ISSMGE Webinar
2020

Geosynthetic-Reinforced Soil Structures – Developments from Walls to Bridges – Digest

Fumio Tatsuoka

Professor Emeritus
University of Tokyo and Tokyo University of Science, Japan

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Geosynthetics-Reinforced Soil Structures - Developments from Walls to Bridges- | ISSMGE

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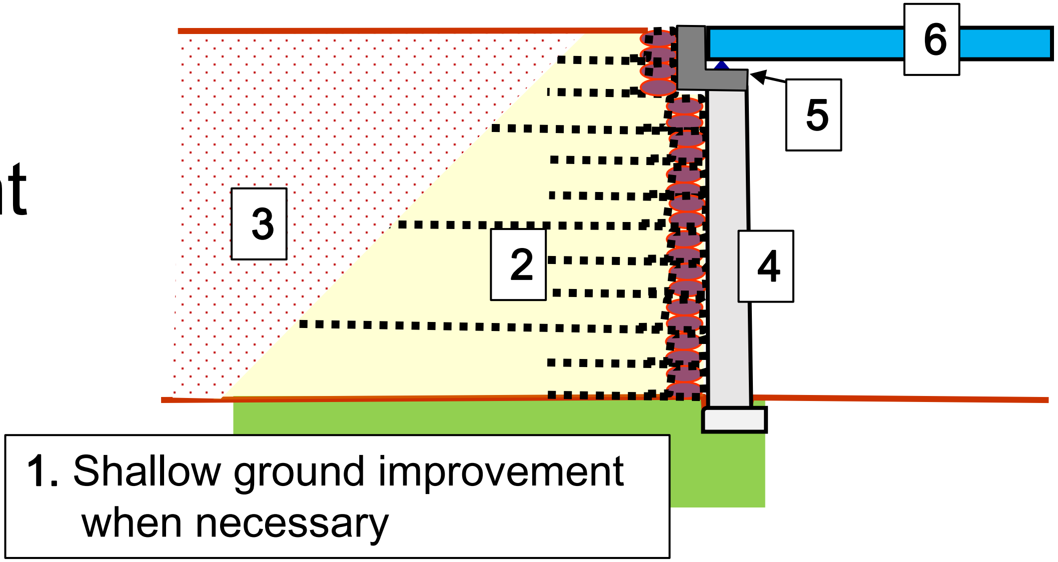
GRS Bridge Abutment



