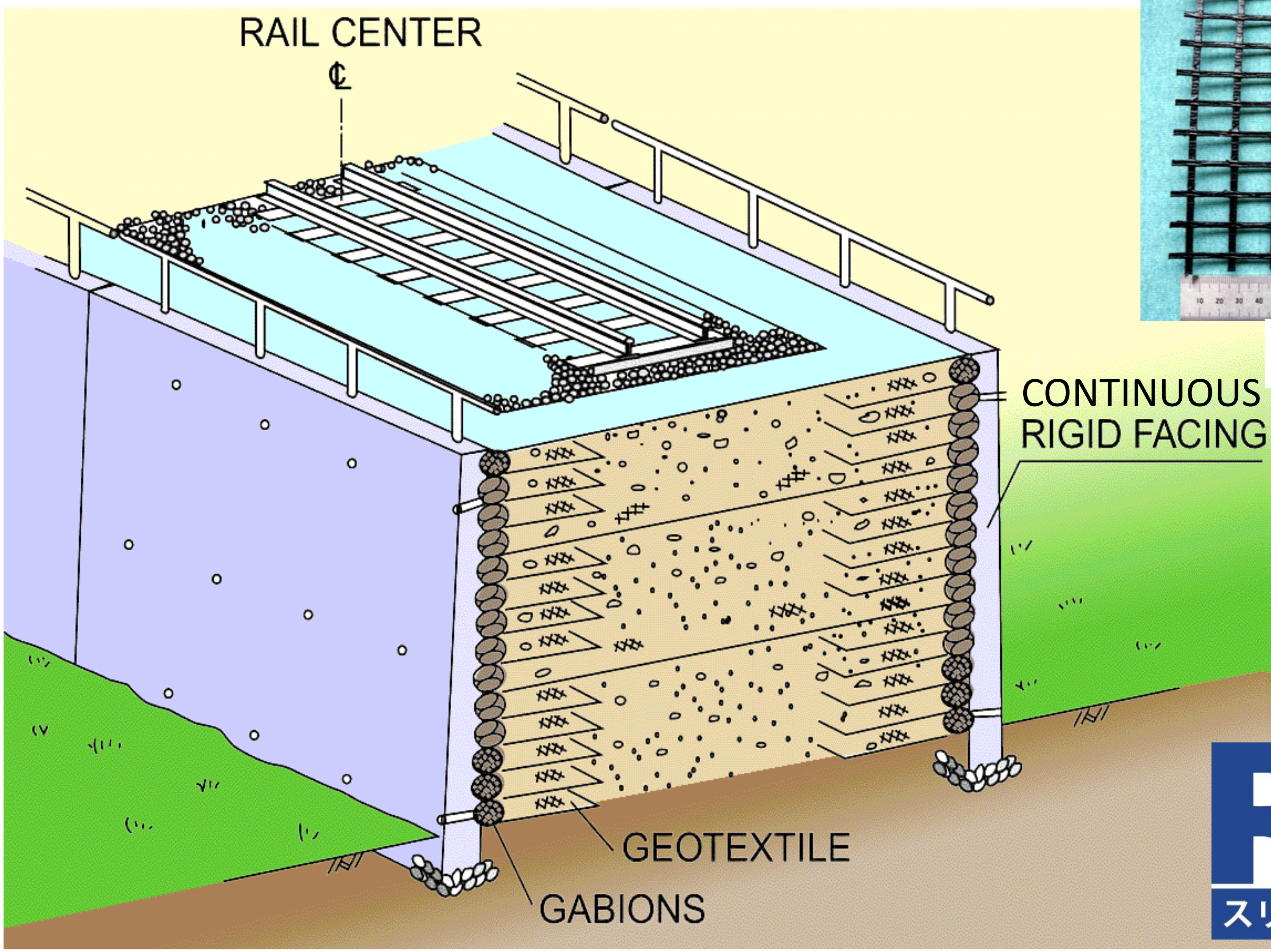


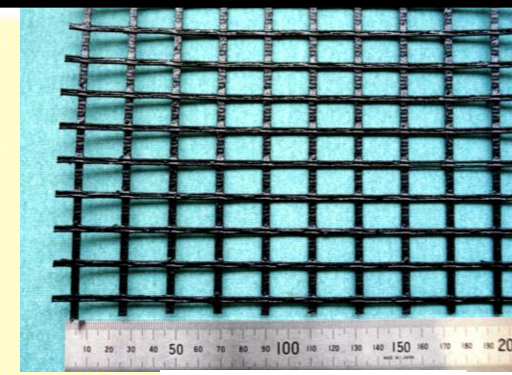
Deformation after Loading Test



- The wall became more stable as the rigidity of facing increased.
- Long term stability was also confirmed from this full scale test embankments.

Development of GRS retaining wall





Geotextile

RRR
スリーアール工法協会

Reinforced Railroad with Rigid Facing-Method

Pamphlet: https://drive.google.com/file/d/1Z1W9b2RA5xGmlVeYJK-ty1A3BloPgYmY/view?usp=sharing

RRR Association: http://www.rrr-sys.gr.jp/ (English site is coming soon)

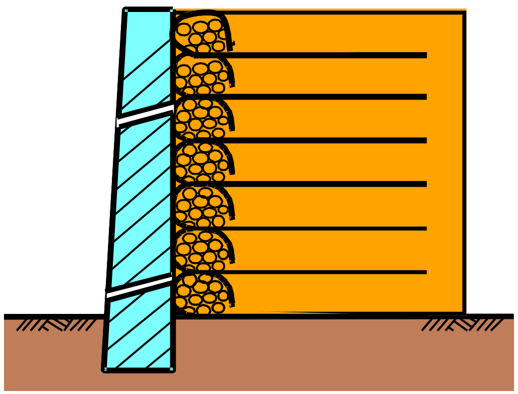
Contents

There main elements of Reinforced-soil wall

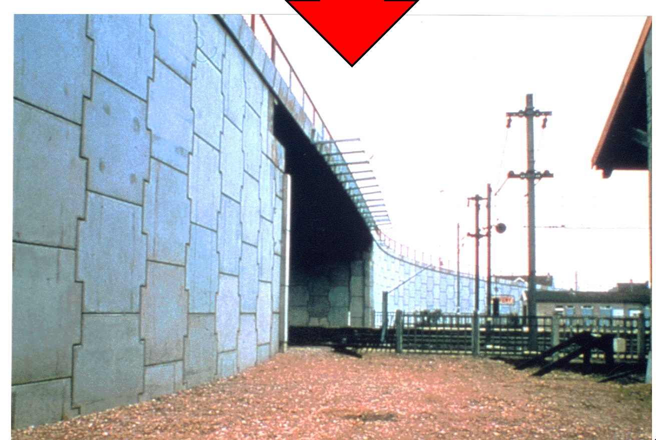
Soil, reinforcement, and facing

Functions of Facing?

GRS-retaining wall
(RRR-method)



Terre Armée



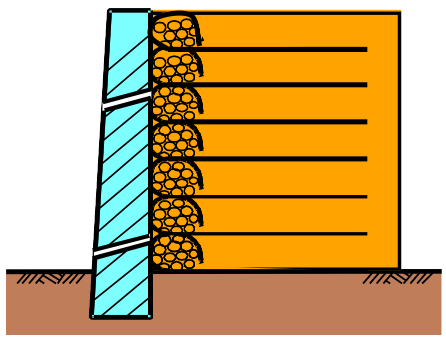
What are the functions of facing?? Question

1) Earth pressure does not act on the facing. This is because the reinforcement (geosynthetics or metal strips) reduces the earth pressure

2) Facing is used only for covering the backfill, preventing from local erosion, local failure and ultraviolet wave

True or false?

GRS retaining wall



Terre Armée

What are the functions of facing??

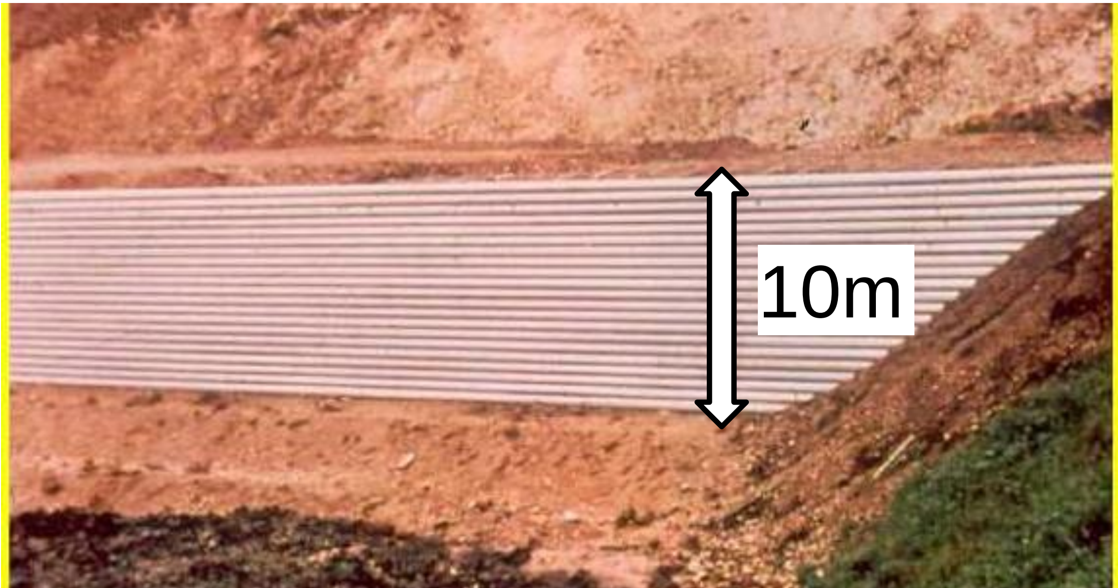
Henri Vidal (Inventeur de la Terre Armée)

If we could put in place one layer of grains in contact with one layer of reinforcement, then one layer of grains, and so on, we should not have any need for a facing.
The facing retains the grains located near the exterior between two layers of reinforcement; it corresponds to a very local problem, and is not important.

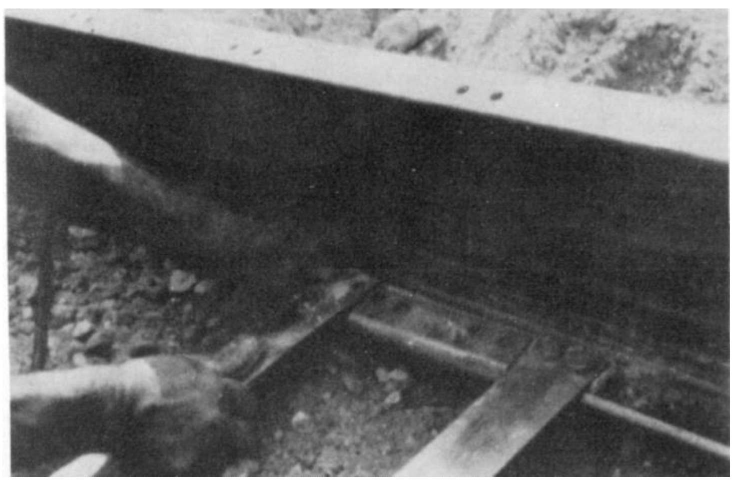
Vidal, H. : The development and future of Reinforced Earth, Keynote Address, *Proc. of Symposium on Earth Reinforcement*, ASCE , pp.1〜61,1978.

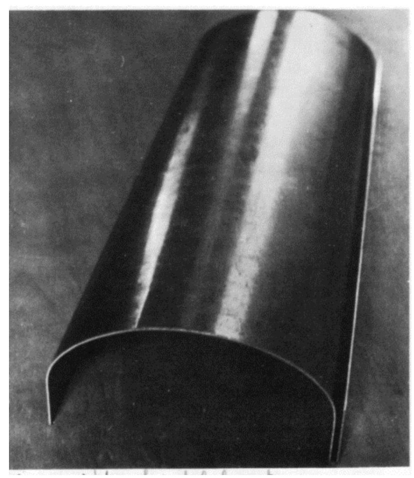
It seems that functions of facing is not important….

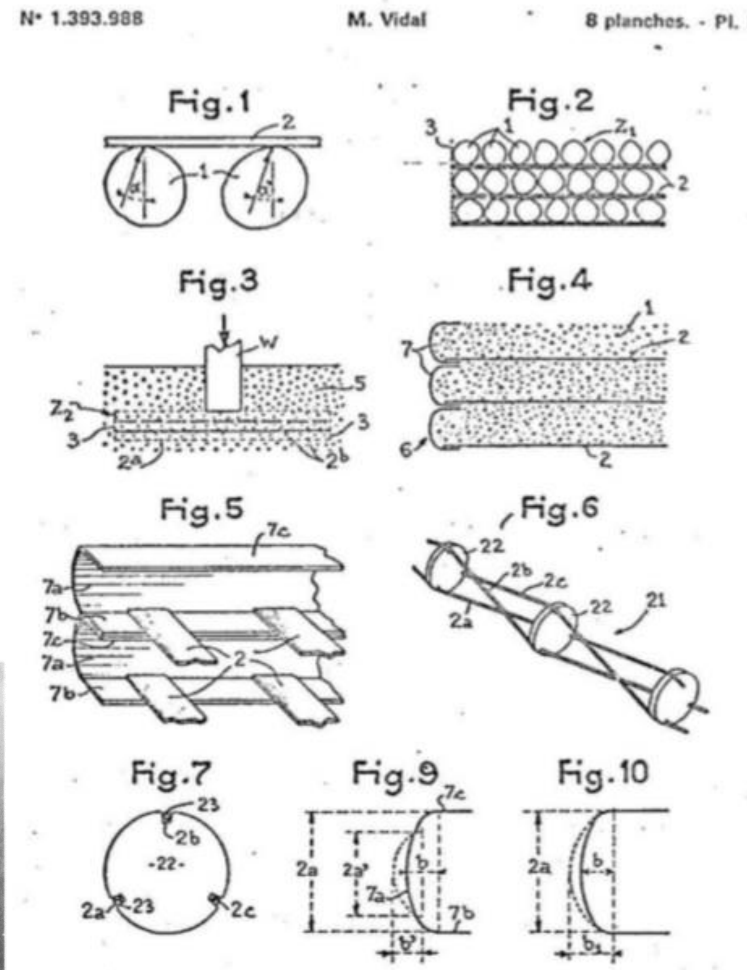
Terre Armée at initial stage(1960's)



U-shape metallic skin was used as facing







Patent by H. Vidal
(27th, May, 1963)

Schlosser F. : "Henri VIDAL (1925 – 2007) Inventeur de la Terre Armée et Pionnier du renforcement des sols "
http://www.cfms-sols.org/sites/default/files/manifestations/090325/Francois%20Schlosser.pdf#search='Terre+ar"mee+vidal'

H.Vidal’s lecture at 14th December, 1965

(chaired by Prof. Albert Caquot)

- This extremely interesting result is physically observed on a reduced model (fig. 37); it can also be demonstrated mathematically, on the condition that it is assumed that the stresses in the earth trapped inside a skin element satisfy an Rankine equilibrium
- The facing must therefore have the particular property of being locally resistant enough while being flexible as a whole

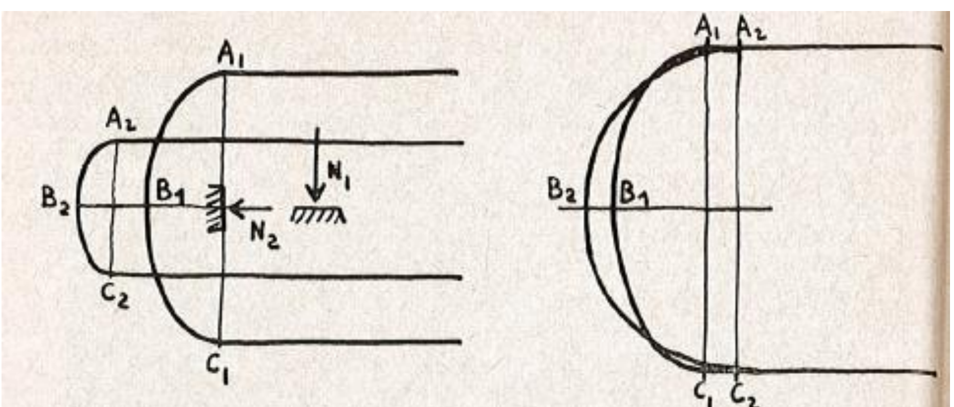
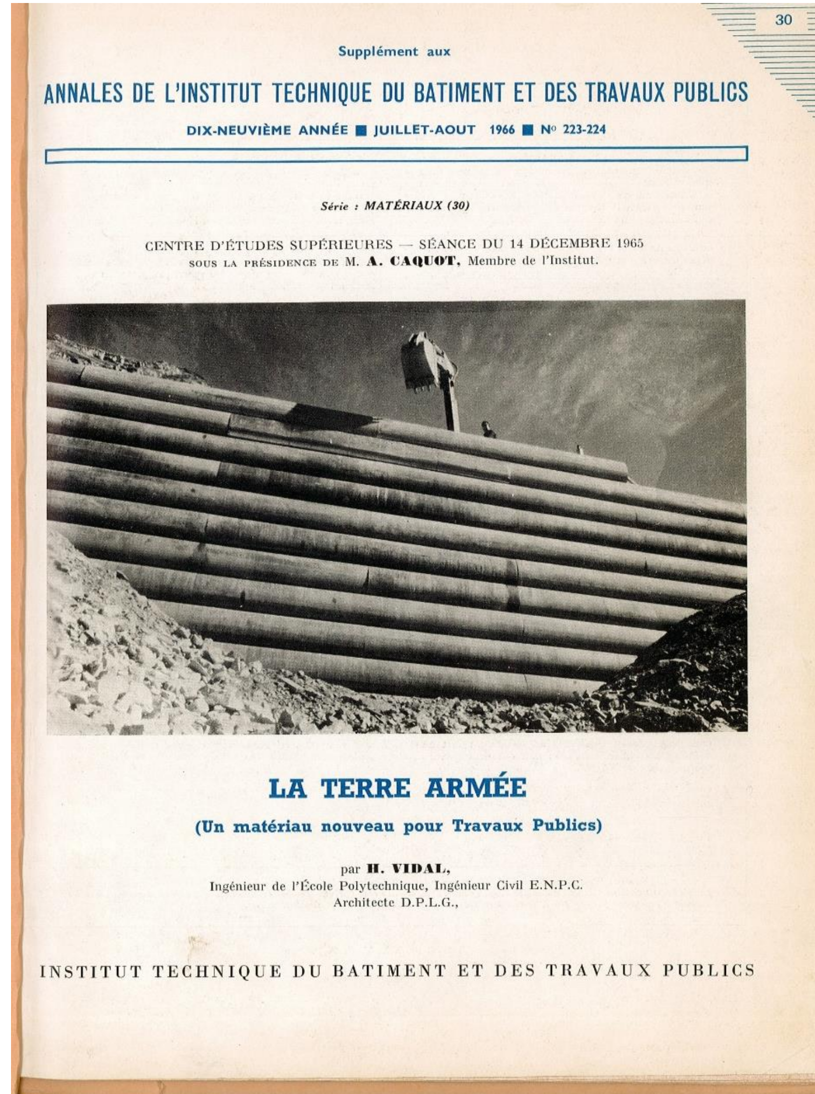


FIG. 37. FIG. 38.



30

Supplément aux

ANNALES DE L'INSTITUT TECHNIQUE DU BATIMENT ET DES TRAVAUX PUBLICS

DIX-NEUVIÈME ANNÉE ■ JUILLET-AOUT 1966 ■ N° 223-224

Série : MATÉRIAUX (30)

CENTRE D'ÉTUDES SUPÉRIEURES — SÉANCE DU 14 DÉCEMBRE 1965
SOUS LA PRÉSIDENCE DE M. A. CAQUOT, Membre de l'Institut.

LA TERRE ARMÉE

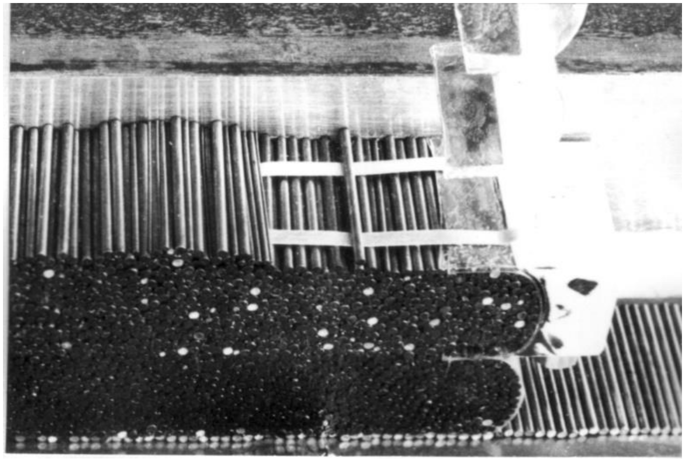
(Un matériau nouveau pour Travaux Publics)

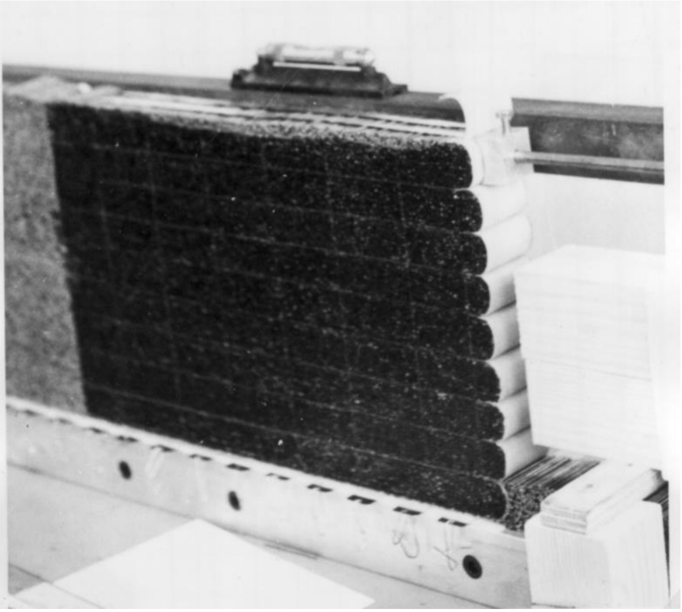
par **H. VIDAL**,
Ingénieur de l'École Polytechnique, Ingénieur Civil E.N.P.C.
Architecte D.P.L.G.,

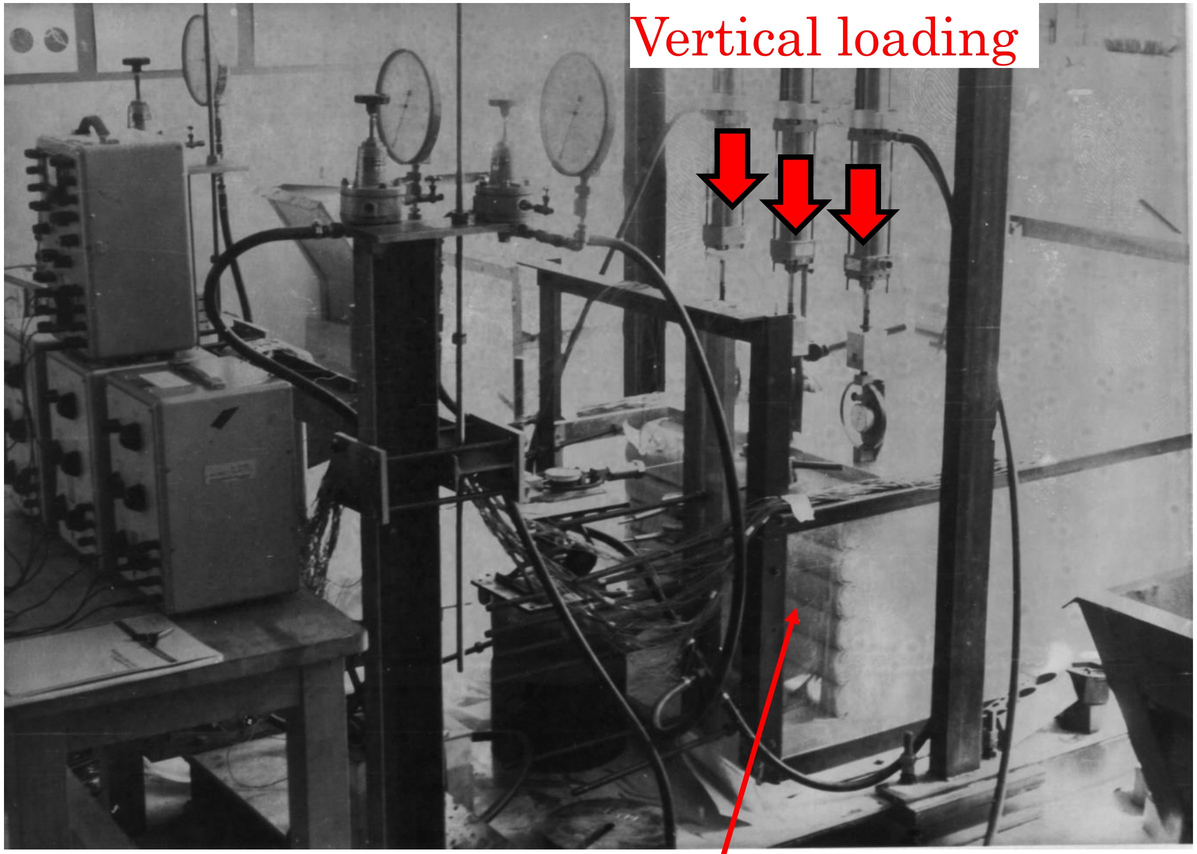
INSTITUT TECHNIQUE DU BATIMENT ET DES TRAVAUX PUBLICS

Annals of the Technical Institute of Building and Public Works, 1966

Model test performed at LCPC (IFSTTAR, after 2010)







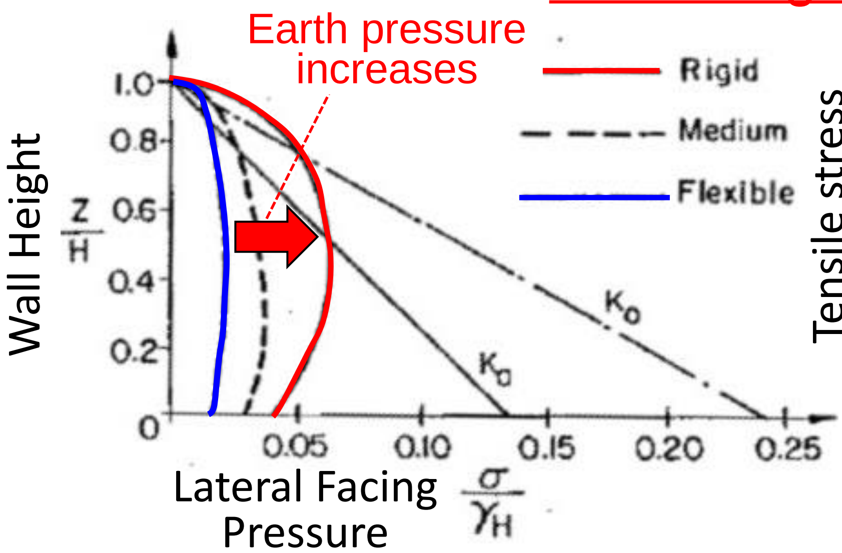
Earth pressure does not act on facing?

Travail de fin d'études, Dimensionnement d'un mur en terre armee soumis a un effort horizontal applique entete, June, 1975

What are the functions of facing??

F. Schlosser (Professor, Ecole Nationale des Ponts et Chaussees)

- Increasing the stiffness of the wall facing decreases the deformation of the wall while increasing the lateral pressure applied to the facing.



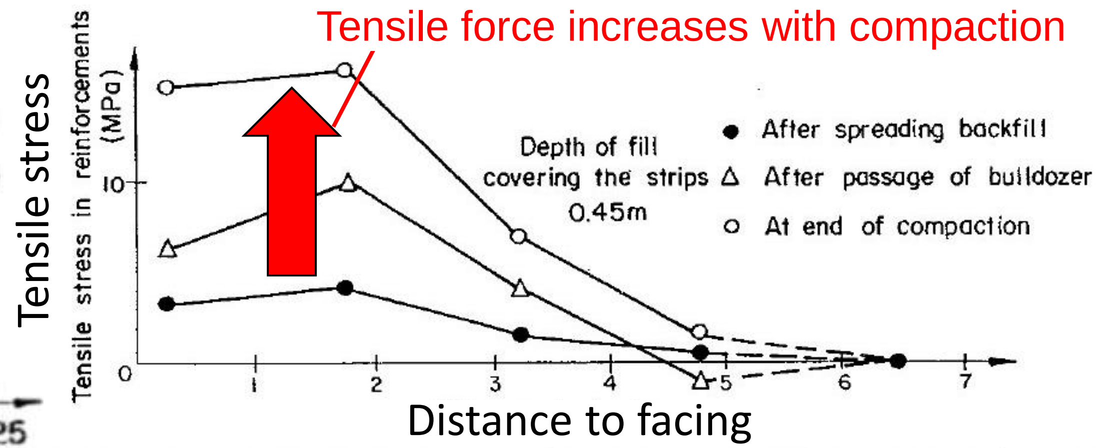


Fig. 11: Effect of Compaction on the Tensile Forces in the Reinforcements: Granton Wall Great Britain, 1973 (T.A.I., 1989).

Schlosser F. : Mechanically stabilized earth retaining structures in Europe, Design and Performance of Earth Retaining Structures, Geotechnical Special Publications No.25, ASCE (Lambe and Hansen), pp.347-378, 1990

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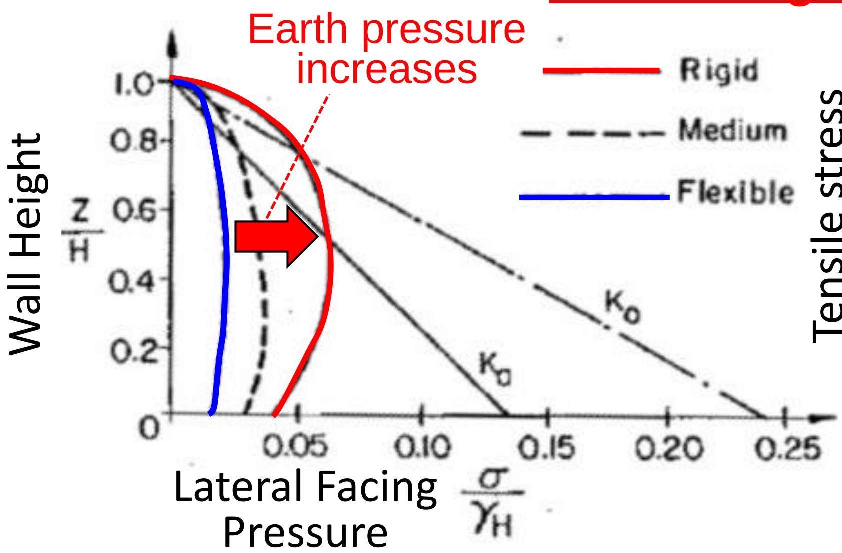


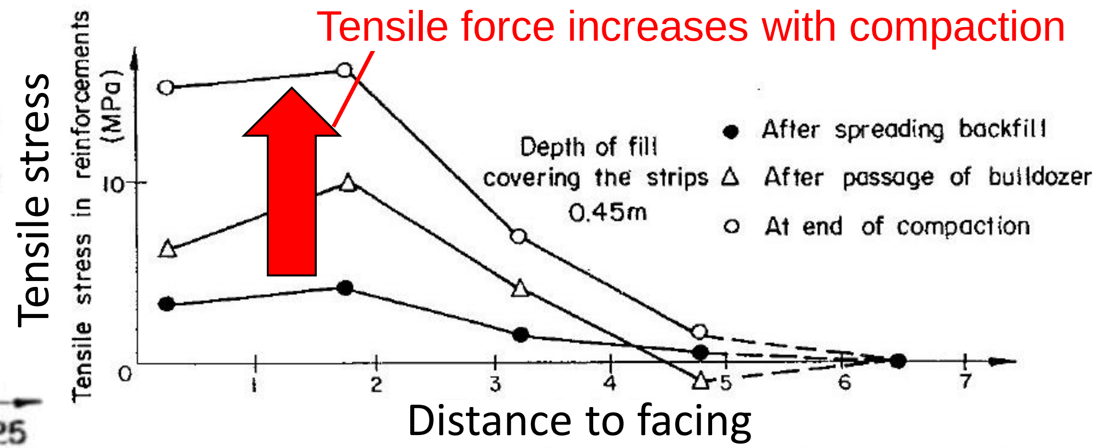


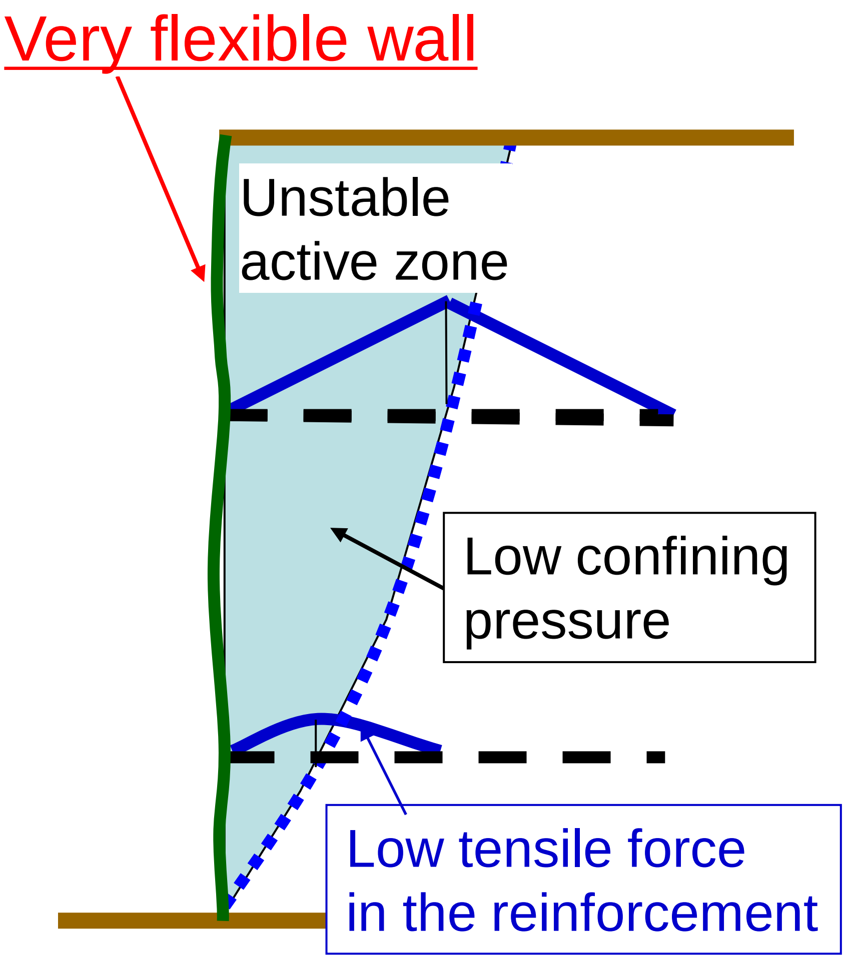
Fig. 11: Effect of Compaction on the Tensile Forces in the Reinforcements: Granton Wall Great Britain, 1973 (T.A.I., 1989).

The functions of facing is very important.

- Tensile force is large at the connection with the wall
- Wall resist against earth pressure (restrain the soil)

Schlosser F. : Mechanically stabilized earth retaining structures in Europe, Design and Performance of Earth Retaining Structures, Geotechnical Special Publications No.25, ASCE (Lambe and Hansen), pp.347-378, 1990

Available tensile forces when the connection strength is zero, or if the facing is very flexible



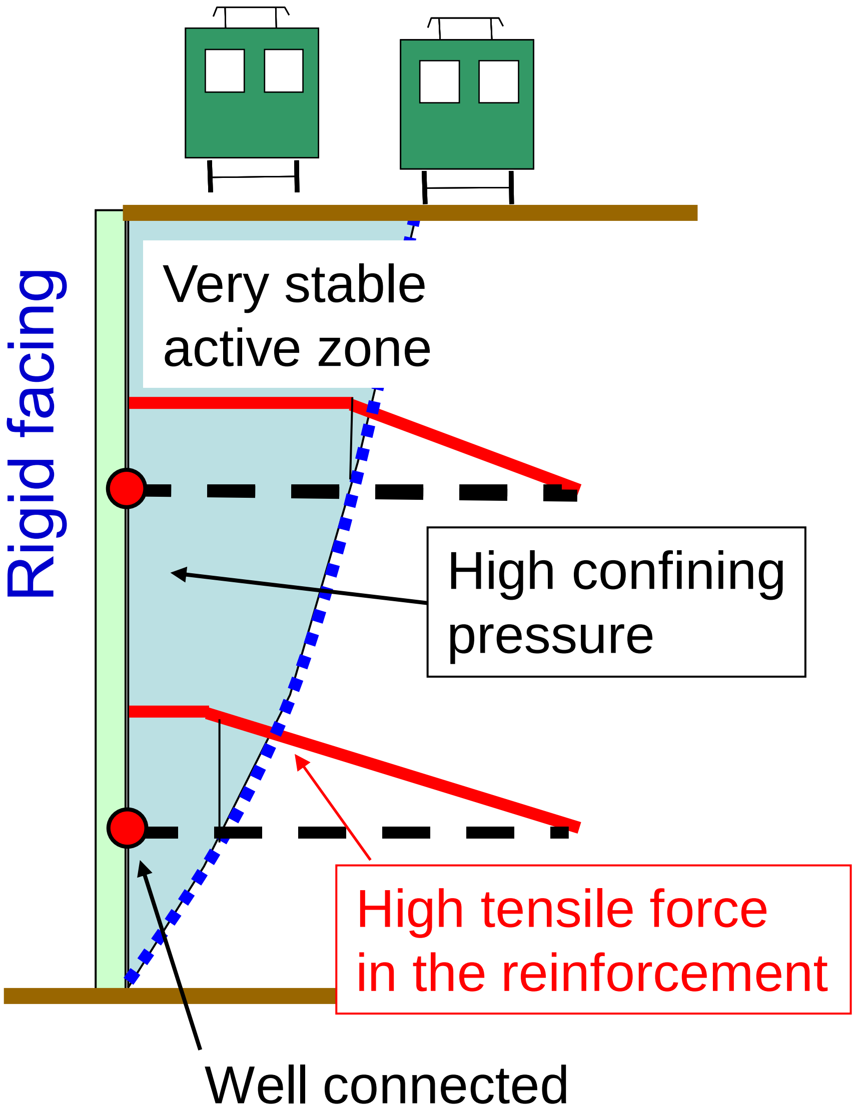
→ No earth pressure at the wall face

→ Low tensile forces in the reinforcement, in particular at the low wall level

→ In the active zone, low confining pressure, therefore, low soil strength

→ Low stability of the wall

Available tensile forces when the facing is rigid enough & the connection strength is high enough



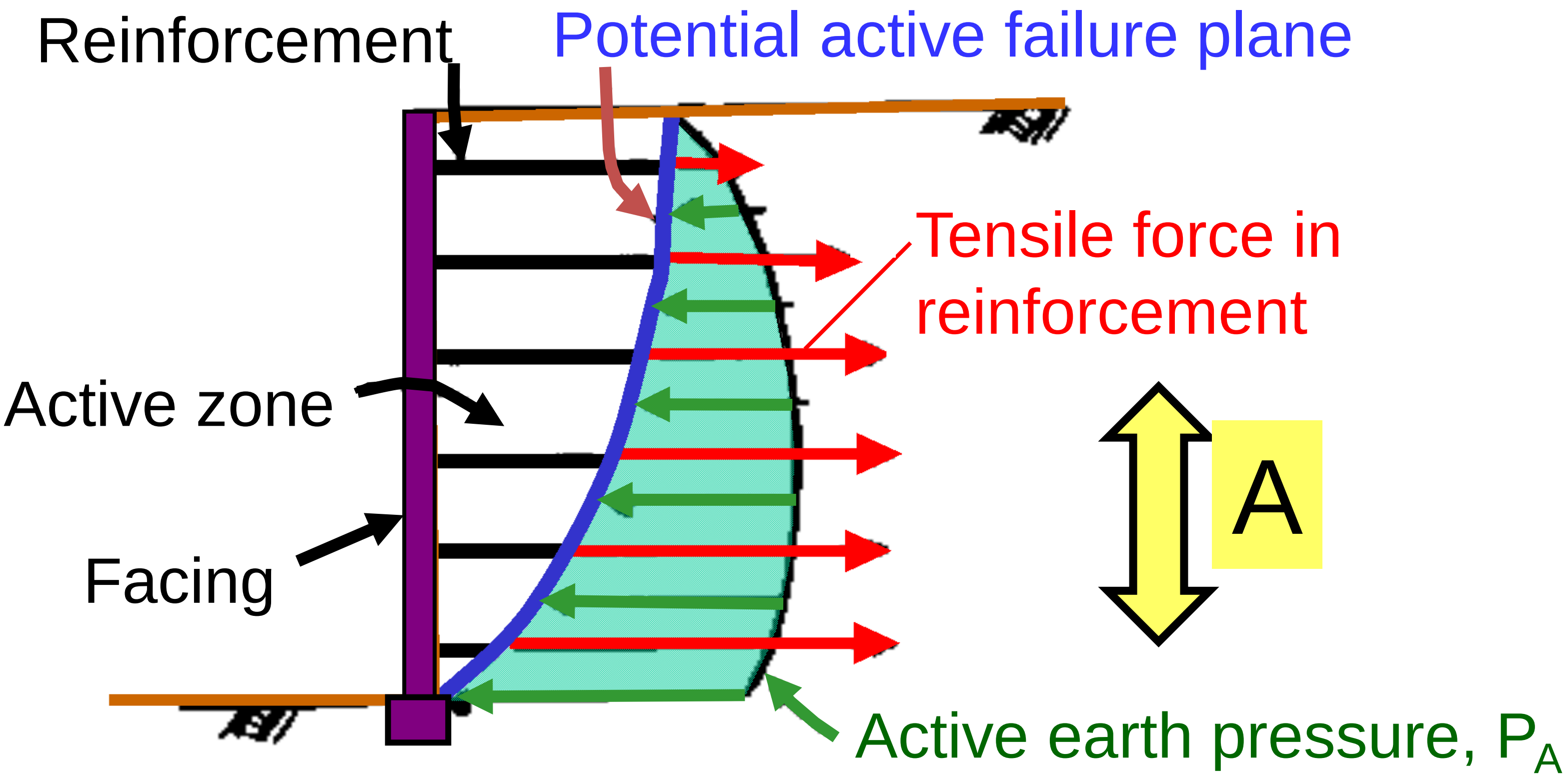
→ High earth pressure at the wall face

→ High tensile forces in the reinforcement

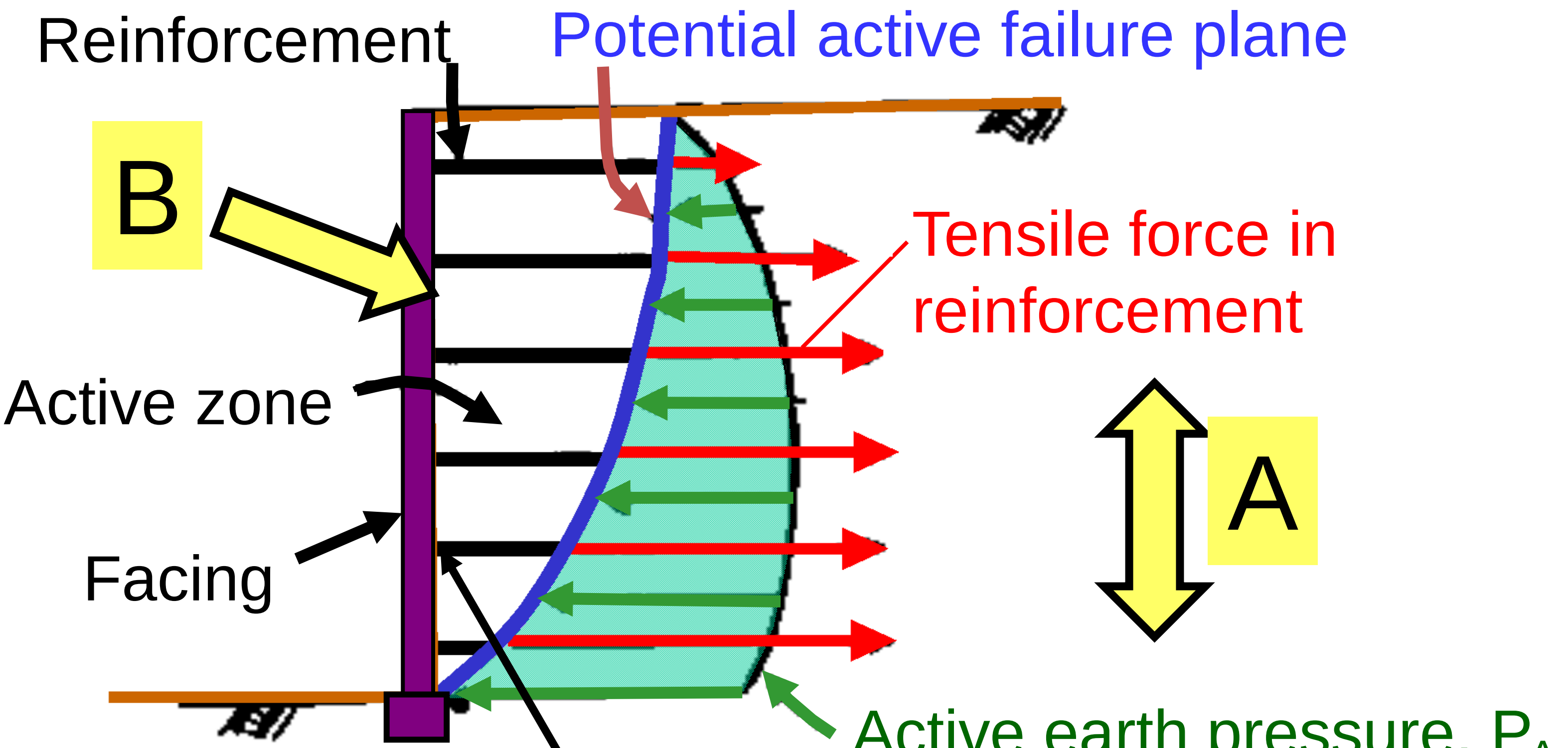
→ In the active zone, high confining pressure, therefore, high soil strength