13.4 m-high, Mantaro site

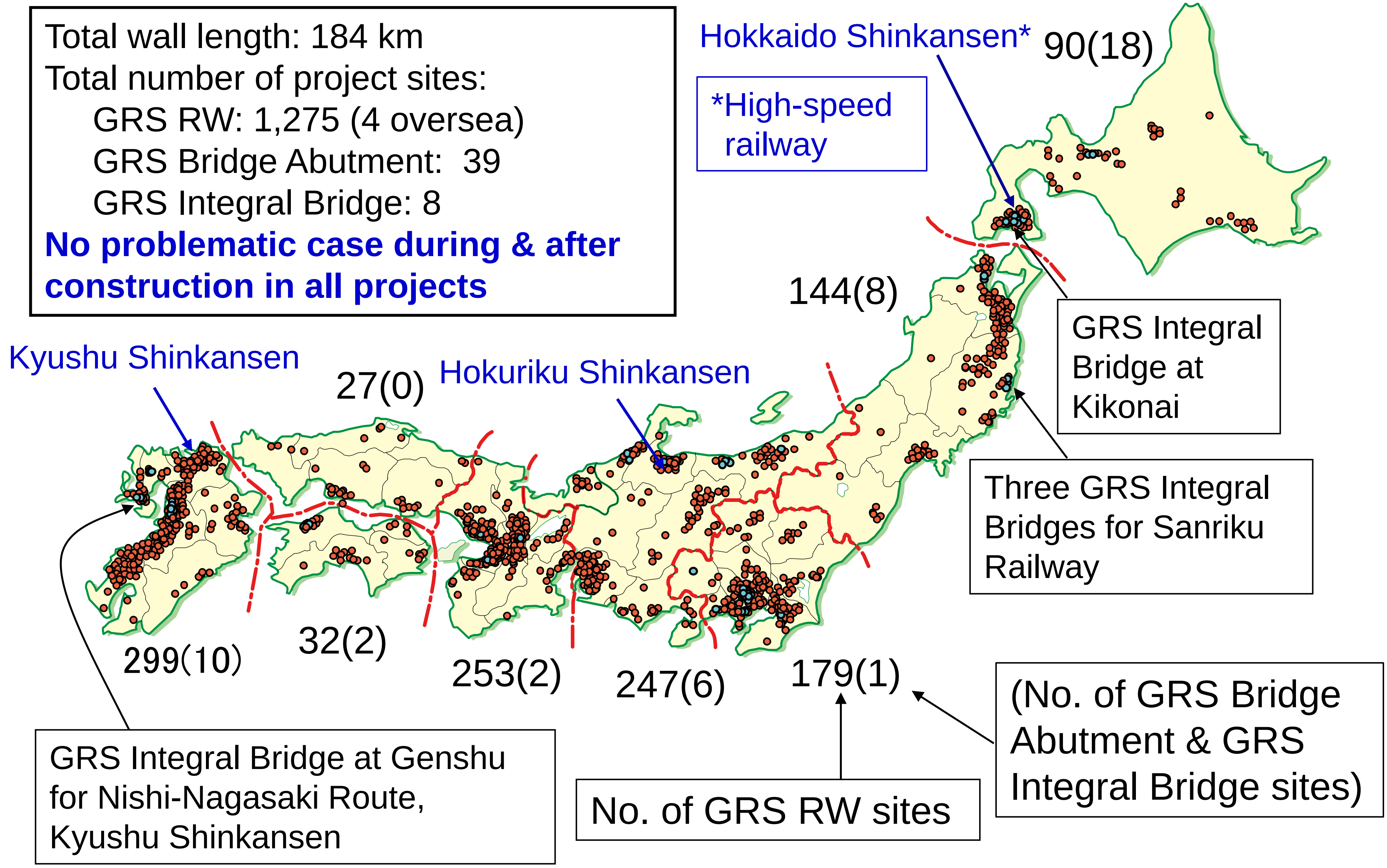
Under construction
Oct. 2011

Completed
Aug. 2012

Construction sites of GRS RWs with FHR facing & the related other GRS structures (as of June 2019)

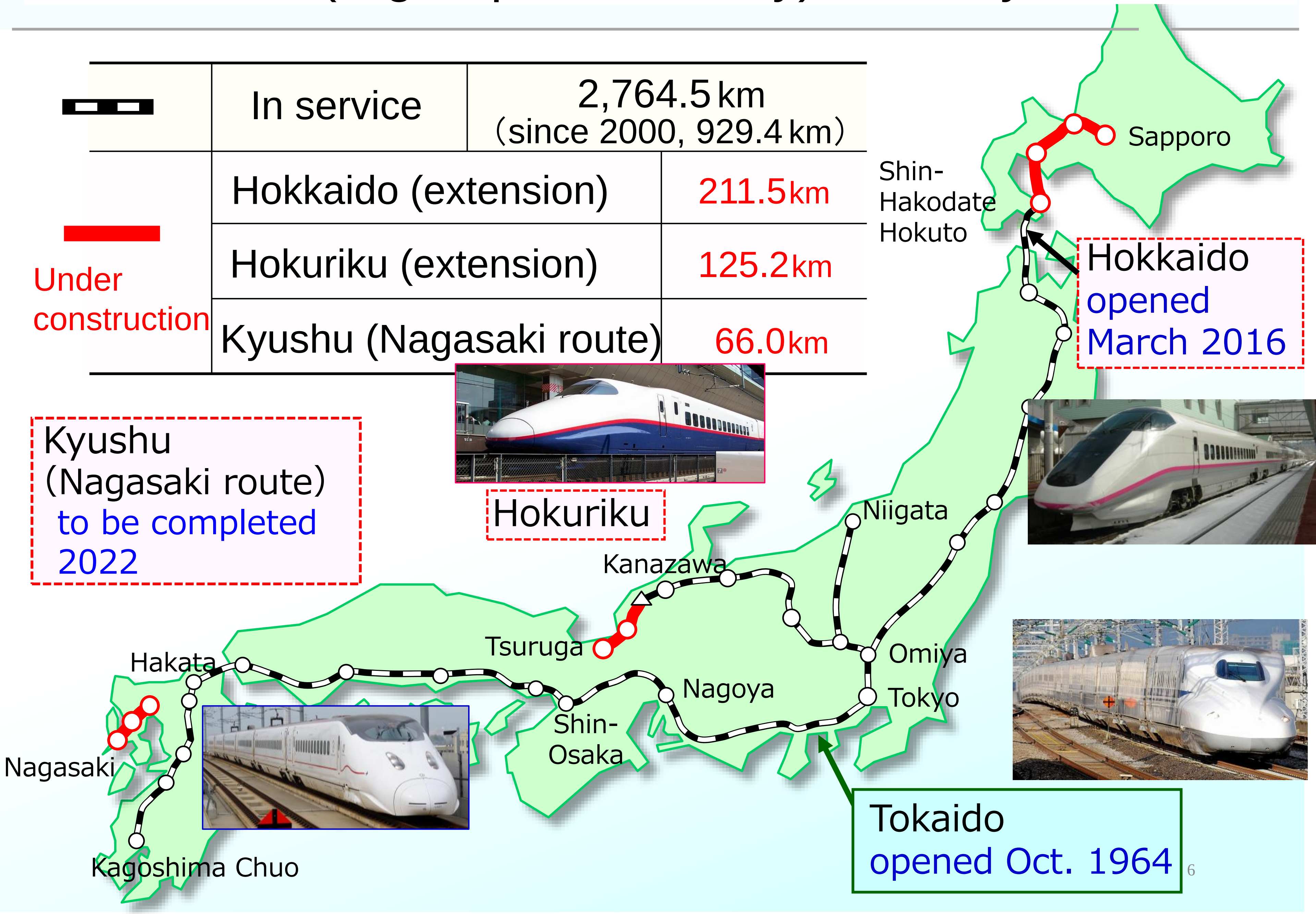
Total wall length: 184 km
Total number of project sites:
- GRS RW: 1,275 (4 oversea)
- GRS Bridge Abutment: 39
- GRS Integral Bridge: 8