→ High stability of the wall

Two basic force equilibriums with reinforced soil walls:
(A) along the potential active failure plane
→ always considered in design



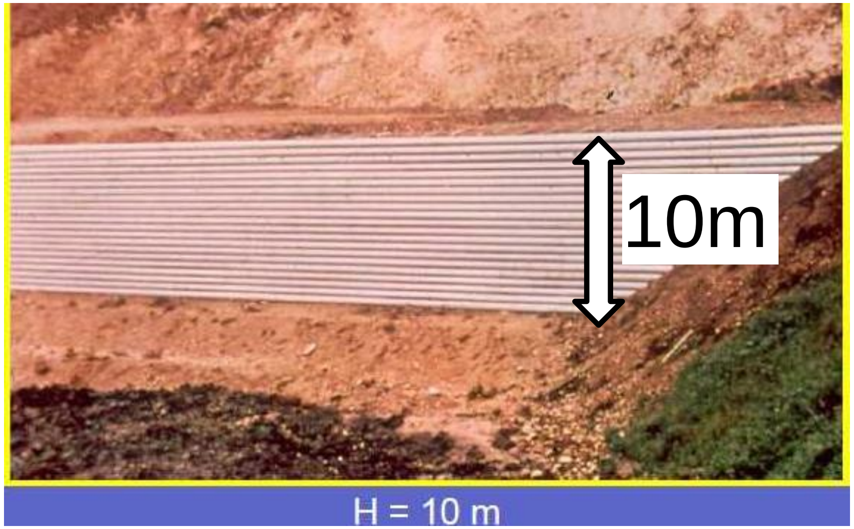
Two basic force equilibriums with reinforced soil walls:
(A) along the potential active failure plane
→ always considered in design
(B) at the facing → very important, but often ignored

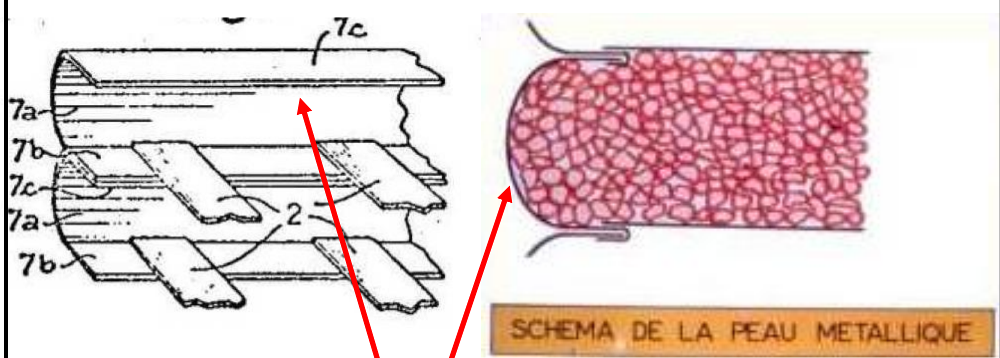


Paramount importance of connection strength

Development of Terre Armée

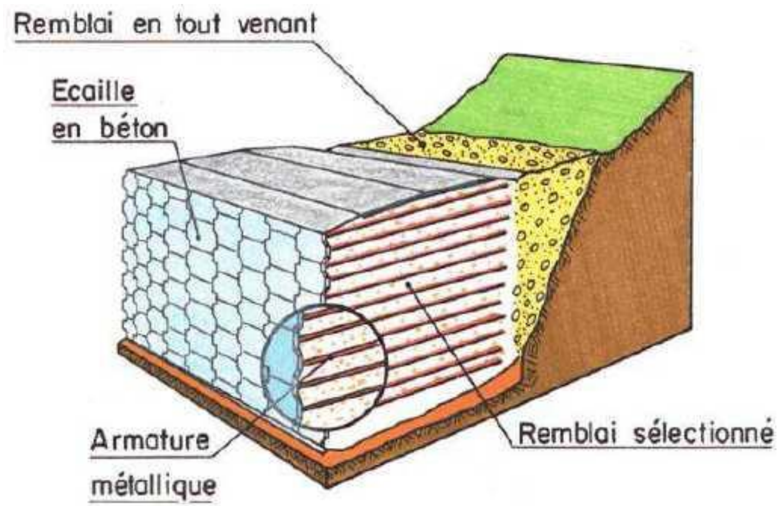
Terre Armée at initial stage(1960’s)





U-shaped metallic elements

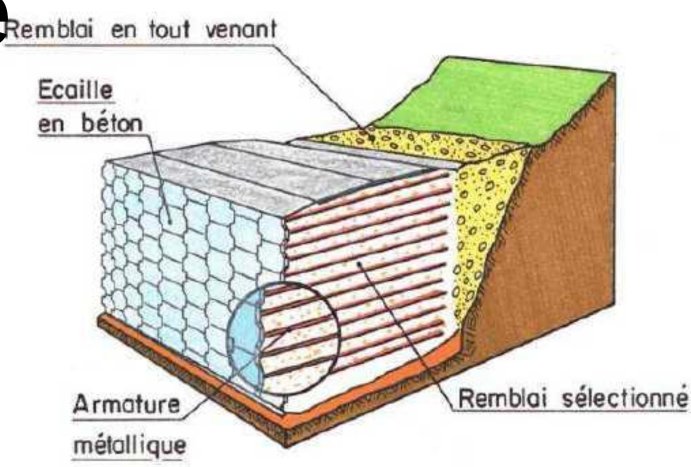
Development of a standard cruciform facing panel (1971)



Schlosser F. : “Henri VIDAL (1925 – 2007) Inventeur de la Terre Armée et Pionnier du renforcement des sols ”

http://www.cfms-sols.org/sites/default/files/manifestations/090325/Francois%20Schlosser.pdf#search='Terre+ar”mee+vidal'

Development of Terre Armée



Reasons for using facing panel

- Vital: " Appearance "

  (Attractive and aesthetic)

- Schlosser: "Various architectural possiblilities"

  (curving facing etc)

There are no explanations about
"earth pressure effect"
which mobilizes higher tensile force in reinforcement.
(This is the another big advantage of using the facing panel !)

What is the functions of facing??

Answer

1)The facing is an important and essential **structural component**

2) The earth pressure at the facing should be **high** enough to provide sufficient confining pressure to the backfill.

The importance of the facing rigidity and the facing/ reinforcement connection should not be over-looked !

Problem of discrete panel facing (1)

Collapse of discrete panel in Eastern Tennessee, USA (Lee et al. 1994)

Local failure may quickly result into collapse of the whole wall !

Problem of discrete panel facing (2)

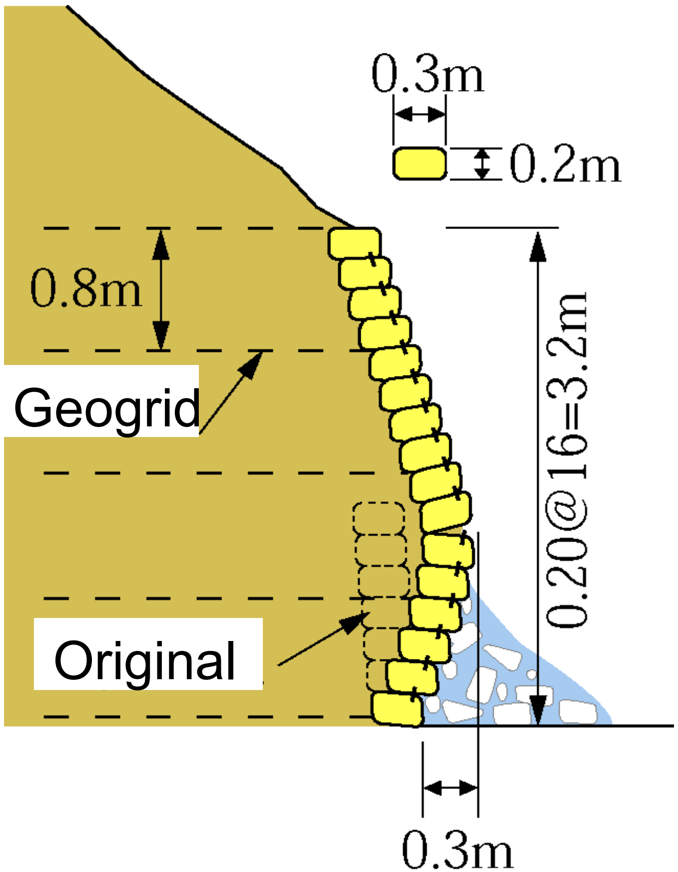
Collapse due to scouring at the bottom of the facing
(Mexico during a Hurricane June 2010)

(By the courtesy of Leshchinsky, D.)

Local failure in <u>a limited number of discrete panel facing</u> caused by scouring of the supporting ground <u>resulted into the failure of the whole wall</u>.

Problem of discrete panel facing (3)

Failure of a GRS RW with modular block facing in Taiwan during the1999 July Chi-Chi Earthquake



Local failure in the modular block facing due to connection failure between blocks and geogrid reinforcement resulted in the failure of the whole wall.

How to attach geogrid to the full height rigid facing??

F. Schlosser (1990)

- The first geotextile reinforced wall was built in 1971 by the LCPC.
- However, until now, their utilization (of geotextile) has been rather limited, because of their high deformability.
- The problems related to the facing must still be solved, specifically the unaesthetic appearance of the geogrid facing, difficulties in construction, and the method for attaching the geogrid to the facing panel

of geotextiles in multi-layered reinforced soil retaining systems. In this technique, geotextile sheets provide simultaneously the planar reinforcements and the facing, which is constructed by wrapping the end of the sheet upwards in a "U" shape. The first geotextile reinforced wall was built in France in 1971 by the LCPC (42). It was an experimental wall using non-woven fabric (Bidim) and a very poor backfill material (wet clayey and sensitive soil). The wall was 4 m high and was founded on a very compressible soil (peat layer 3 m thick). Since this first application, geotextiles have been frequently used in reinforced soil retaining walls, as a consequence of their low cost, drainage properties and the possibility of using poor backfill material. However, until now, their utilization has been rather limited, because of their high deformability (particularly in the case of non-woven geotextiles) and relatively unaesthetic appearance of the facing. In 1987, the French laboratory LCPC patented a technique of geotextile reinforced soil walls, called Ebal Wall, in which a precast concrete facing is placed in front of the soil reinforced wall in order to facilitate the erection of the wall, improve the aesthetic aspect of the facing, and to protect the geotextile facing from degradation by ultraviolet rays.

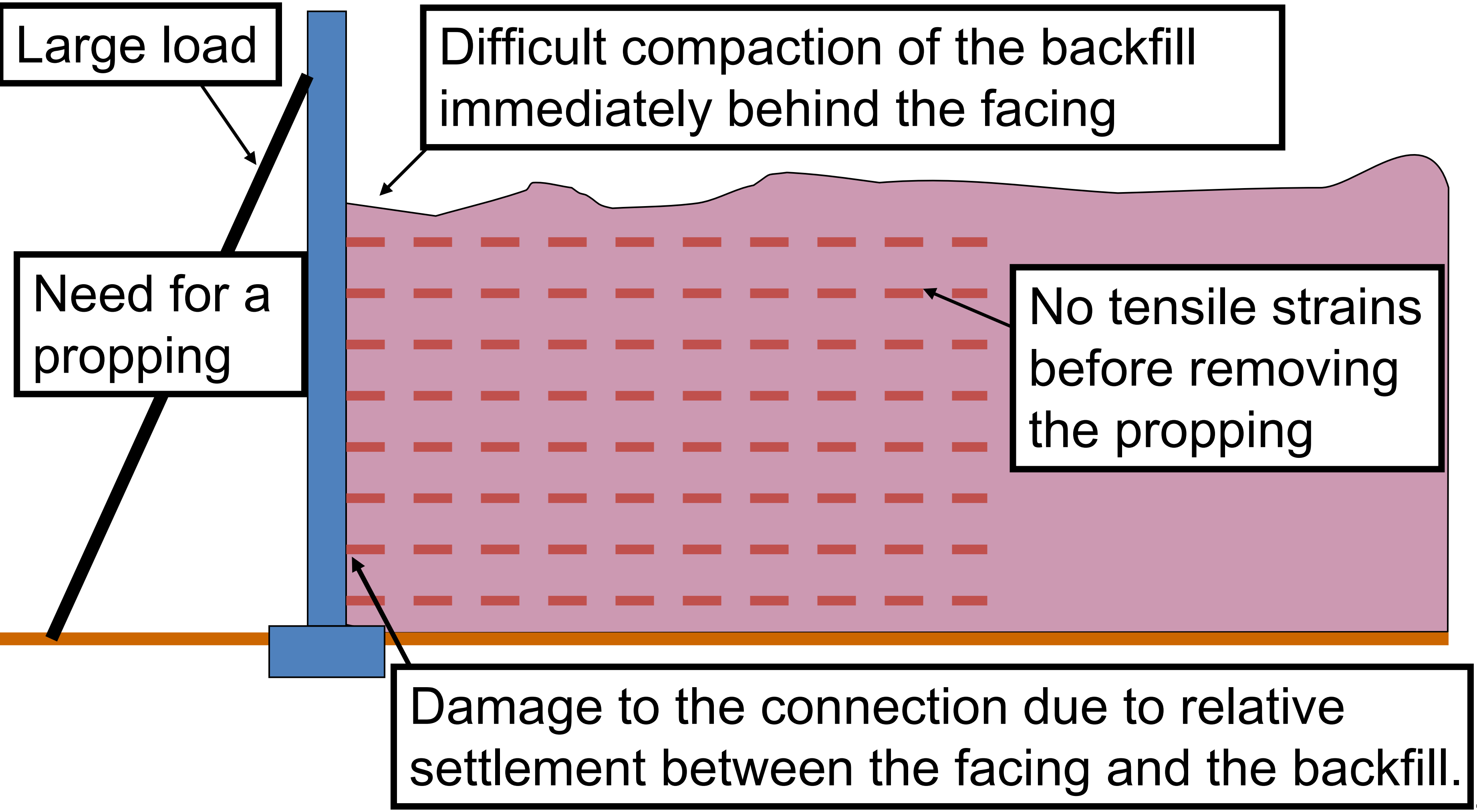
Metallic and polymeric grids have also been used as reinforcements, although Europe was not a pioneer in this area. The first grid reinforced soil retaining structure (welded wire bar mat) was constructed in the USA in 1974, along Interstate highway 5, near Dunsmuir, California (20). The bar mat/soil interaction is complex and involves both friction along the longitudinal bars and passive resistance against the transversal elements. Because of the mobilized passive resistance, bar mats are more resistant in pull-out than strips, but only for large displacements (5 to 10 cm). If the lateral displacements necessary to generate the passive resistance are acceptable for the structure, bar mat reinforcement permits the use of poor quality backfill material, with a relatively large fine-grain portion. In the early 80's, Netlon, in the UK, developed and manufactured a plastic grid reinforcement, called Tensar. This product consists of a high strength oriented polymer grid structure obtained from punched and stretched polymer sheets. Tensar has become rapidly accepted in a large variety of soil reinforcement applications (embankment reinforcement, retaining walls, rafts, repairs of slope failures, and gabions) and has resulted in a new type of two-dimensional reinforcement, called geogrids. Compared with non-woven geotextiles, geogrids exhibit a larger deformation modulus and tensile resistance. Up to now, geogrids have been widely used in all areas of soil reinforcement, except retaining walls. Similar to geotextiles, the problem related to the facing must still be solved, specifically, the unaesthetic appearance of the geogrid facing, difficulties in construction, and the method for attaching the geogrid to the prefabricated facing panels.

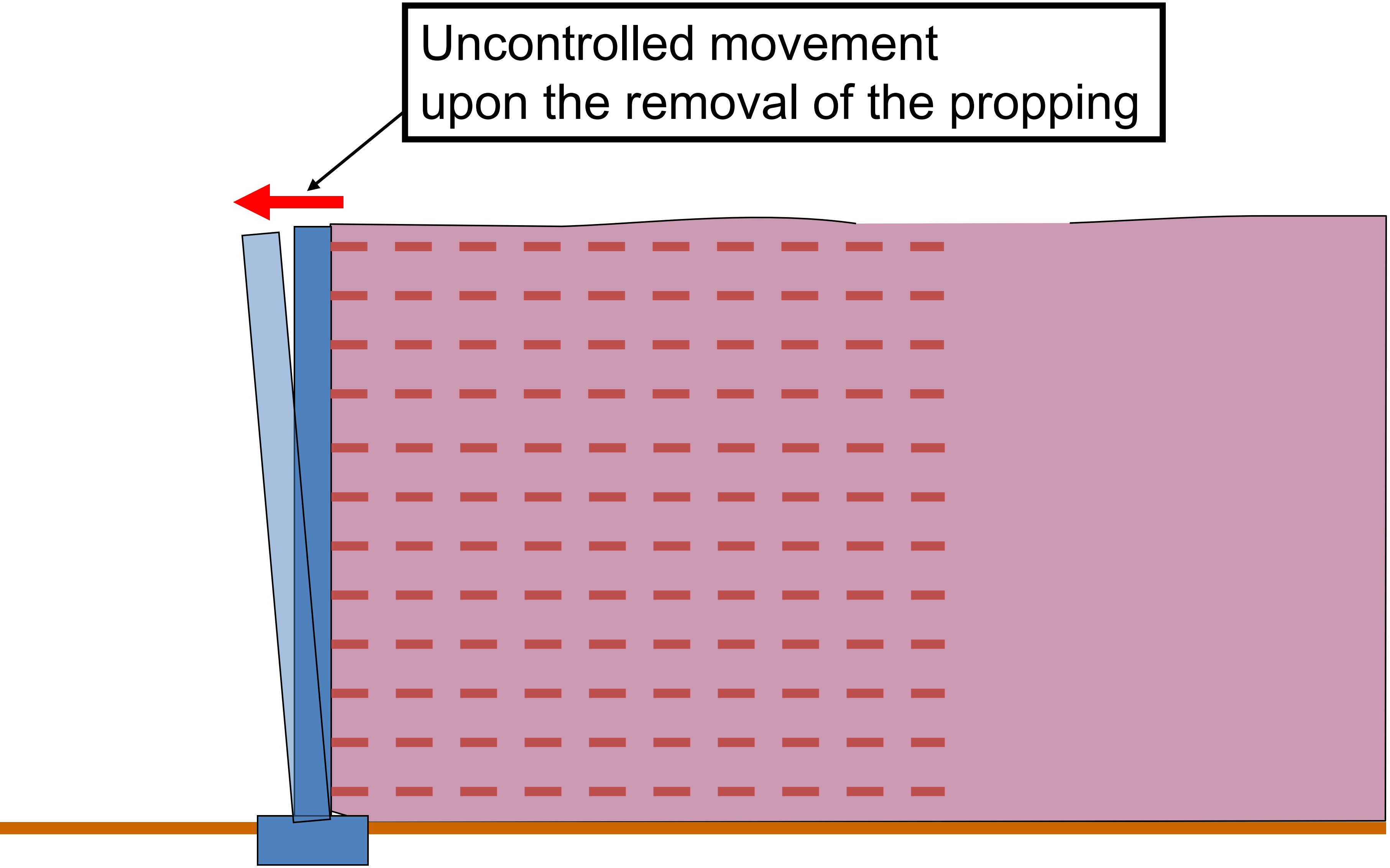
Schlosser F. : Mechanically stabilized earth retaining structures in Europe, 1990

- It is not difficult to achieve strong facing/ reinforcement connection by constructing the wall before backifill…

There are critical problems of this construction procedure

Several problems if the wall constructed before, or simultaneously with, the construction of the backfill

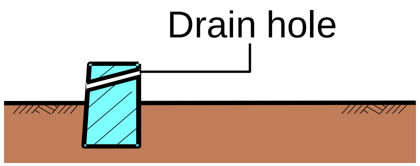




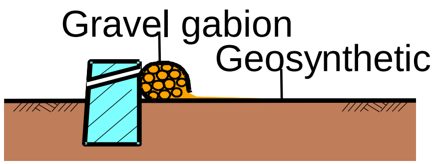
- These problems can be solved by the staged construction procedure …..