No problematic case during & after construction in all projects



Shinkansen (High Speed Railway), January 2019

(black/white dashed line)	In service	2,764.5 km (since 2000, 929.4 km)
Under construction (red line)	Hokkaido (extension)	211.5 km
	Hokuriku (extension)	125.2 km
	Kyushu (Nagasaki route)	66.0 km



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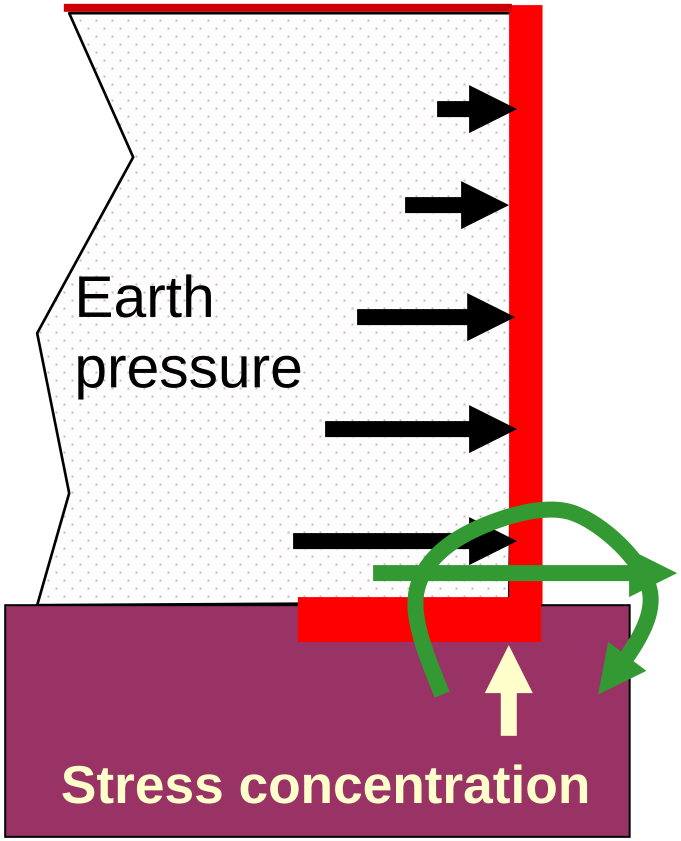
Conventional RW is a cantilever structure

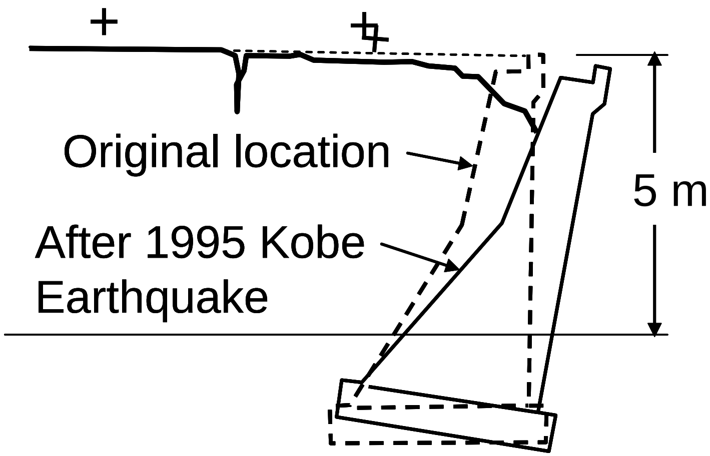


- Large forces in the facing
- Large overturning moment & large lateral load at the facing base

Need for a massive strong facing structure and
a pile foundation

Relatively unstable, particularly against seismic loads

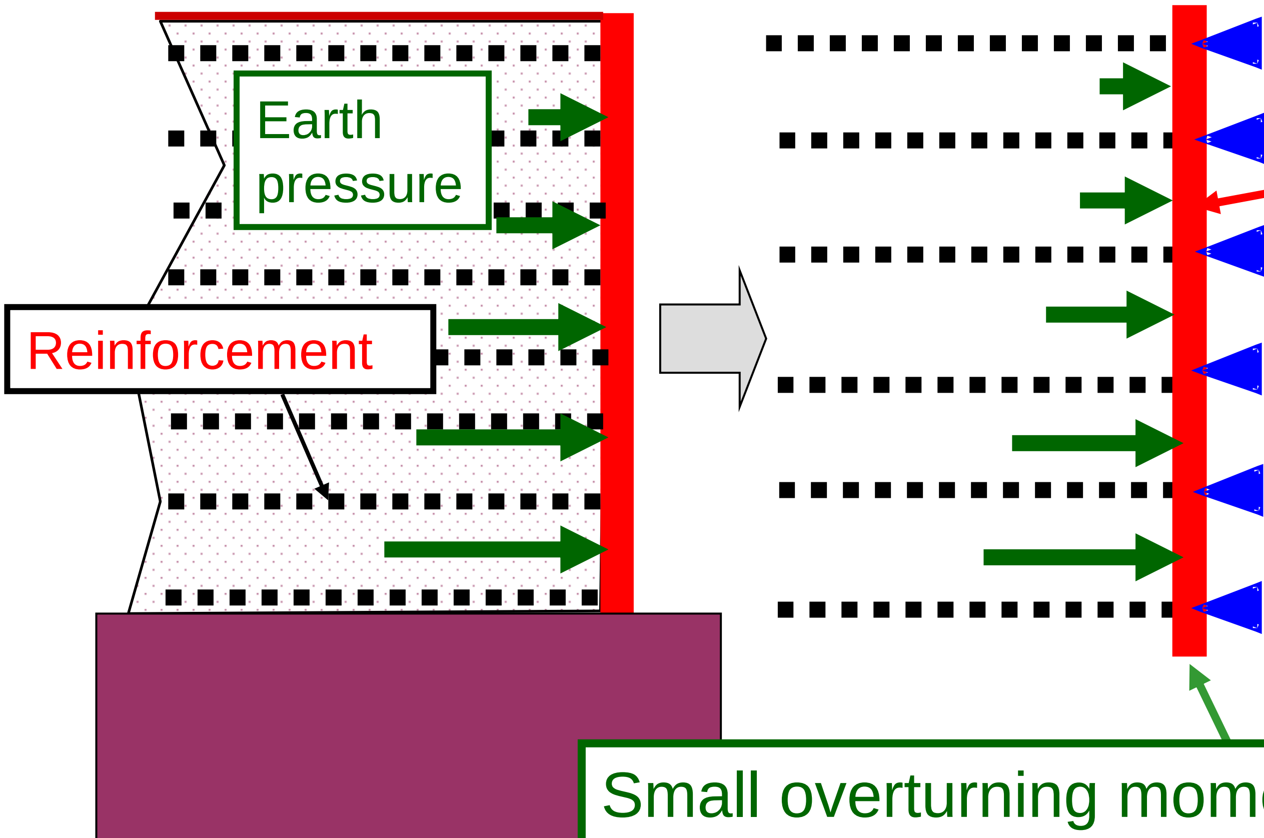
1995 Kobe Earthquake
Collapse of gravity type walls at Ishiyagawa