Staged construction – 1) & 2)

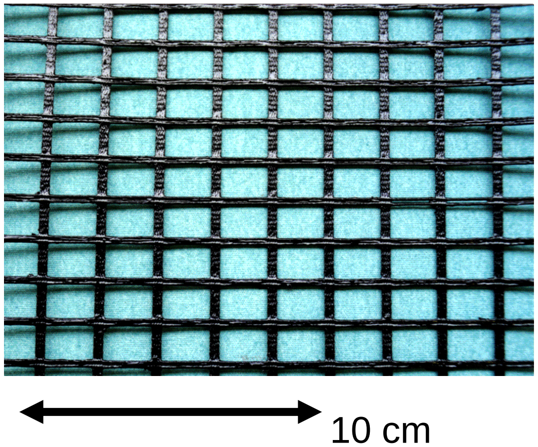
- Construction with a help of gravel gabions placed at the shoulder of each soil layer



1) Leveling pad for facing



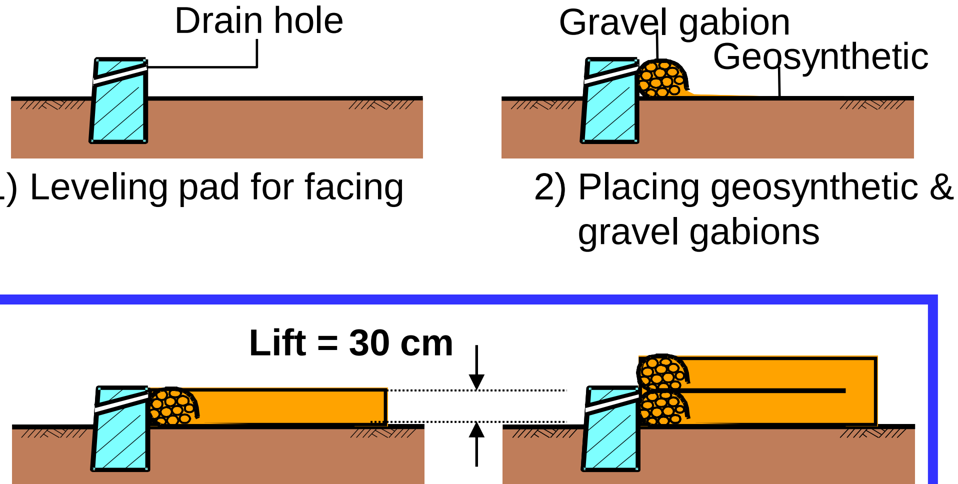
2) Placing geosynthetic & gravel gabions



Typical polymer geogrid: bi-axial PVA grid (very high resistance against high PH: & high anchorage strength)

Staged construction – 3) & 4)

- Construction with a help of gravel gabions placed at the shoulder of each soil layer



1) Leveling pad for facing

2) Placing geosynthetic & gravel gabions

3) Backfilling & compaction

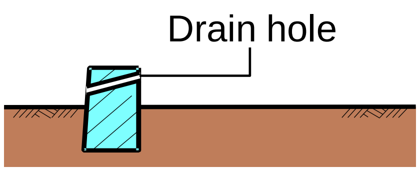
4) Second layer

➢ Good compaction of the backfill

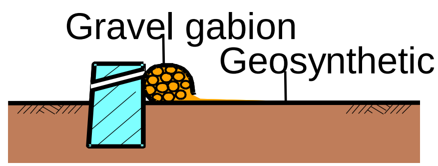
➢ No rigid facing during backfill compaction

Staged construction – 5)

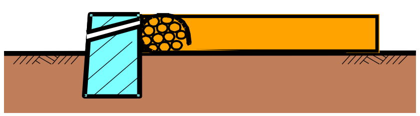
- Construction with a help of gravel gabions placed at the shoulder of each soil layer



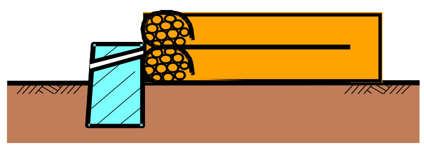
1) Leveling pad for facing



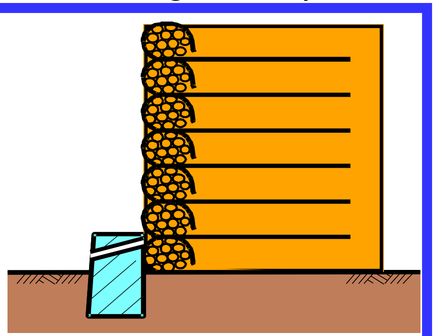
2) Placing geosynthetic & gravel gabions



3) Backfilling & compaction



4) Second layer

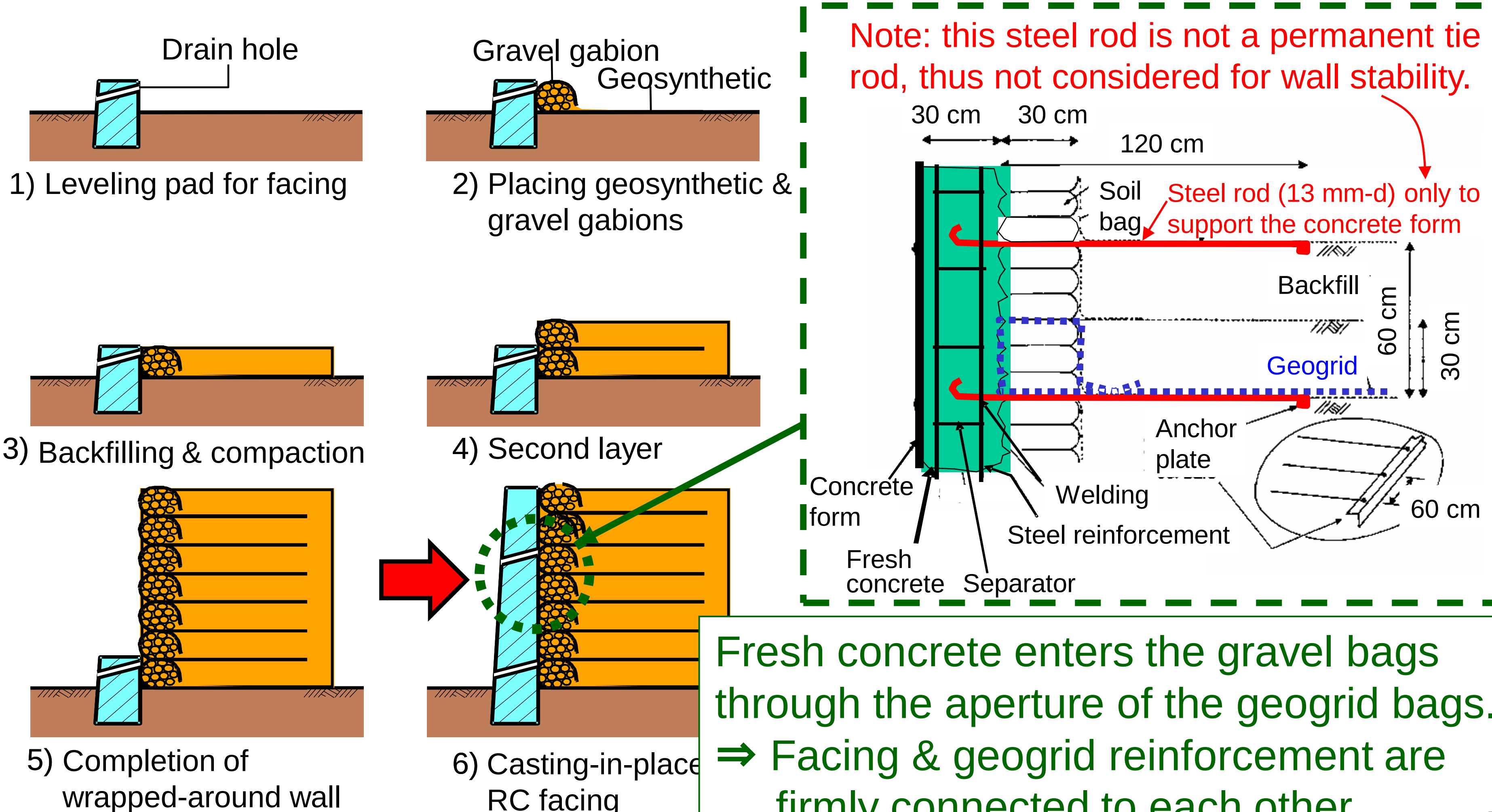


5) Completion of wrapped-around wall

After sufficient compression of backfill and ground…….

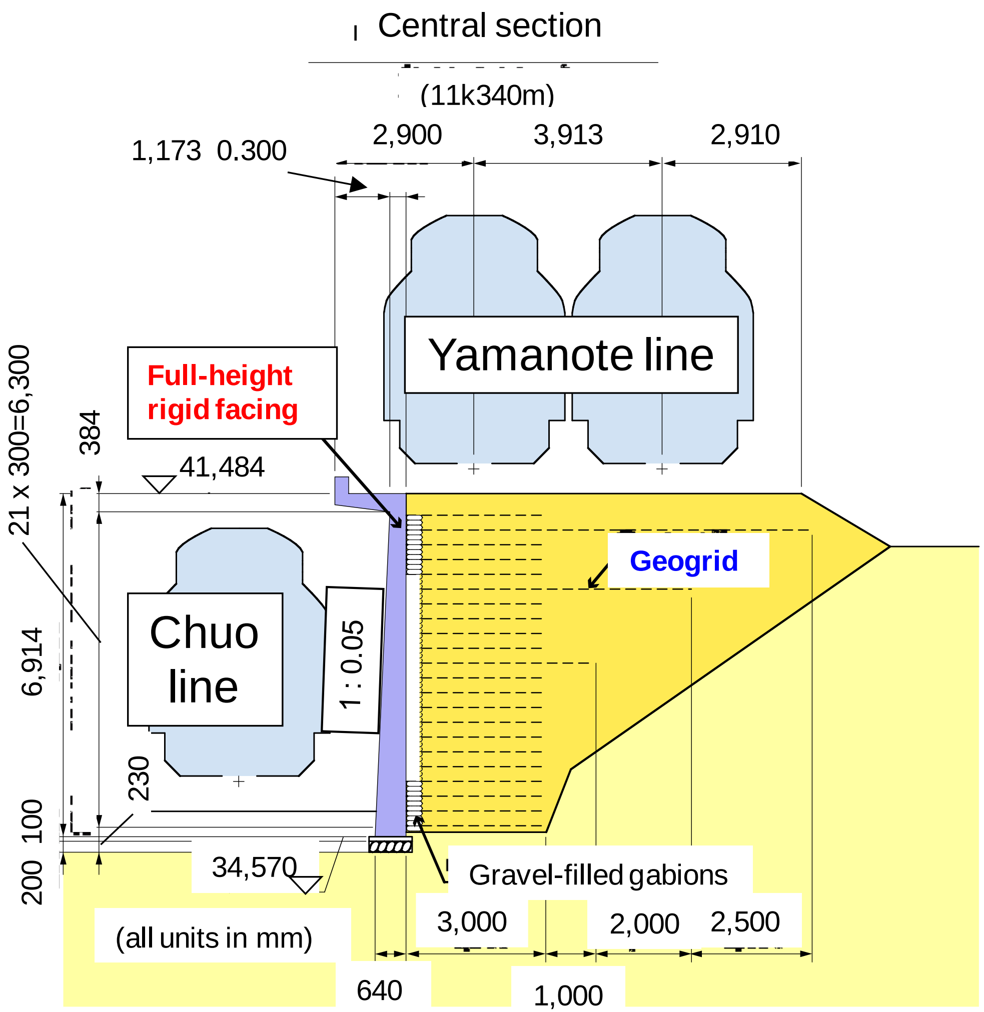
Staged construction – from 5) to 6)

- After sufficient compression of backfill and supporting ground has taken place, a full-height rigid facing is constructed by casting-in-place concrete directly on the wrapped-around wall.



Fresh concrete enters the gravel bags through the aperture of the geogrid bags.
⇒ Facing & geogrid reinforcement are firmly connected to each other.

GRS RW supporting very busy urban trains in Tokyo

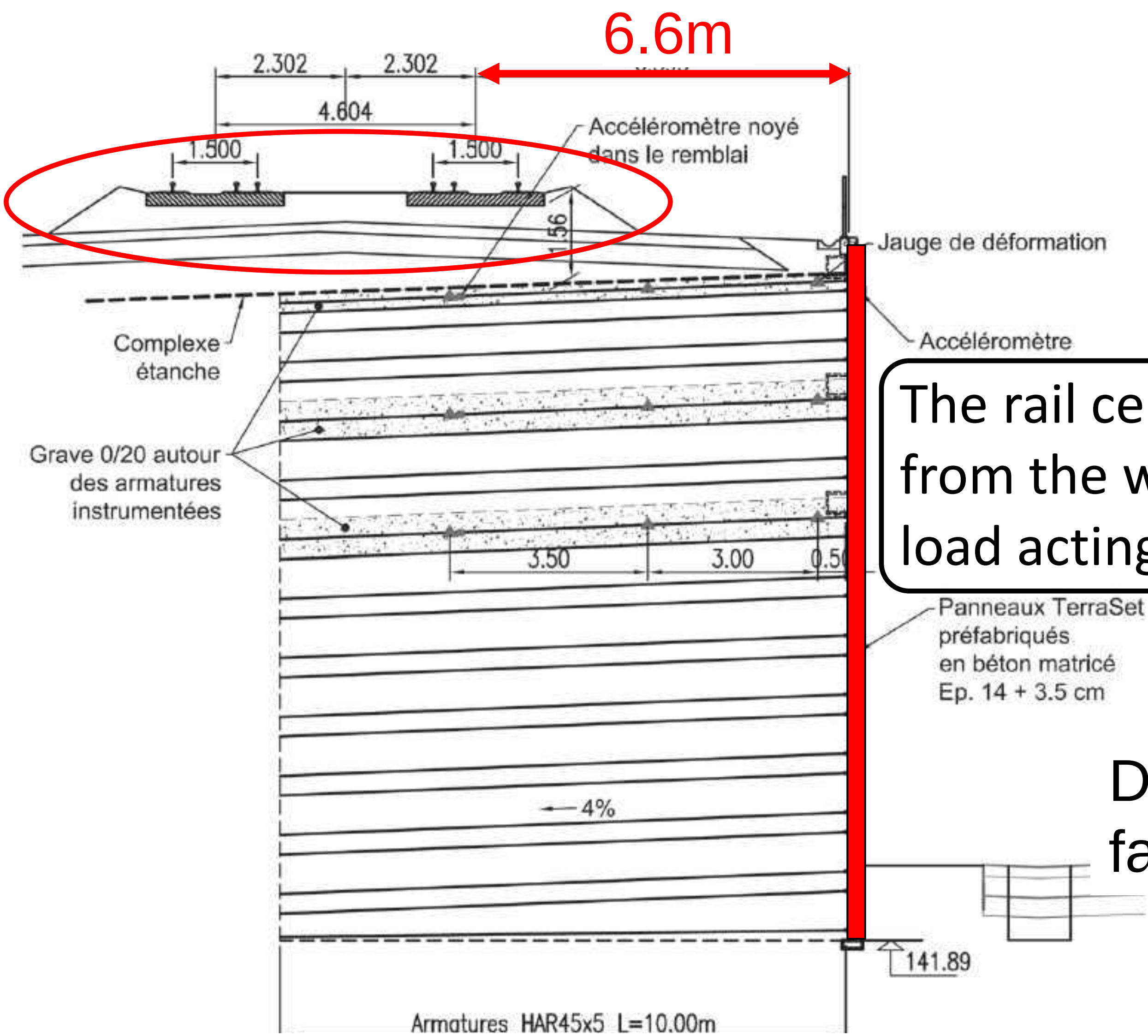


Near Shinjuku Station, Tokyo, constructed during 1995 – 2000

Passenger: 6.4million/day

Terre-Armée method for TGV in France

(2012-2014)



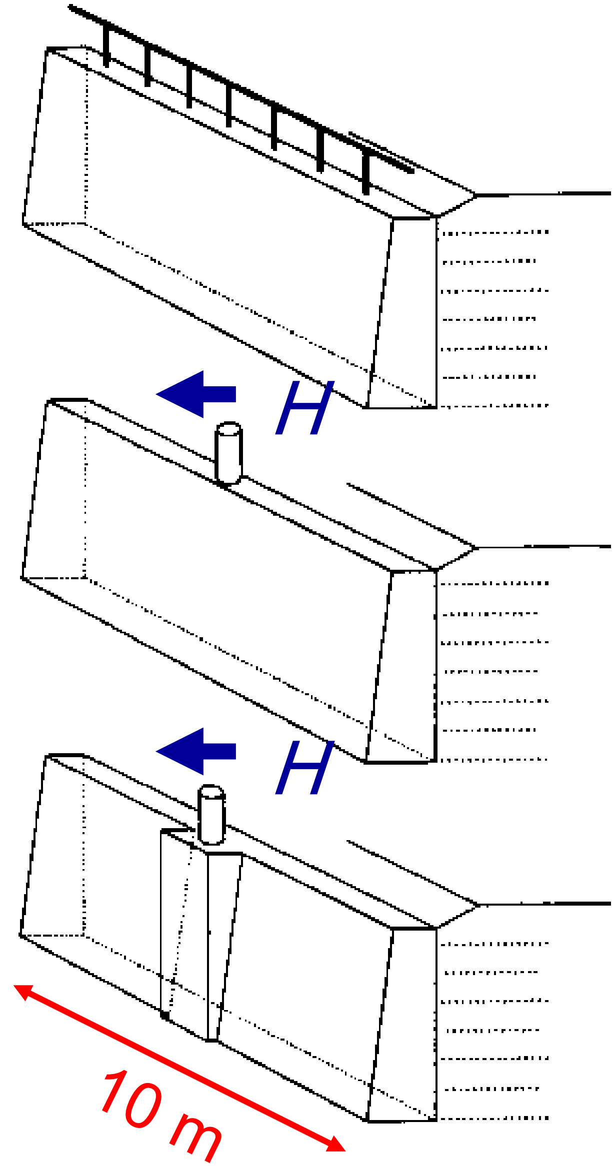
The rail center is constructed far from the wall (avoiding the traffic load acting on the wall directly)

Due to the uncontinuous facing (discrete panel)

Nicolas FREITAG, Yassine BENNANI, Patrick JOFFRIN, Laurent SOYEZ: STABILITÉ D'UN OUVRAGE EN TERRE ARMÉE® SOUS LIGNE À GRANDE VITESSE : APPLICATION AU PROJET SEA TOURS –BORDEAUX, *Symposium International GEORAIL, 2014*

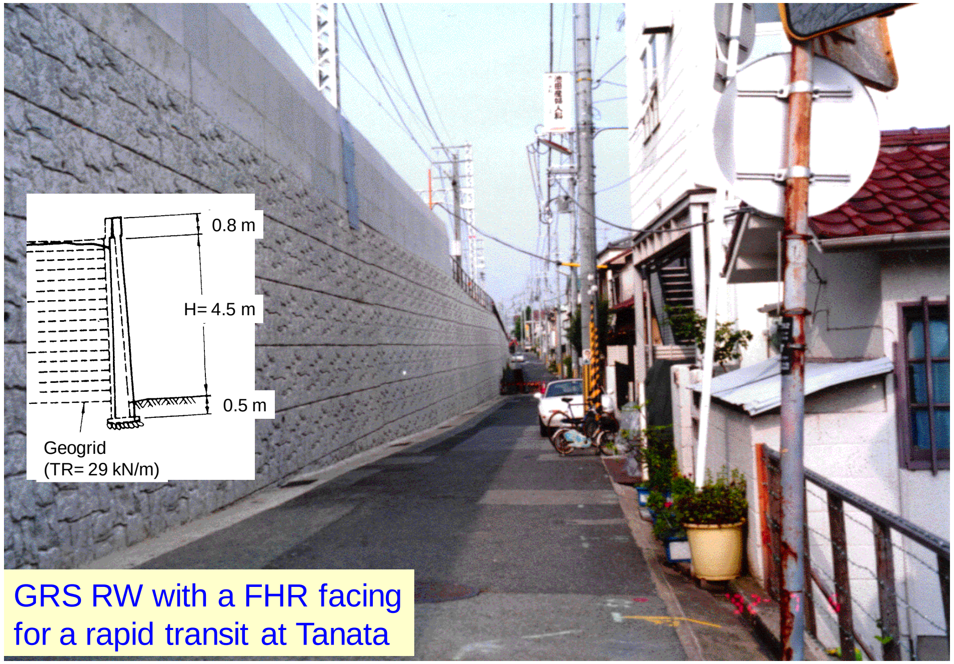
3D effects of full-height rigid facing!

Full-height rigid facing becomes a foundation for super-structures, such as electric poles, noise barrier walls, bridge girders etc.



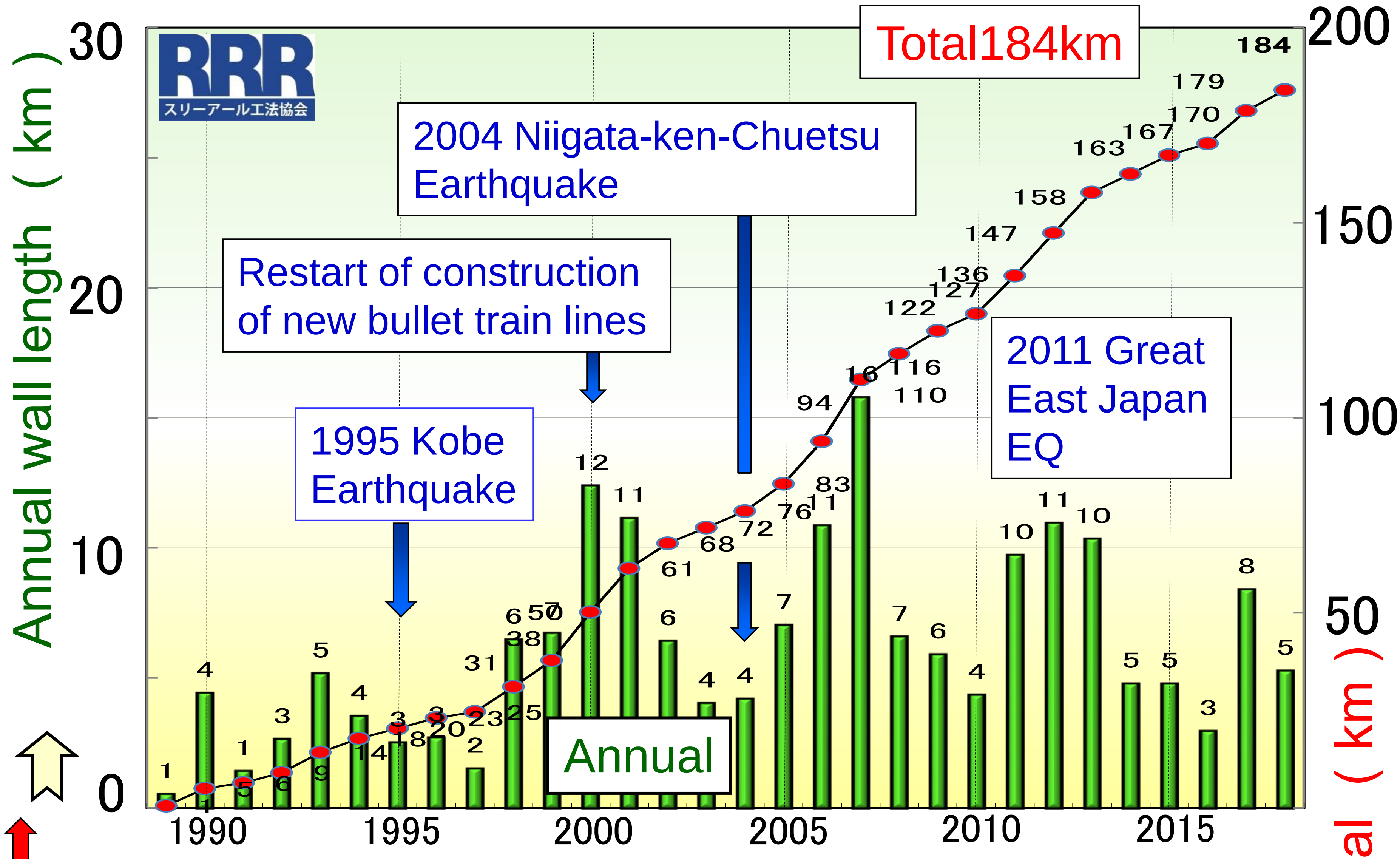
Performance of GRS-RW during severe earthquake

Immediately after completion, 1992

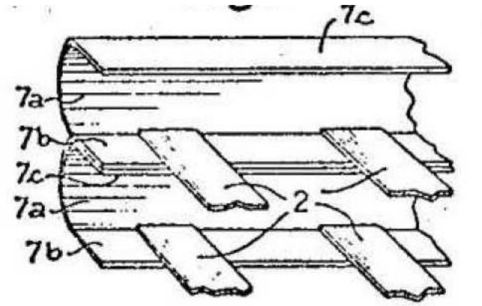


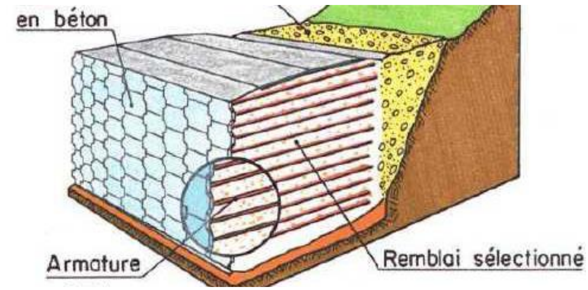
A week after the 1995 Kobe Earthquake

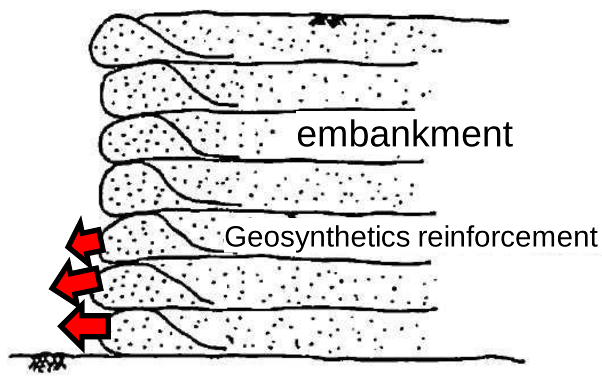
GRS RWs performed very well during severe earthquakes !