Collapse of gravity type walls, despite seismic design using k_h= 0.2 with $(F_s)_{allowable}$= 1.5

GRS RW with full-height rigid (FHR) facing:

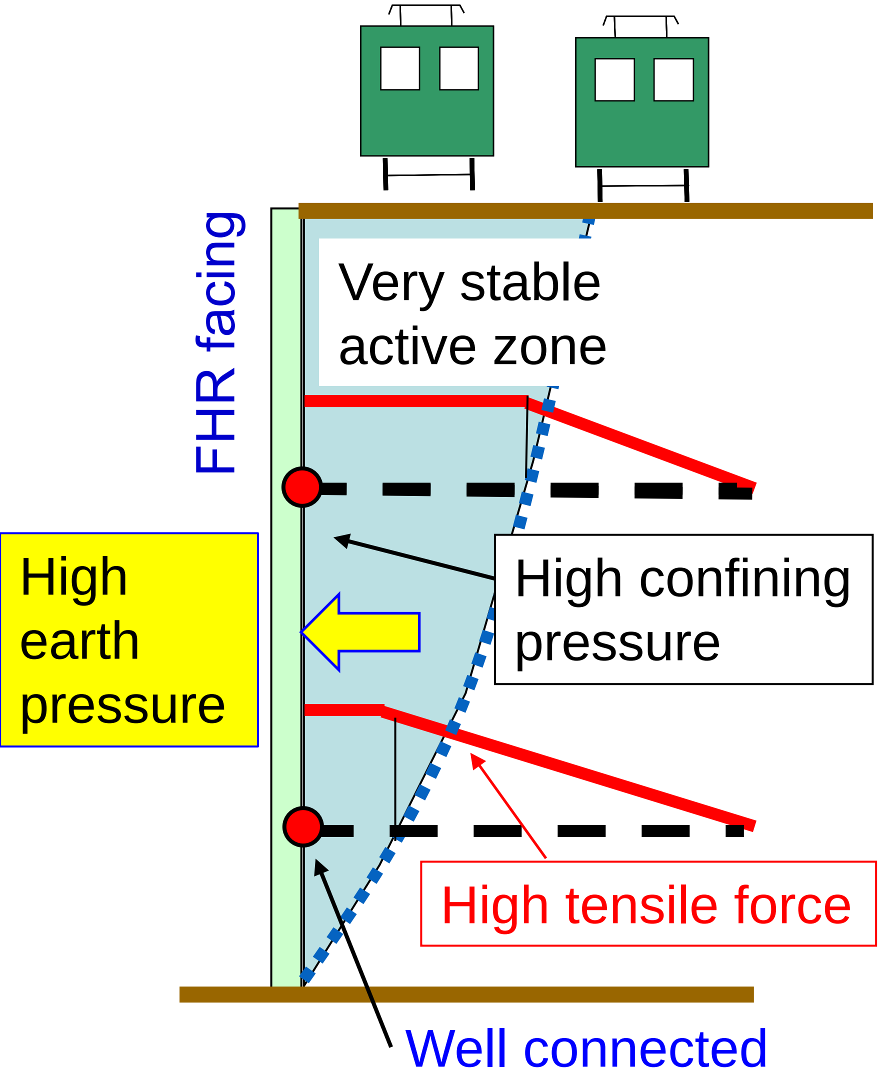
FHR facing is “a continuous beam supported by many reinforcement layers at a small span”



Very small forces in the facing
⇒ a simple facing structure

Small overturning moment & lateral force at the facing base
⇒ no need for a pile foundation
⇒ stable, particularly against seismic loads

Importance of firm connection between FHR facing and reinforcement layers



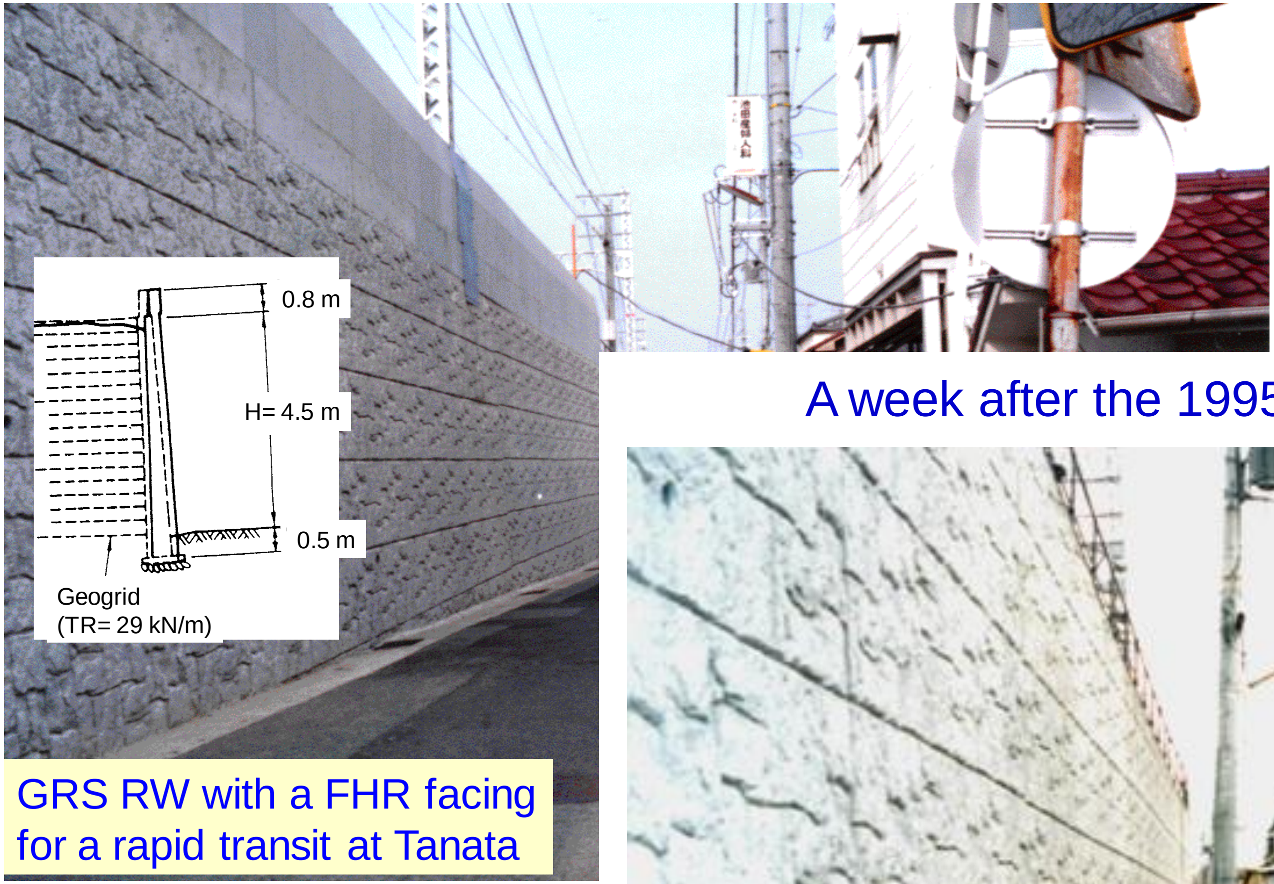
→ High earth pressure at the wall face

→ High tensile forces in the reinforcement

→ In the active zone, high confining pressure, therefore, high strength & stiffness of the backfill