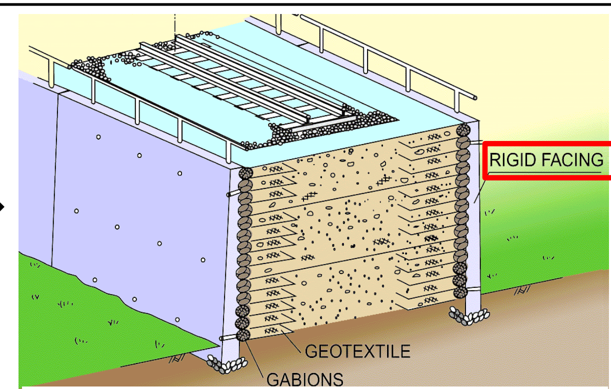


From 1982: joint research at the University of Tokyo & Railway Technical Research Institute

<table>
<tr><td colspan="2"></td><td colspan="2">Stiffness of facing</td></tr>
<tr><td colspan="2"></td><td>Soft
(doesn’t accept earth pressure)</td><td>Hard
(accept large earth pressure)</td></tr>
<tr><td rowspan="2">Structure and Material of reinforcement</td><td>Strip, band (metal)</td><td>


Metalic skin</td><td>


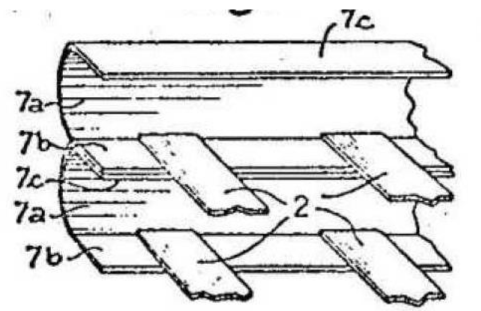
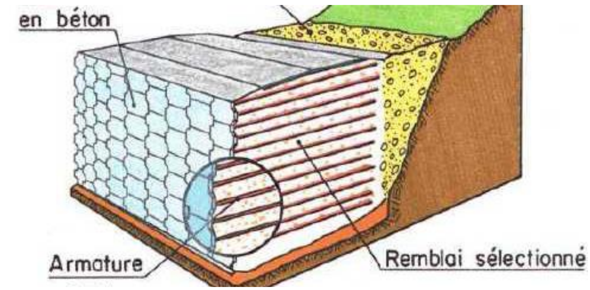
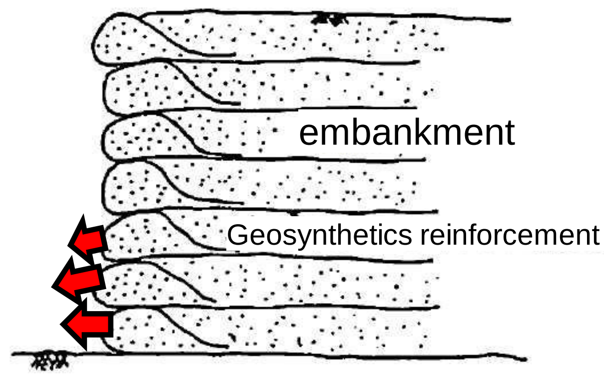
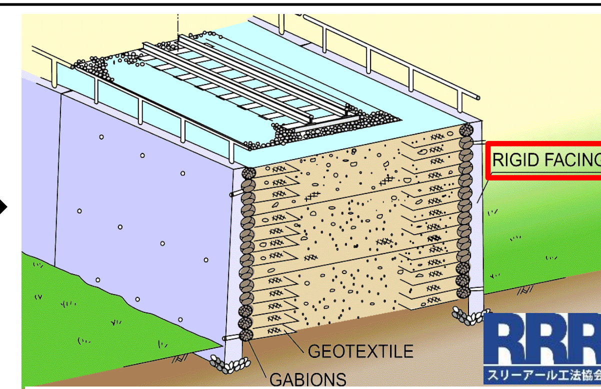
Cruciform facing panel</td></tr>
<tr><td>Planar, Grid (Polymar)</td><td>


no facing</td><td>


Full heigth rigid facing</td></tr>
</table>

- Facing is not important, we should not have any need for a facing.
- Disadvantages of geosynthetics are the high deformability and difficulties in attaching the geogrid to the facing.

- There is certain effect of facing
- These disadvantages have already overcome

		Stiffness of facing	
		Soft (doesn't accept earth pressure)	**Hard** (accept large earth pressure)
Structure and Material of reinforcement	Strip, band (metal)	 Metalic skin	 Cruciform facing panel
	Planar, Grid (Polymar)	 no facing	 Full heigth rigid facing

- ~~Facing is not important, we should not have any need for a facing.~~
- ~~Disadvantages of geosynthetics are the high deformability and difficulties in attaching the geogrid to the facing.~~

- There is certain effect of facing
- These disadvantages have already been overcomed

Many engineers are still misunderstanding

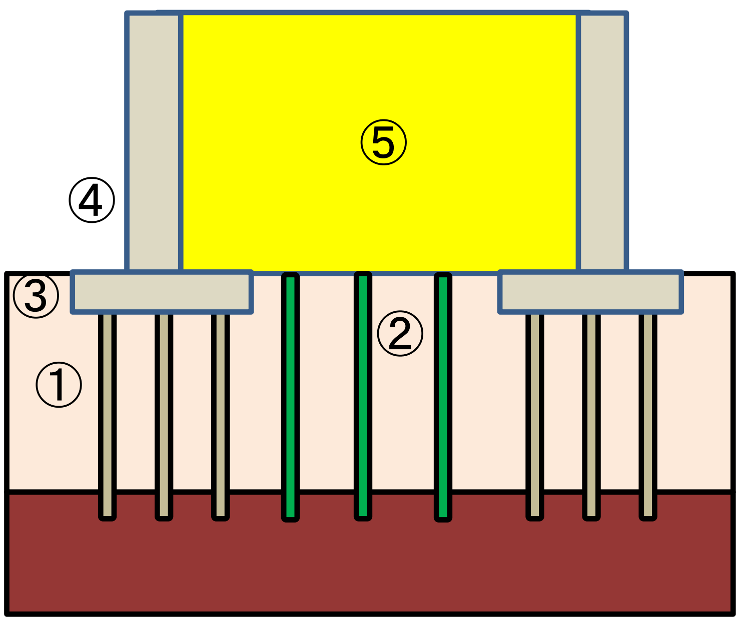
Contents

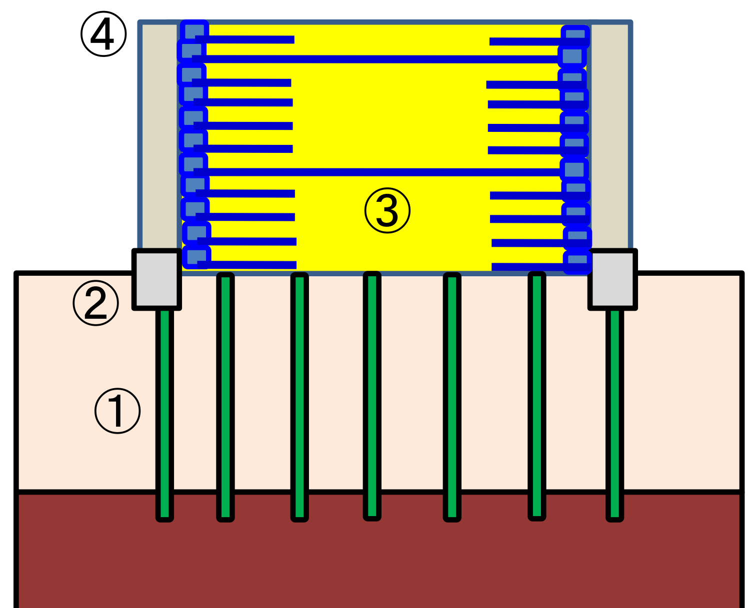
Advantage of GRS RWs in construction

Subsoil condition	Conventional RWs	GRS RWs
Extremely weak		
Relatively weak		
Good		

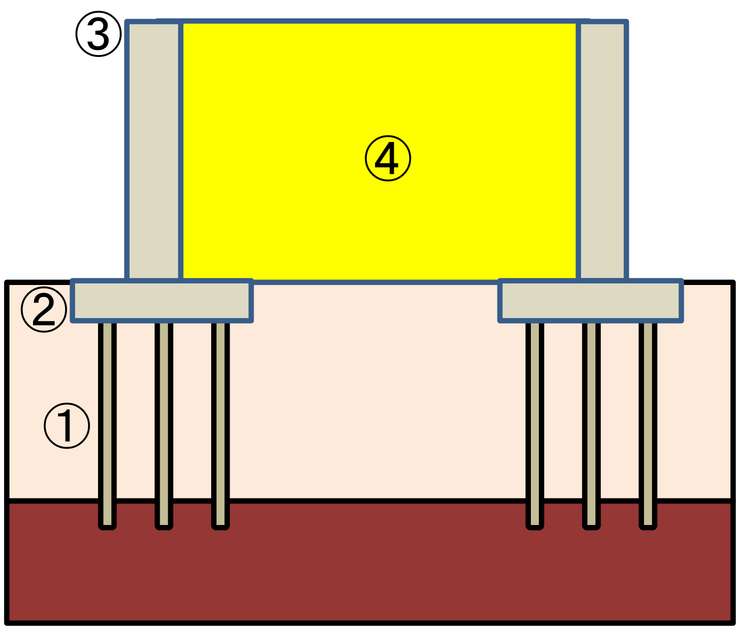
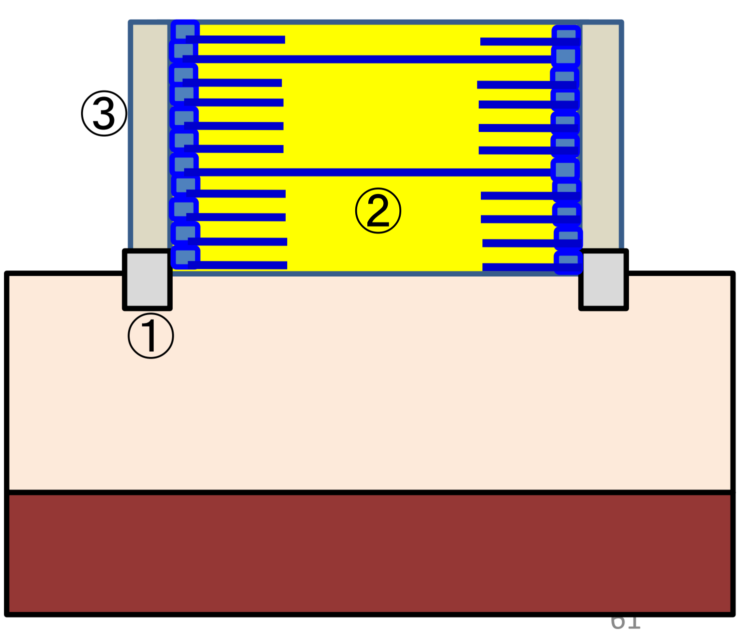
Advantage of GRS RWs in construction

Subsoil condition	Conventional RWs	GRS RWs
Extremely weak	Pile foundation and ground improvement is needed.	Ground improvement is needed.



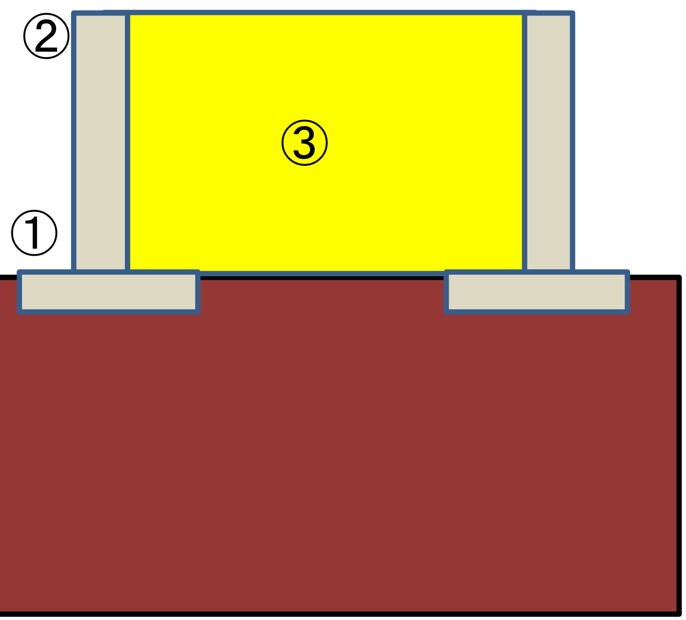


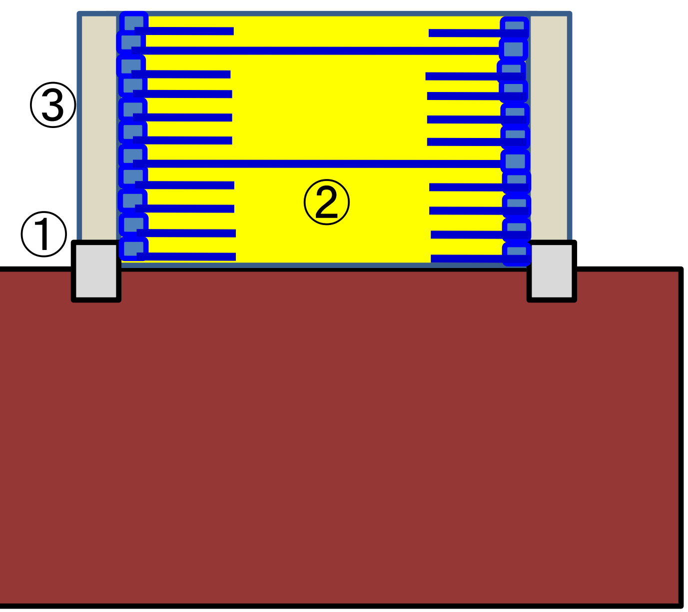
Advantage of GRS RWs in construction

Subsoil condition	Conventional RWs	GRS RWs
Relatively week	Pile foundation is needed because settlement of the RWs is not allowed.	RC facing can be constructed after settlement finished
		

Advantage of GRS RWs in construction

Subsoil condition	Conventional RWs	GRS RWs
Good	Large footing is required.	Large footing is not needed.



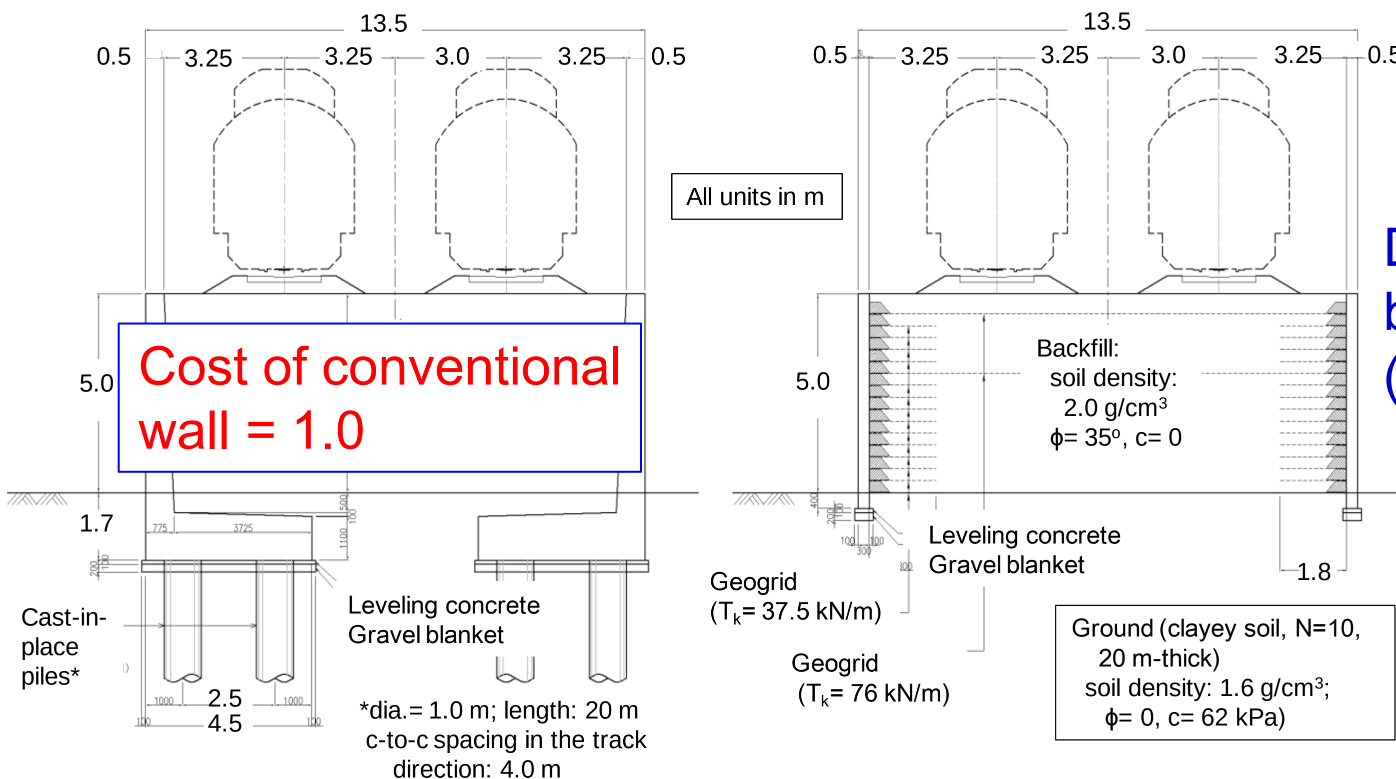


Advantage of GRS RWs in construction

Subsoil condition	Conventional RWs	GRS RWs
Extremely weak	Pile foundation and ground improvement is needed.	Ground improvement is needed.
Relatively weak	Pile foundation is needed because settlement of the RWs is not allowed.	RC facing can be constructed after settlement finished
Good	Large footing is required.	Large footing is not needed.

Cost ratio for typical GRS RW versus conventional type RW

	Construction	Maintenance	Total
20 m-thick relatively soft ground: - piles for conventional type RWs - no piles for GRS RWs (the case shown in the figure)	0.28	0.50	0.29
Relatively stiff ground: - no piles for conventional type RWs & GRS RWs	0.98	0.50	0.90



Designed by using $(k_h)_{design}$ = 0.2

(as seismic action)

Contents

1. Background (Technical issues around 1990)
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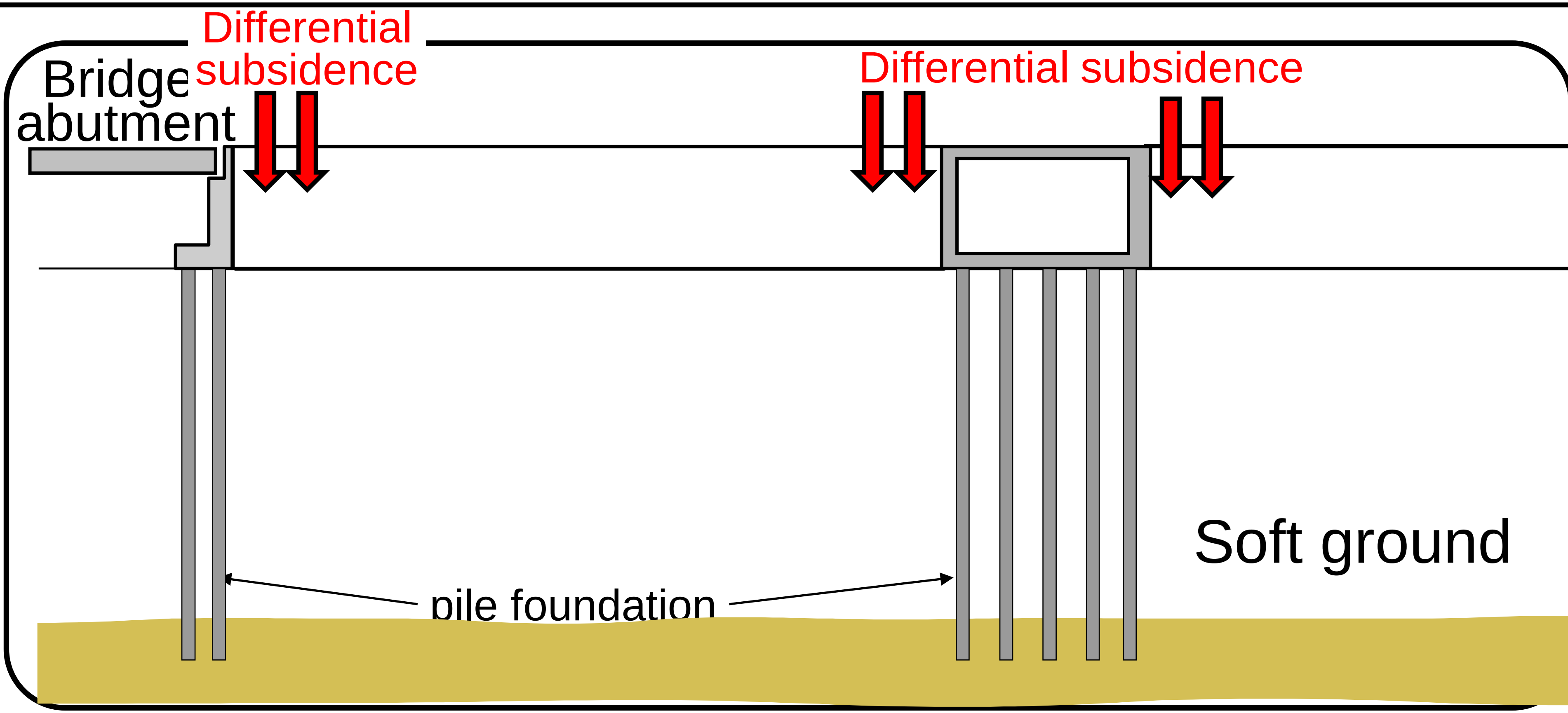
Typical differential settlement at the transition zone



- Transition zone is often suffering from differential subsidence which requires frequent maintenance works.
- Large subsidence often occurred during large earthquake
- Maintenance and reinforce of existing embankment at transition zone are still major technical issue in Japan.