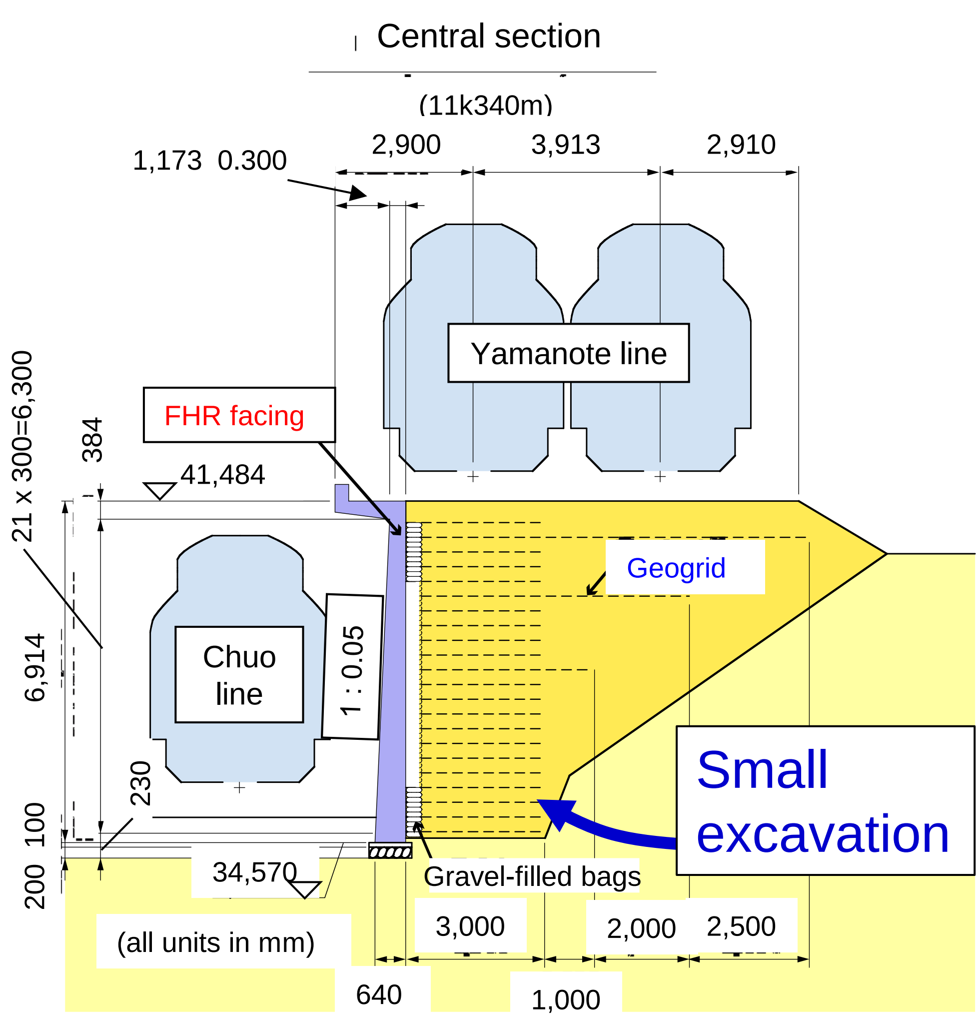
→ High stability of the wall

Immediately after completion, 1992



A week after the 1995 Kobe Earthquake

GRS RW with FHR facing supporting very busy urban railway



Near Shinjuku Station, Tokyo, constructed during 1995 – 2000

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4. **Advantages of staged-construction of FHR facing**

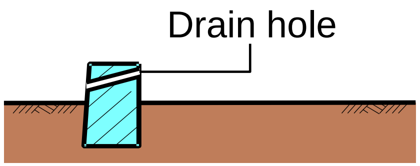
5. GRS Bridge Abutment and GRS Integral Bridge

6. Collapse of soil structures by earthquakes, floods and tsunami and restoration to GRS structures

7. Concluding remarks

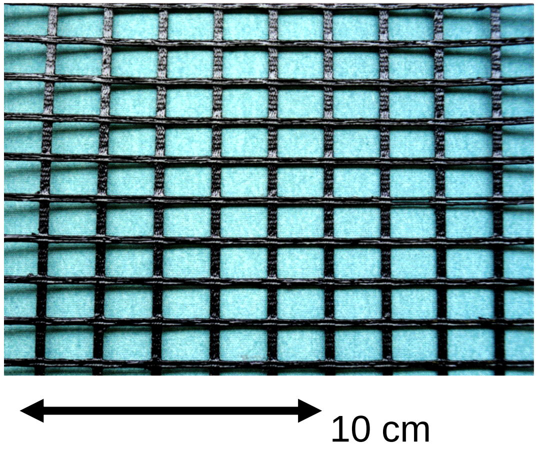
Staged construction: 1) & 2)

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



1) Levelling pad for facing

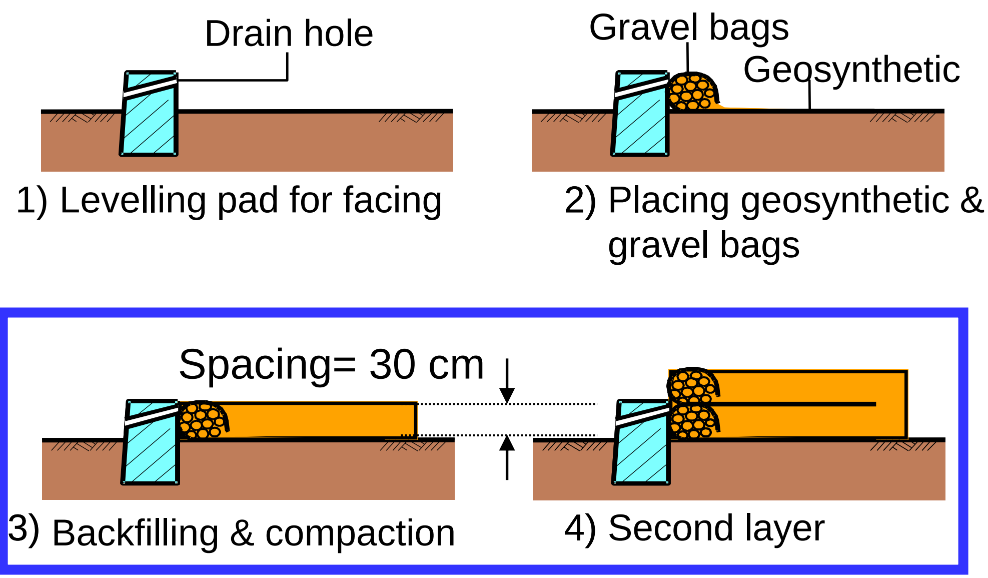
2) Placing geosynthetic & gravel bags



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

Staged construction: 3) & 4)

- Compaction of backfill with a help of gravel bags placed at the shoulder of each soil layer

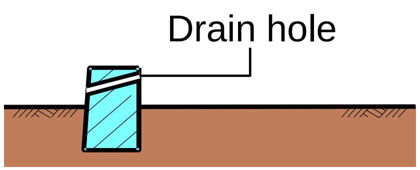


Good compaction of the backfill by:

1) a small lift (15 cm) resulting from a small vertical spacing (30 cm) of geogrid layers; and
2) no rigid facing during backfill compaction

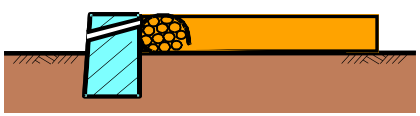
Staged construction: 5)

- Completing the full-height wall without FHR facing

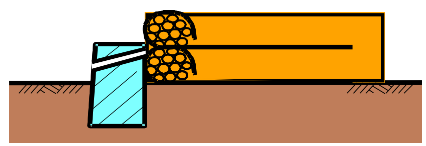


1) Levelling pad for facing

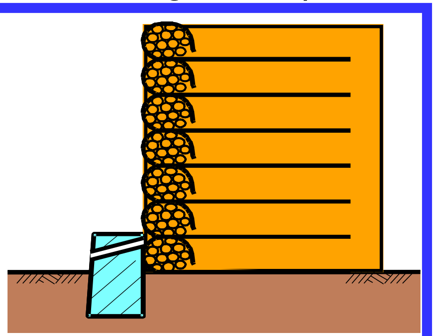