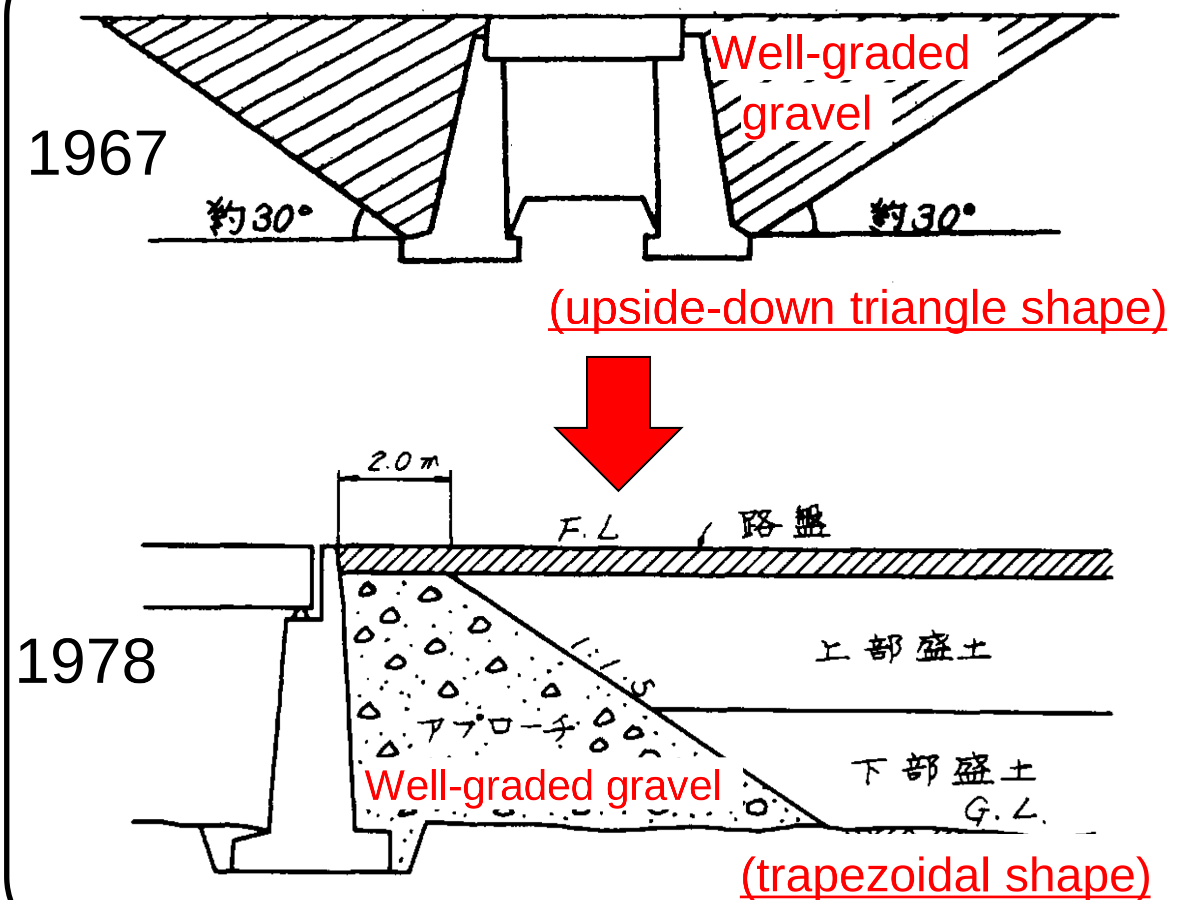
Application of GRS to the bridge abutment

In order to avoid a sudden change of the support rigidity, gravel zone was change to be trapezoidal shape

Isn't it better to apply GRS method to the transition zone?

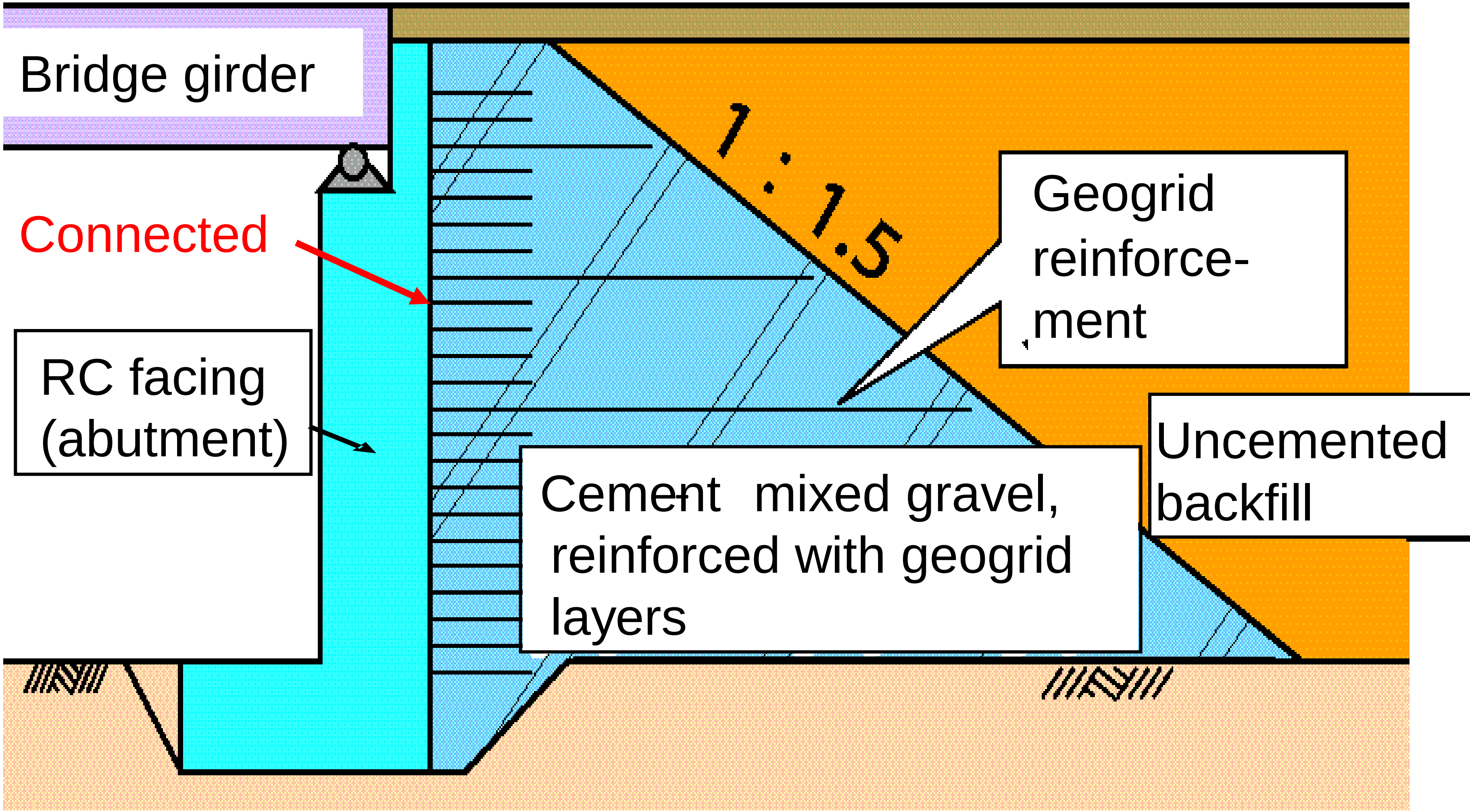
Model tests
Numerical analysis etc…

History of standard for railway structure

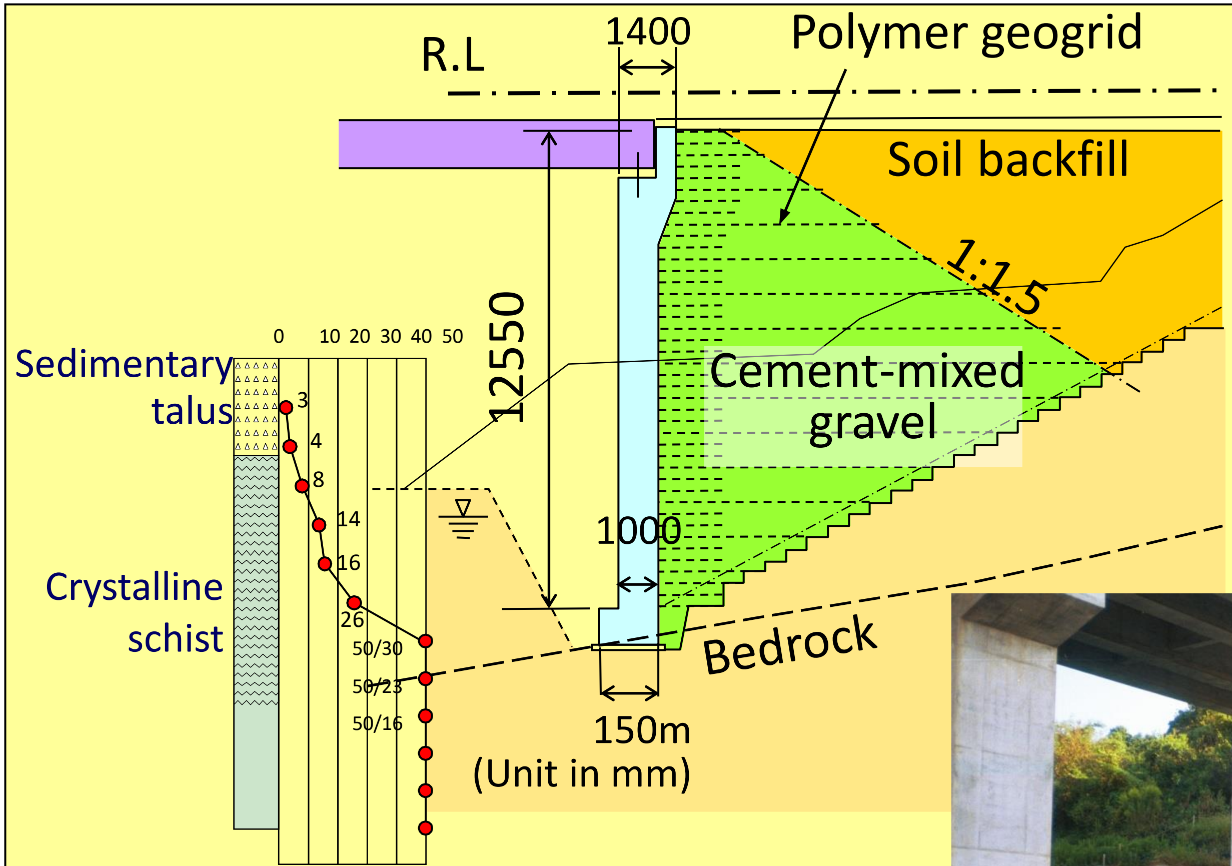


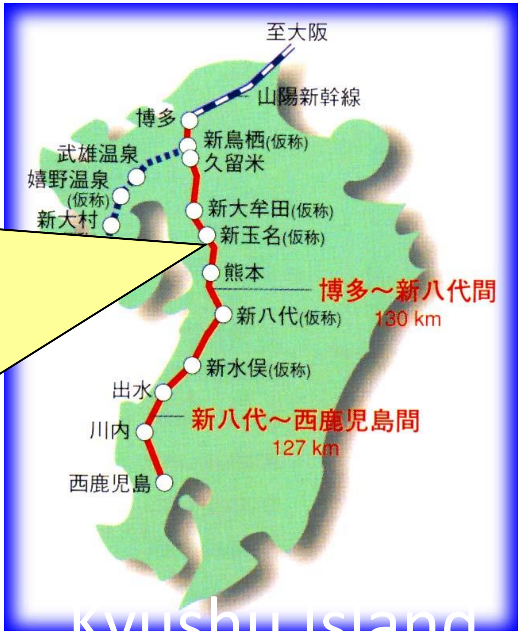
A modification of GRS-RW by

1. Placing a girder directly on the top of the facing
2. cement-mixing the backfill behind the facing.



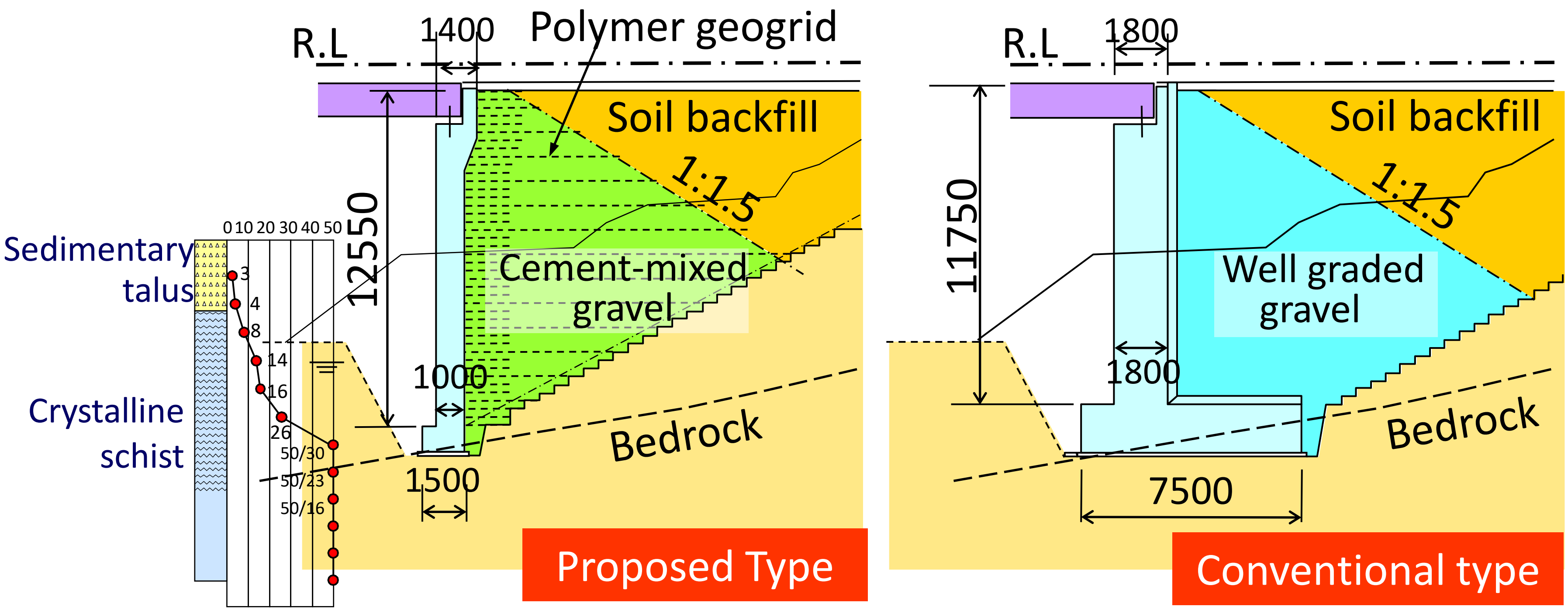
Application to the permanent structure of Shinkansen

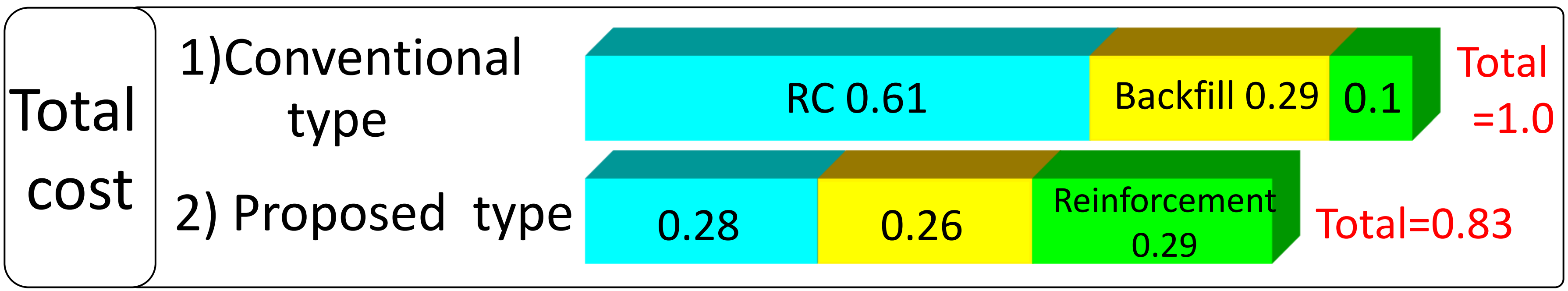




20% of cost reduction was realized by this proposed method

Conventional type versus new type (cost comparison)



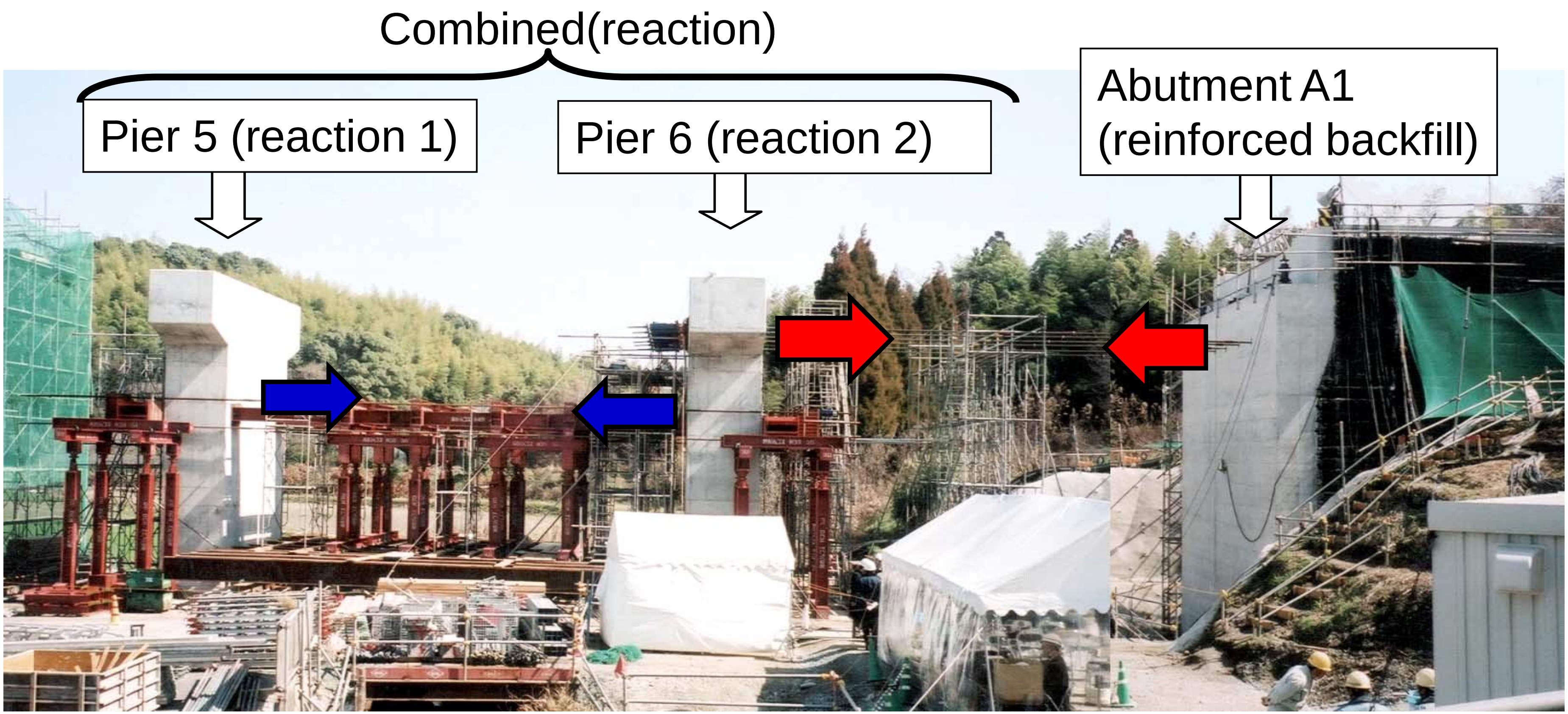


Low construction cost & High seismic stability !

Lateral loading test, 27 February 2003

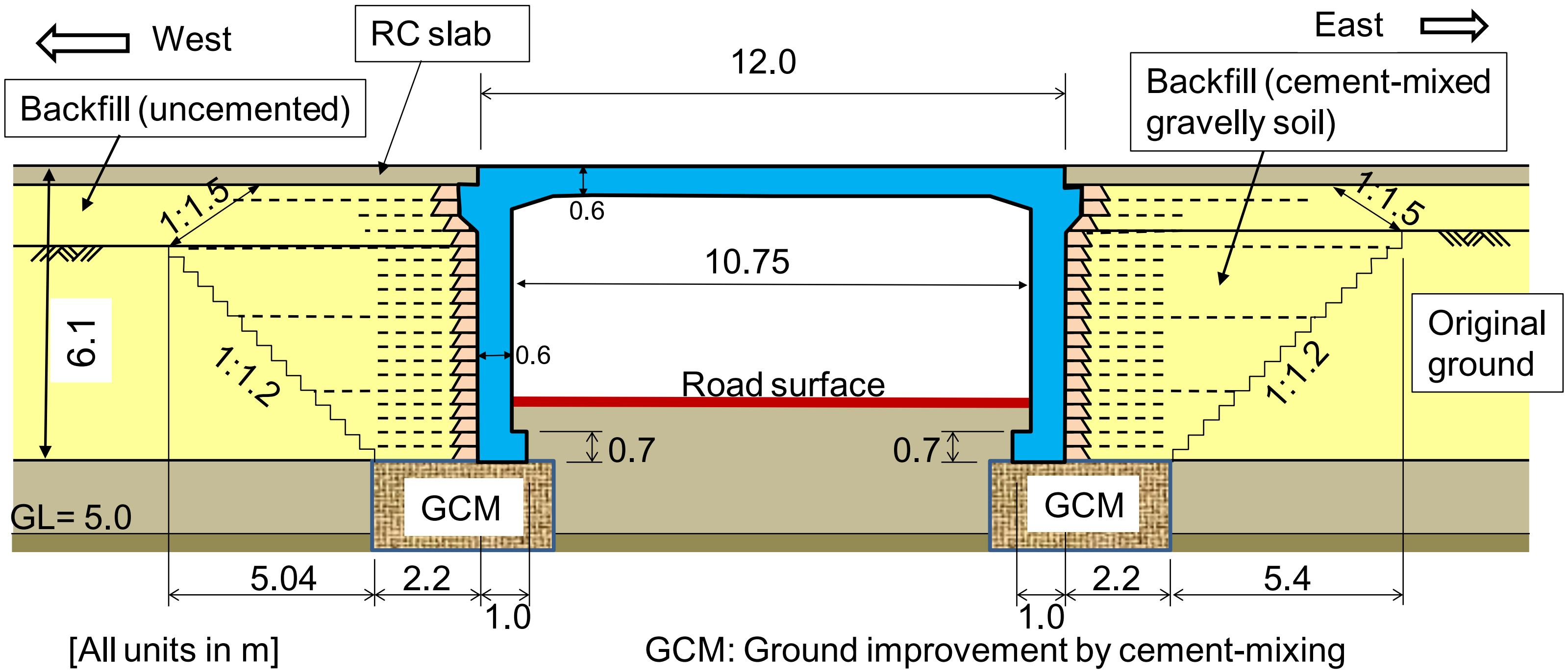
Aoki, H., Yonezawa, T., Tateyama, M., Shinoda, M. and Watanabe, K.: Development of aseismic abutment with geogrid-reinforced cement-treated backfills, *Proc. of the 16th International Conference on Soil Mechanics and Geotechnical Engineering*, pp.1315-1318, Osaka, 2005.

- Lateral loading test to ensure the connection strength and the stability of the RC facing
- Residual displacement was only 10mm after the horizontal loading (4000kN)



Aoki, H., Yonezawa, T., Tateyama, M., Shinoda, M. and Watanabe, K.: Development of aseismic abutment with geogrid-reinforced cement-treated backfills, *Proc. of the 16th International Conference on Soil Mechanics and Geotechnical Engineering*, pp.1315-1318, Osaka, 2005.

First full-scale GRS integral bridge, for a new high-speed train line, Kikonai at the south end of Hokkaido



(14th Oct. 2011).

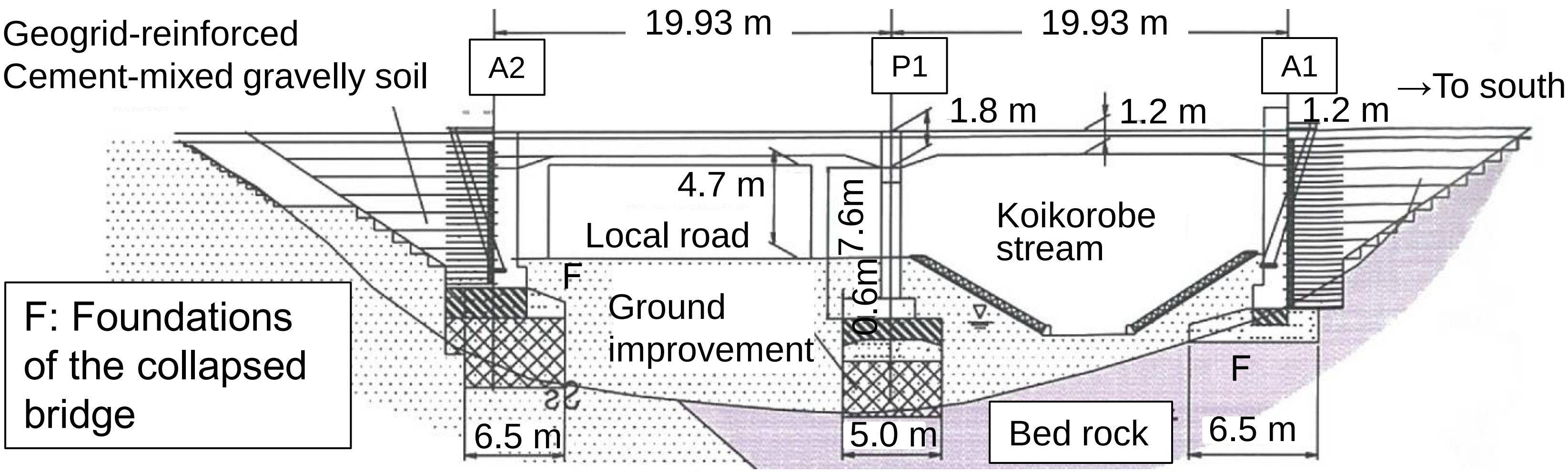
Sanriku Railway:

- constructed 30 years ago taking into account tsunami effects.
- However, three bridges were lost by the tsunami during the 2011 Great East Japan EQ.

Immediately after the earthquake at Koikoreobe

30 March 2011

GRS integral bridge at Koikorobe for Sanriku Railway

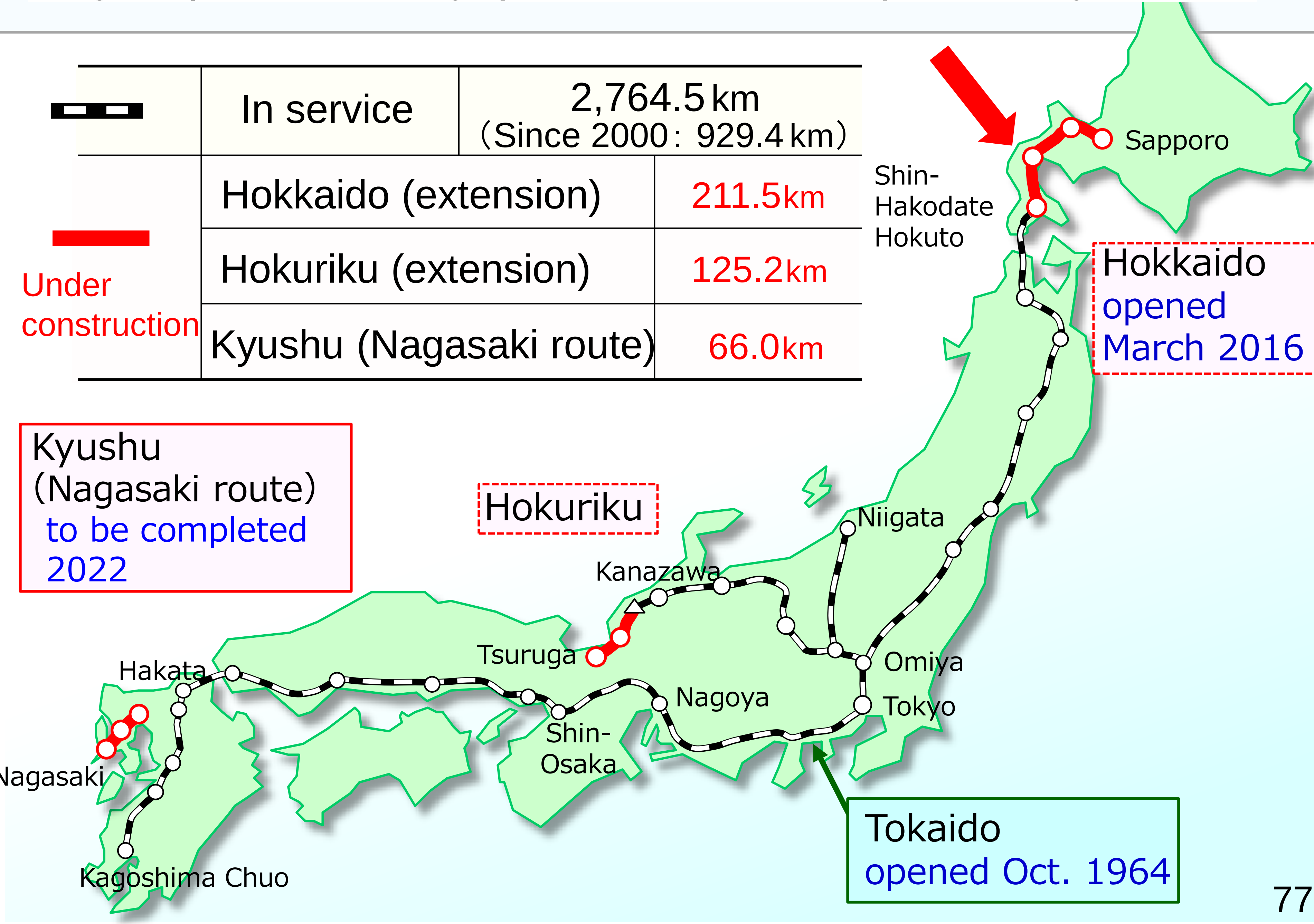


6 April 2014

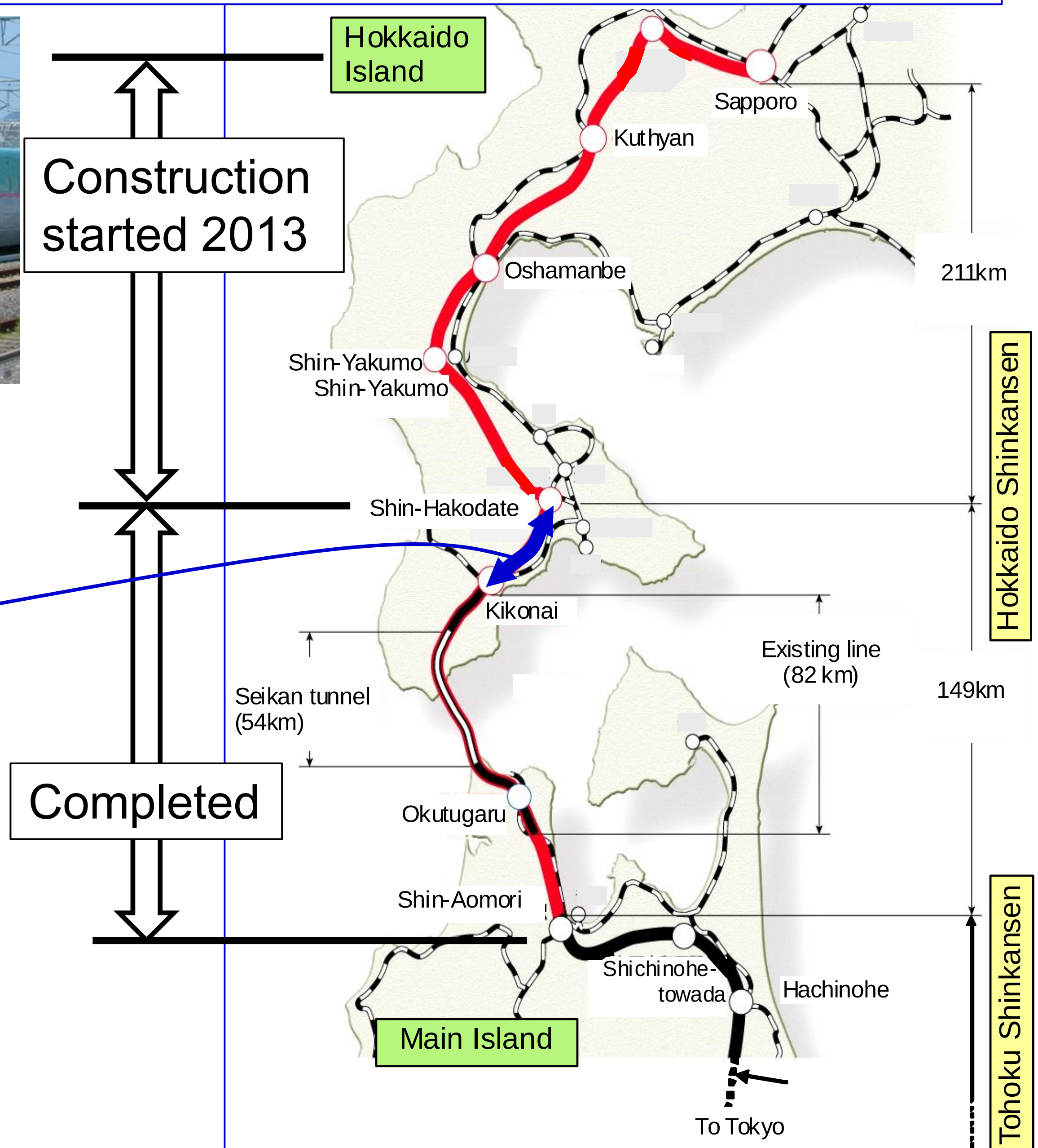
Contents

High-Speed Railway (HSR, Shinkansen), January 2017

In service		2,764.5 km (Since 2000: 929.4 km)
Under construction	Hokkaido (extension)	211.5km
	Hokuriku (extension)	125.2km
	Kyushu (Nagasaki route)	66.0km



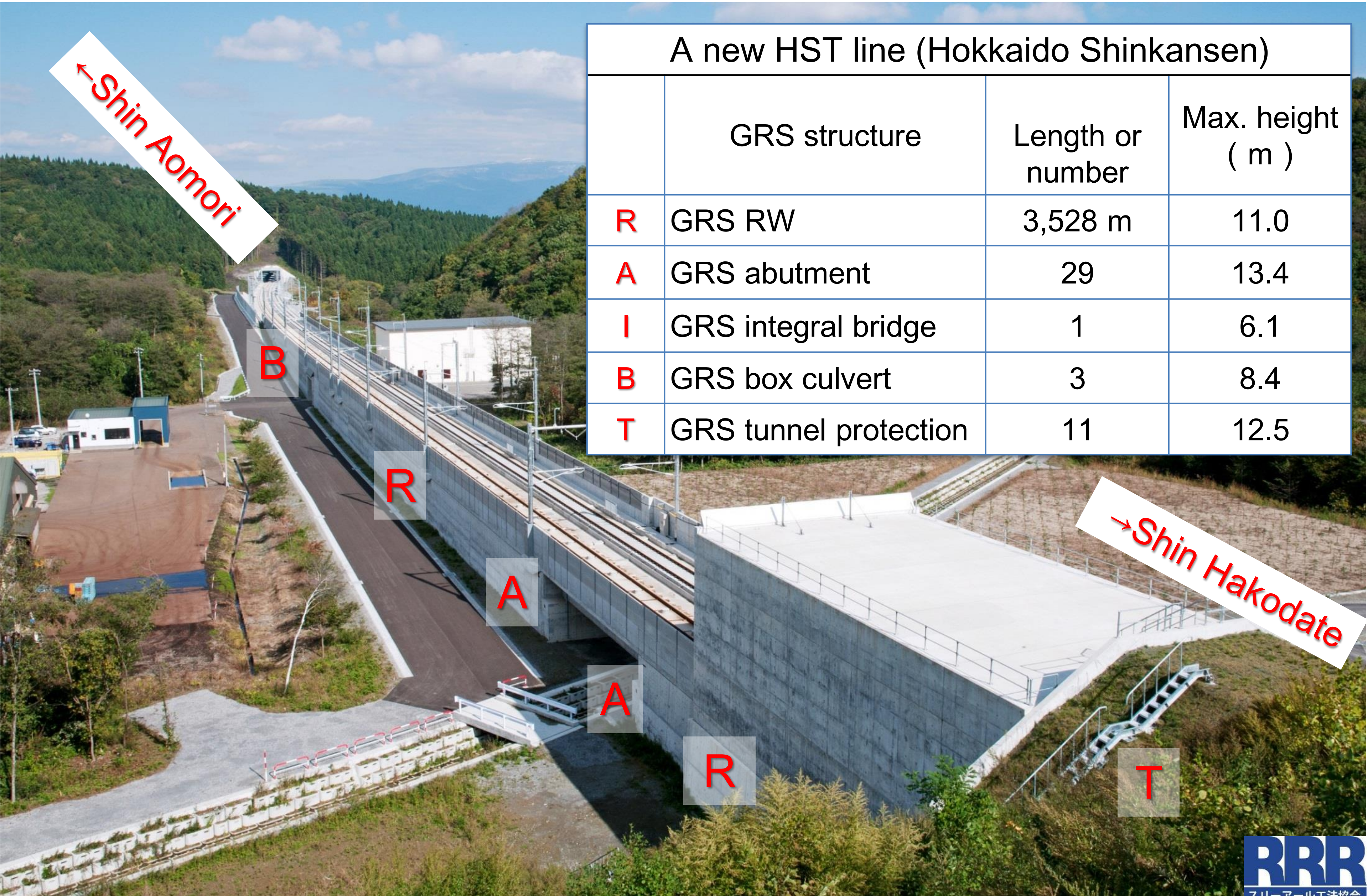
Hokkaido High-Speed Train Line (Shin-kansen)



Opened 26 March 2016

A number of GRS structures were densely constructed in place of conventional type structures

Various GRS structures at Hokkaido Shinkansen (2013)



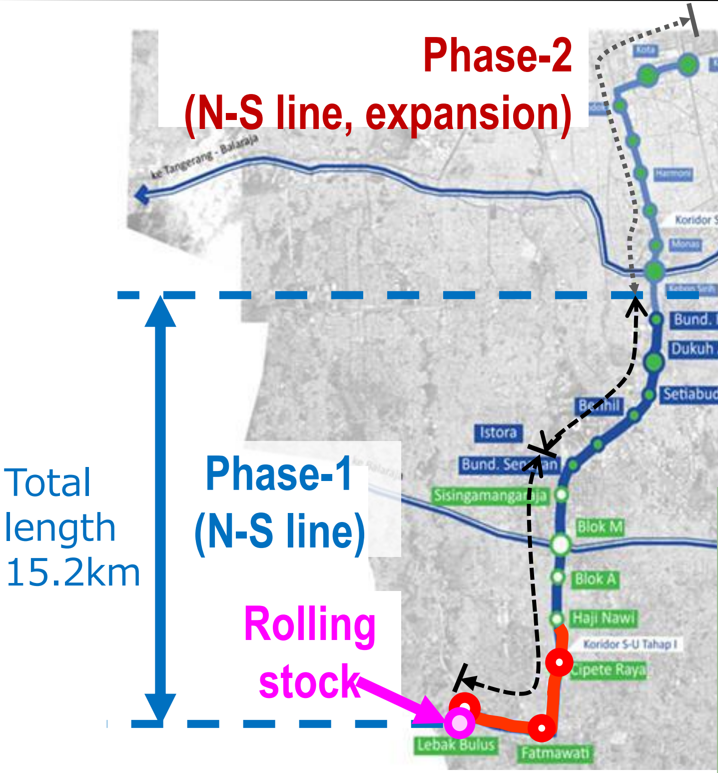
A new HST line (Hokkaido Shinkansen)			
	GRS structure	Length or number	Max. height (m)
R	GRS RW	3,528 m	11.0
A	GRS abutment	29	13.4
I	GRS integral bridge	1	6.1
B	GRS box culvert	3	8.4
T	GRS tunnel protection	11	12.5

High Speed Railway Projects on Hanoi - Vinh

Type	GRS RW
Construction	Mitsui Zosen corp. Rinkai Nissan corp. Taisei corp. Cienco 1(Vietnum)
Height	1.8～5.7 m
Length	1,485 m
Date	2013/July
Reinforcement	60 kN/m　93,000㎡
Design and management	Japan Transportation Consultants

High Speed Railway Projects on Hanoi - Vinh

MRT (Mass Rapid Transit) Projects in Jakarta - Indonesia



図ー1

Rolling stock

MRT (Mass Rapid Transit) Projects in Jakarta - Indonesia

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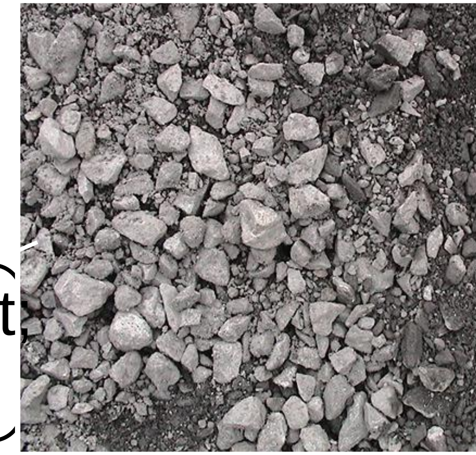
6. Overview of recent application
7. Other examples of GRS structure

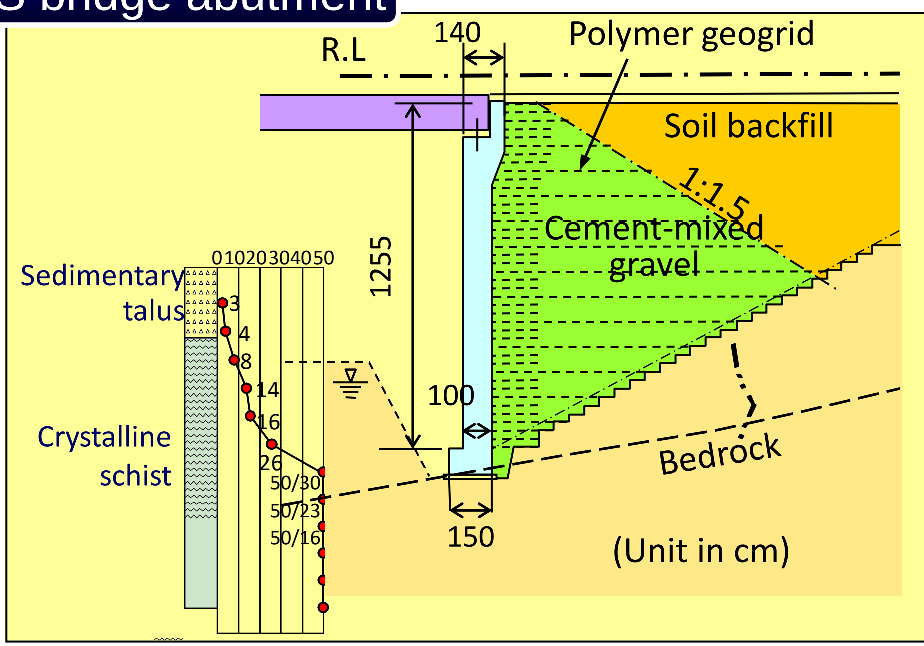
What is Cement-mixed gravel?

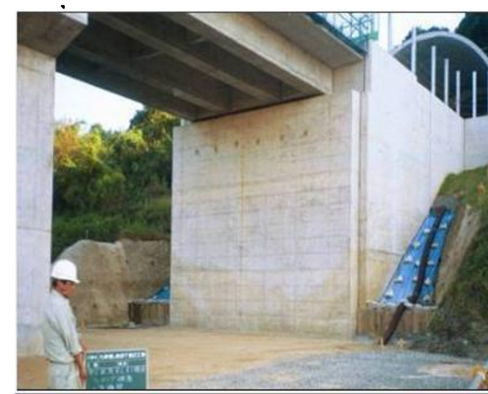
Cement-mixed gravel is often used for important structure for railway allowing a limited amount of deformation.

Well-graded gravel with a little volume of cement: geomaterial in-between soil and concrete.



GRS bridge abutment



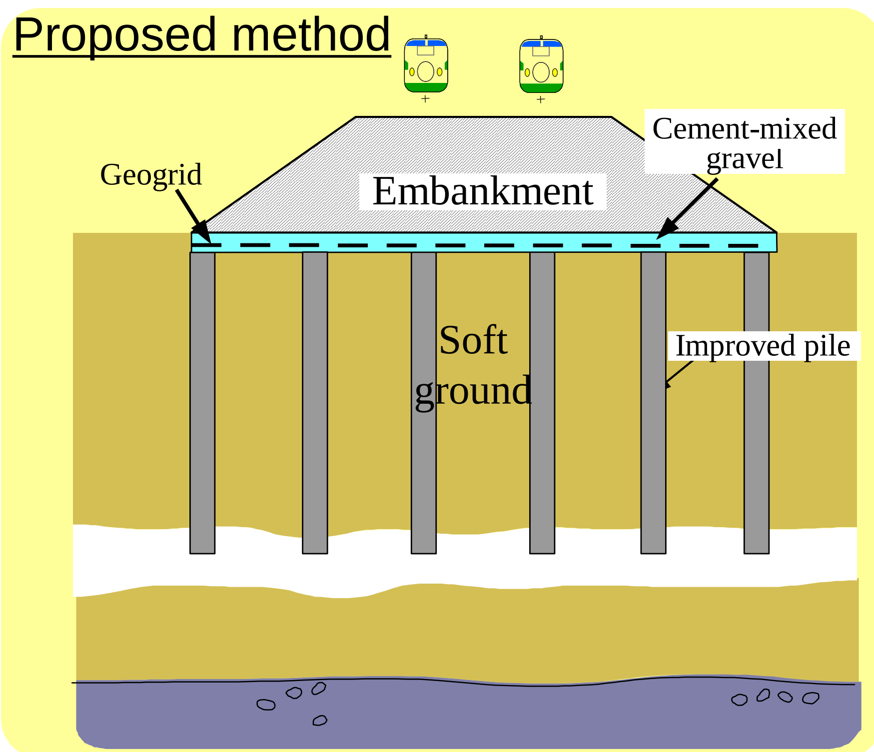


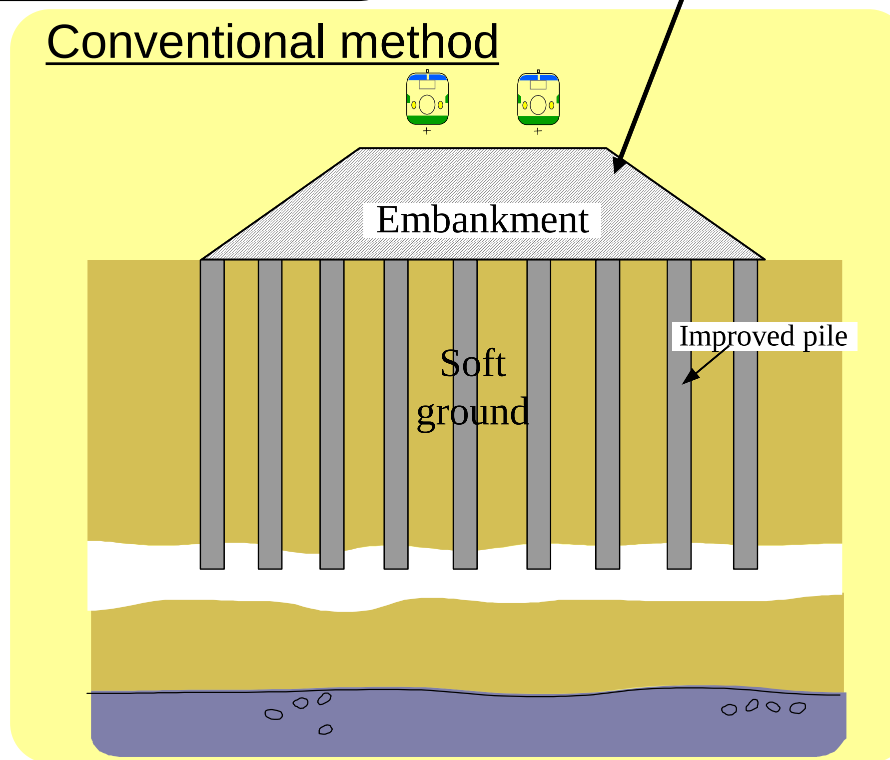
Is there any other application of this composite material?

- Applying to the construction of embankment on soft ground as bending member (slab).

Geogrid → Tension member
Cement-mixed gravel → Compression member

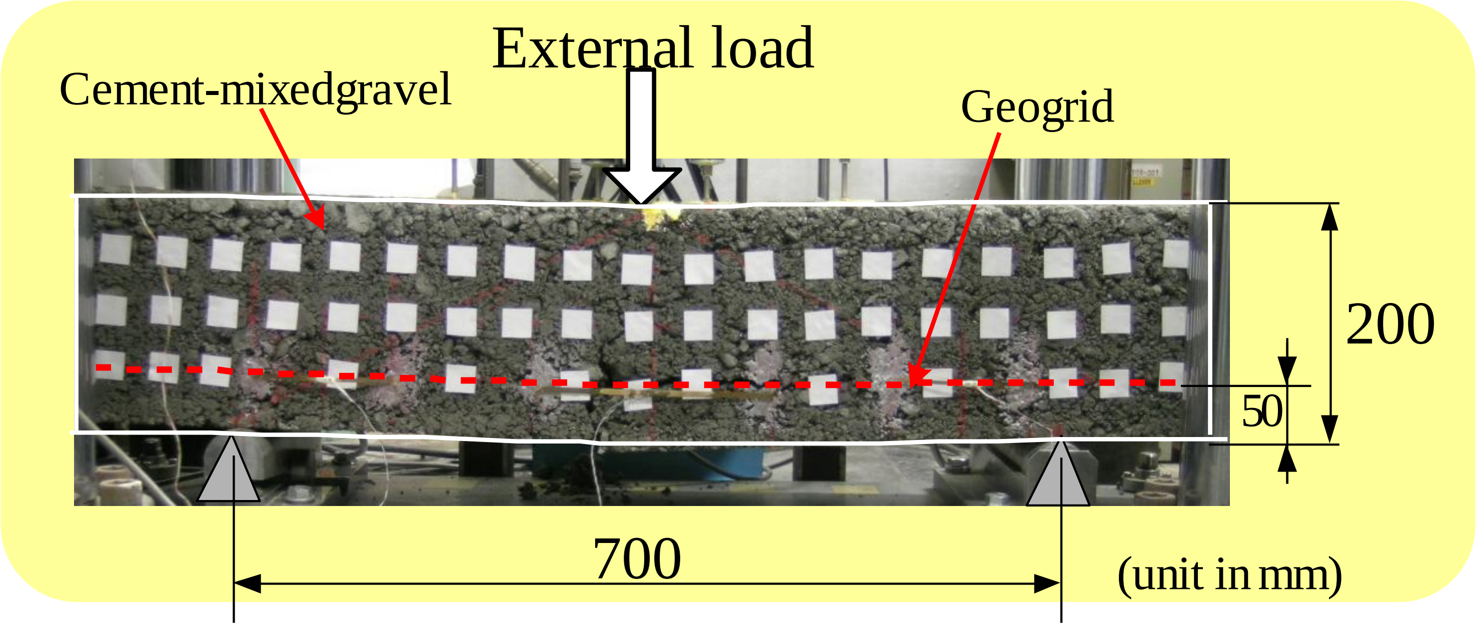
minimum improvement ratio is 25%





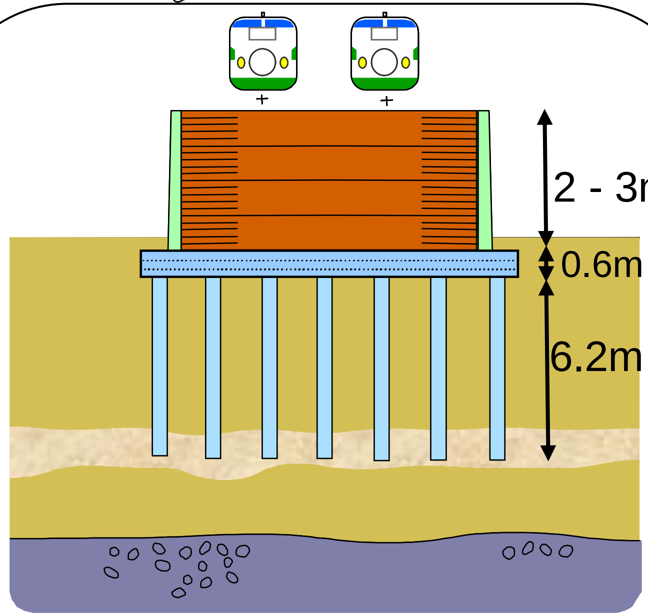
Bending loading Tests of Cement-treated gravel slab

Cement-mixed gravel	well-graded gravel, crushed sandstone cement/gravel ratio in weight : 2.5%
geogrid	polymer geogrid, tensile strength: 30 kN/m
specimen	two rectangular parallelepiped specimens with geogrid and without geogrid



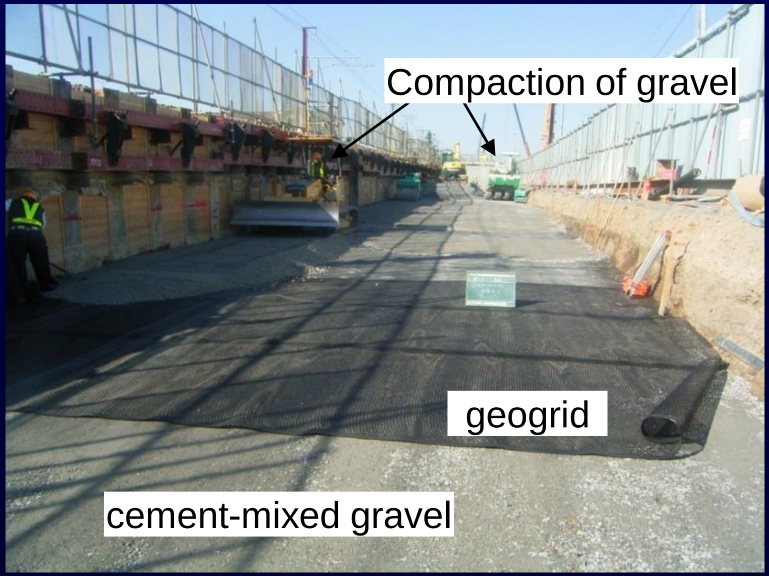
Application for the actual project (1)

Construction of embankment on soft ground at Japan railway



Volcanic clay (N-value: 2 -10)
φ=1.2m, L=6.2m
Improvement ratio: 10-14%

<After the ground improvement>

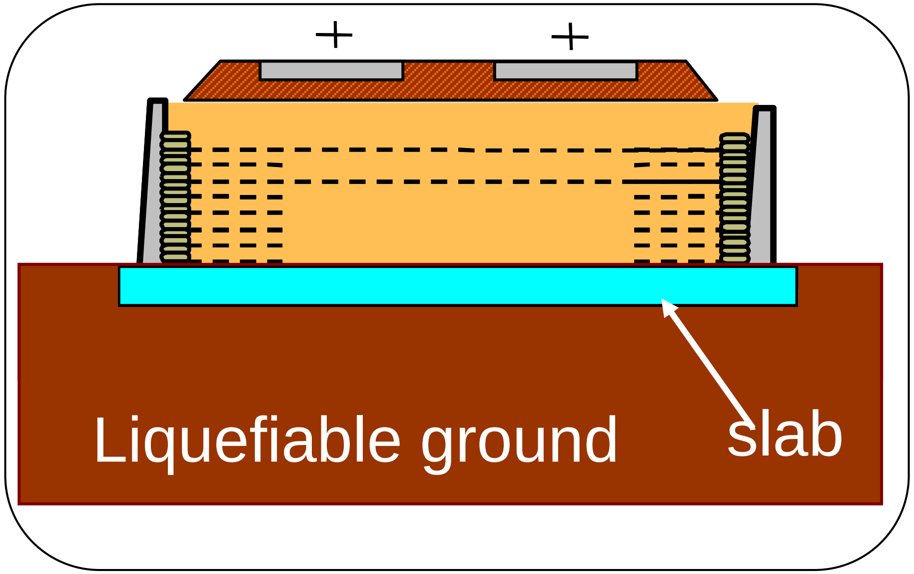


<Construction of the slab, 2009/4>

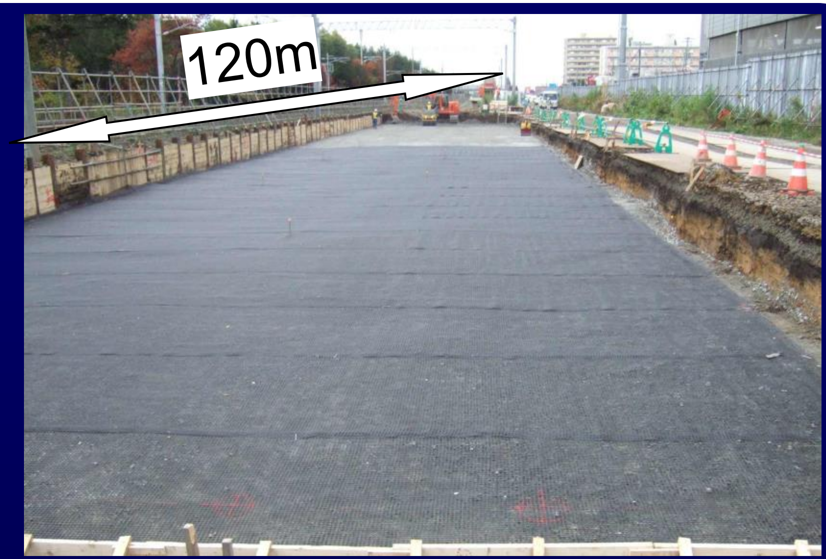
This composite material could be constructed much easier and faster than RC.
50% of cost reduction was realized by this method

Application for the actual project (2)

Construction of embankment on liquefiable ground



By allowing a slight global subsidence (=even subsidence) after the earthquake, the embankment was constructed without ground improvement.

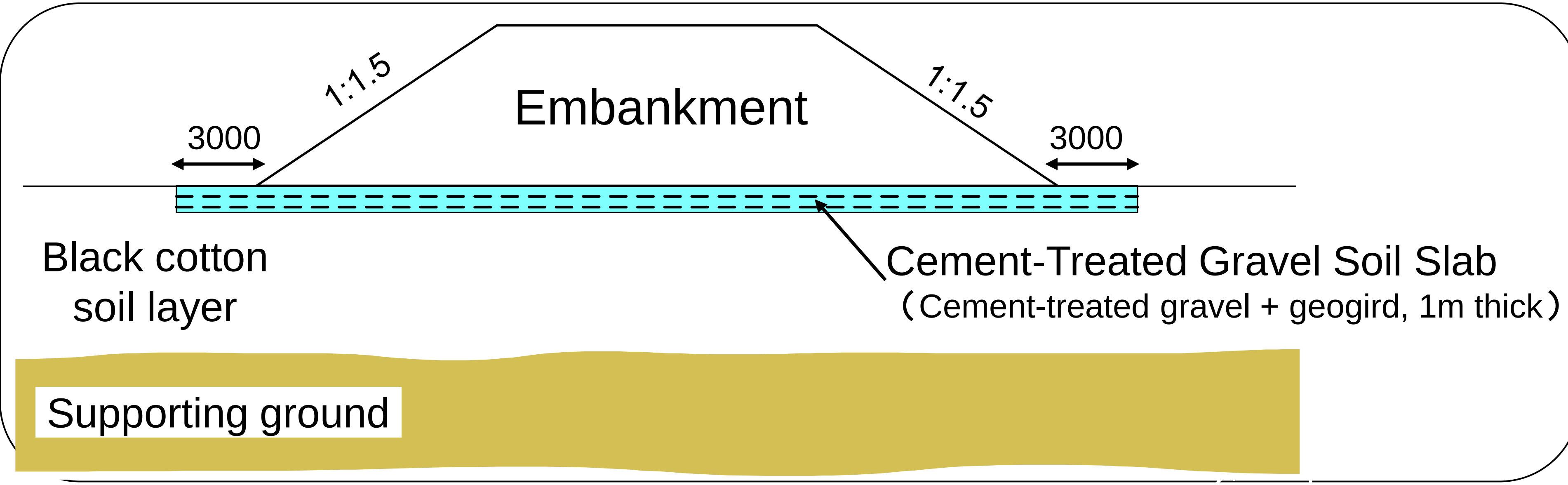


<Arrangement of geogrid >

< Construction of the slab>

Possible application in India

Construction of embankment on ‘Black cotton soil’

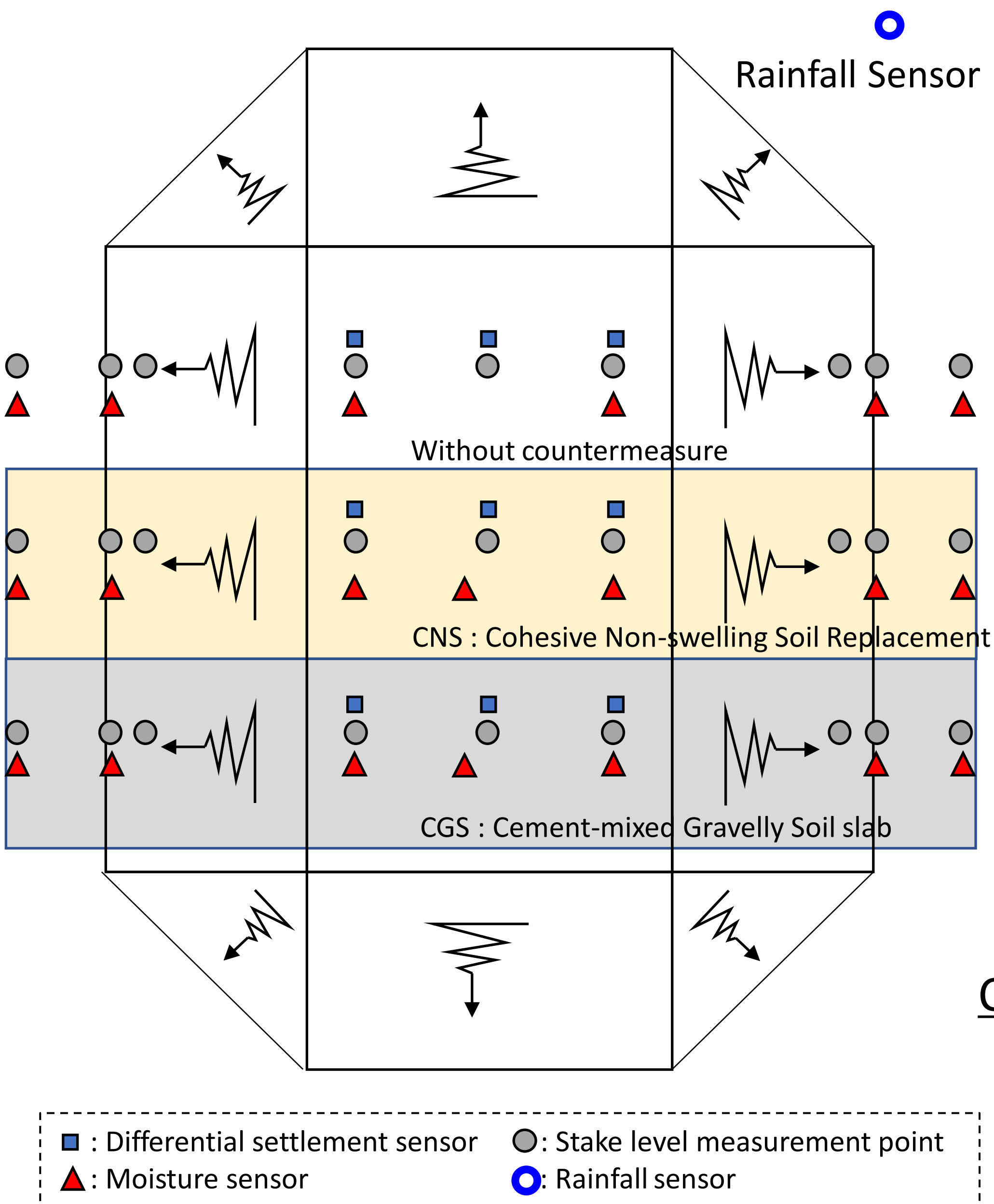


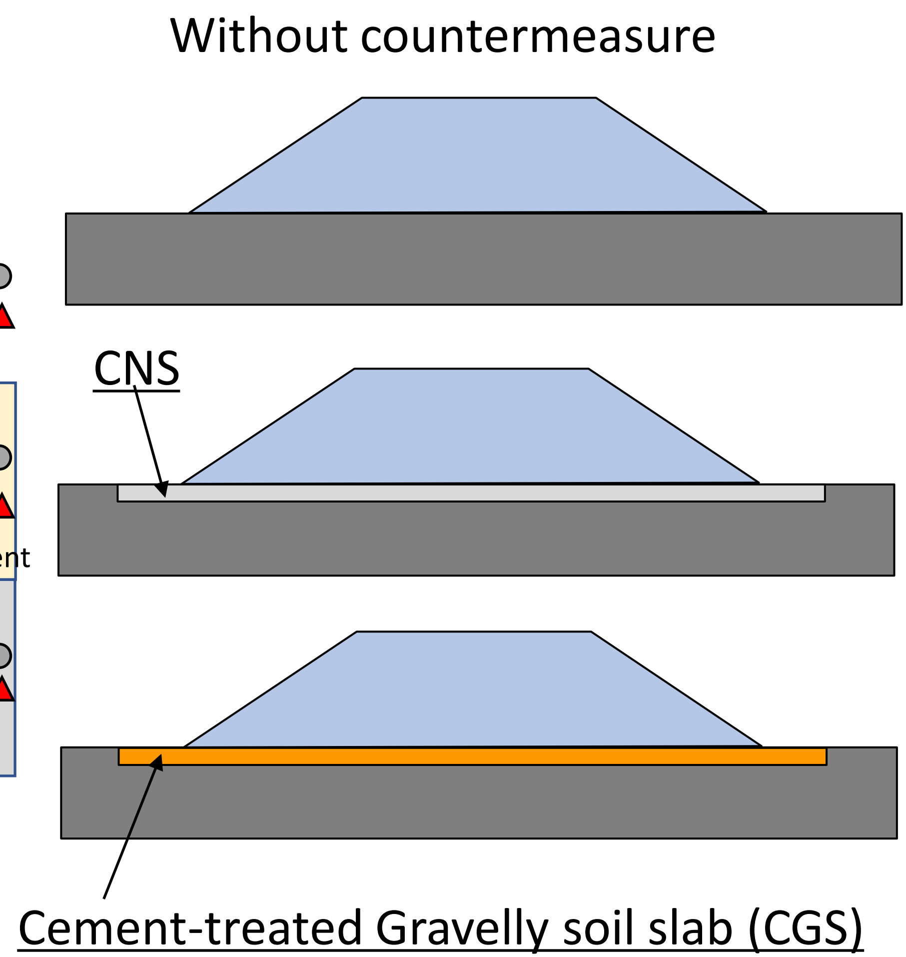
High bending stiffness and low permeability

➡ Test embankment (h=6m) at Vadodara (Amod)

Test embankment on Black Cotton soil (Vadodara)

Test embankment on Black Cotton soil (Vadodara)





Test embankment on Black Cotton soil (Vadodara)

Arrangement of geogrid in CGS improvement layer

Test embankment on Black Cotton soil (Vadodara)

12/7/2016

11/10/2017

Technical meeting @ IIT Gandhinagar

13/7/2016

Conclusion

- GRS-RW with full height rigid facing have been constructed as important permanent structure, mainly for railways including high-speed railway (Shinkansen)
- This is due to its cost-effectiveness by high performance and low life cycle cost
- There are two key aspects of this technique
  - Full-height rigid facing (connected firmly to geosynthetics)
  - Staged construction (constructing the backfill first!)
- This technique was applied to bridge abutment and bridge and have already become common technique
- Cement-mixed gravel slab can be the one of the rational method to construct railway embankment on black cotton soil.

Thank you for your attention!

The University of Tokyo

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