2) Placing geosynthetic & gravel bags



3) Backfilling & compaction



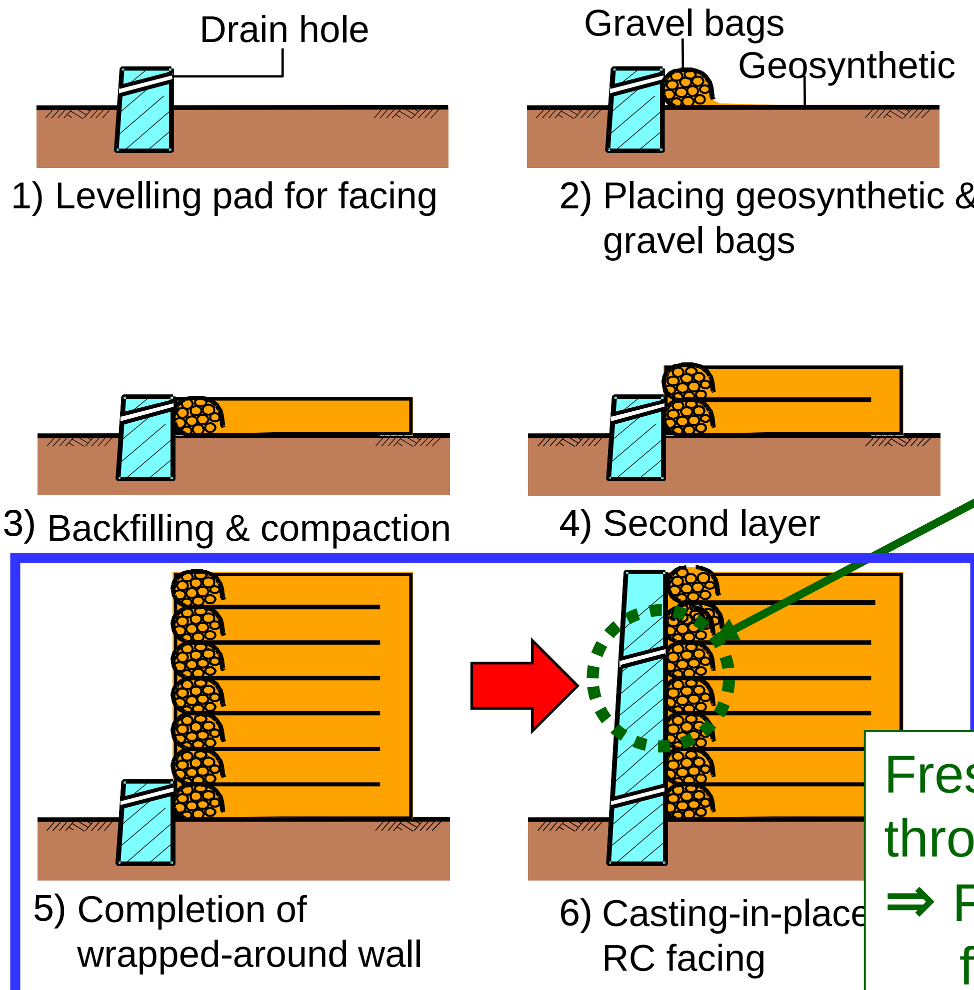
4) Second layer

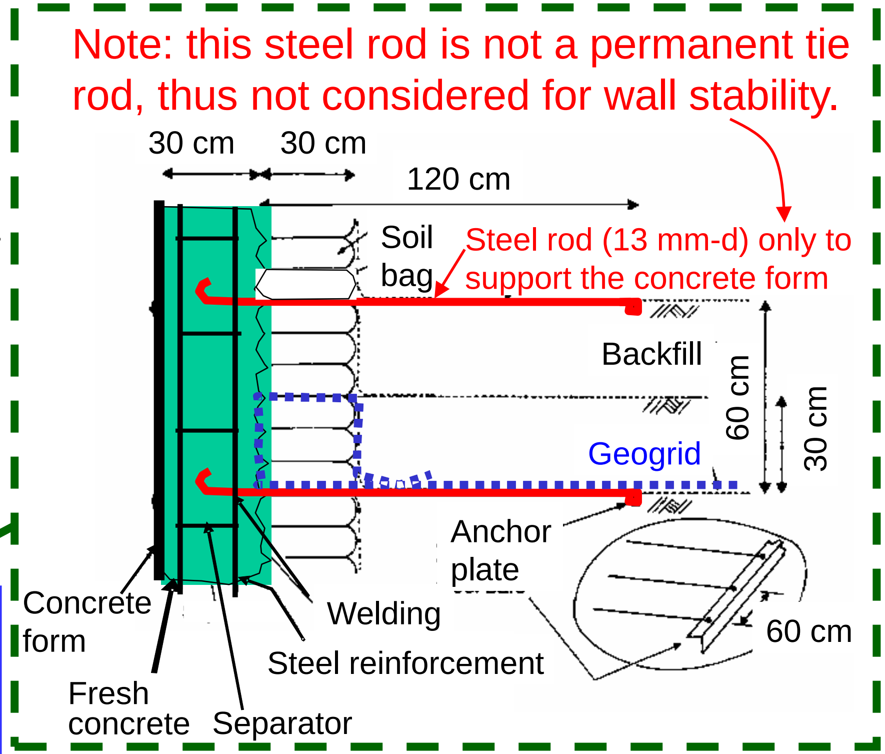


5) Completion of wrapped-around wall

Staged construction: from 5) to 6)

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

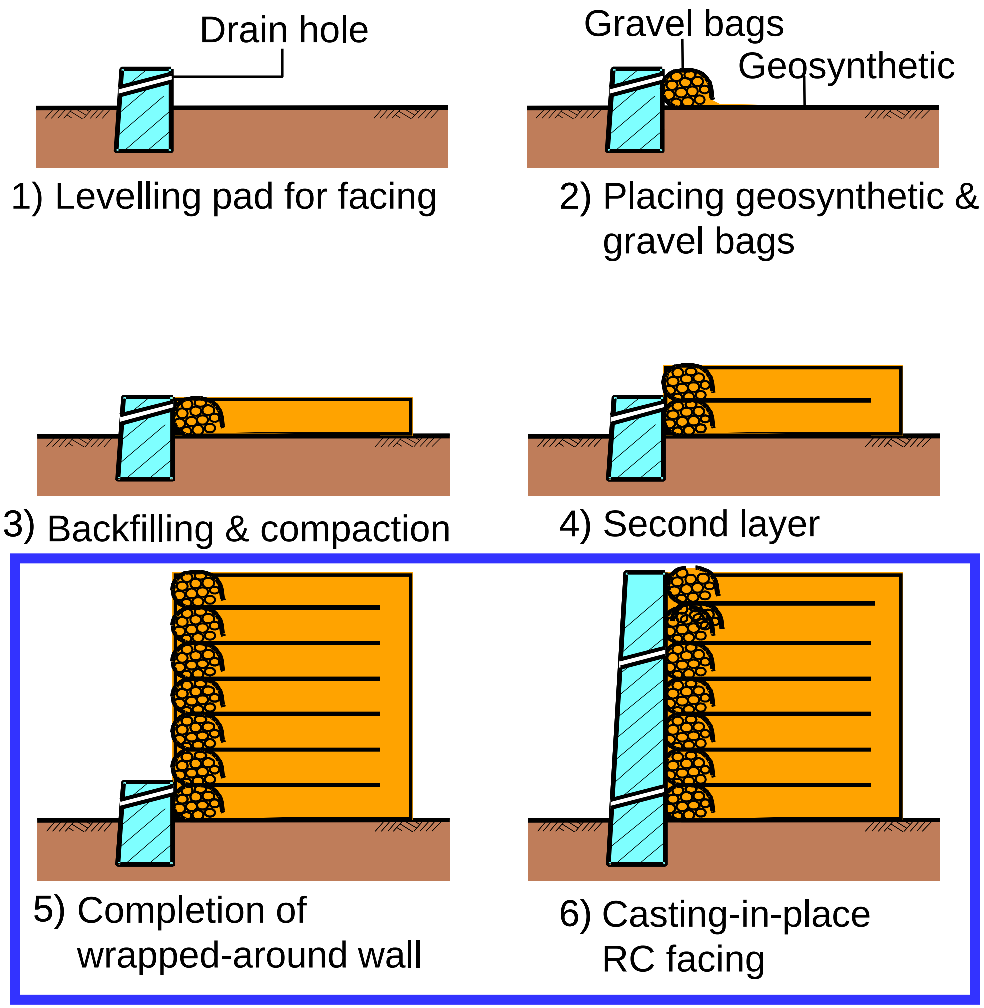




Fresh concrete enters the gravel bags through the aperture of the geogrid bags.
⇒ Facing & geogrid reinforcement are firmly connected to each other.

Staged construction: from 5) to 6)

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

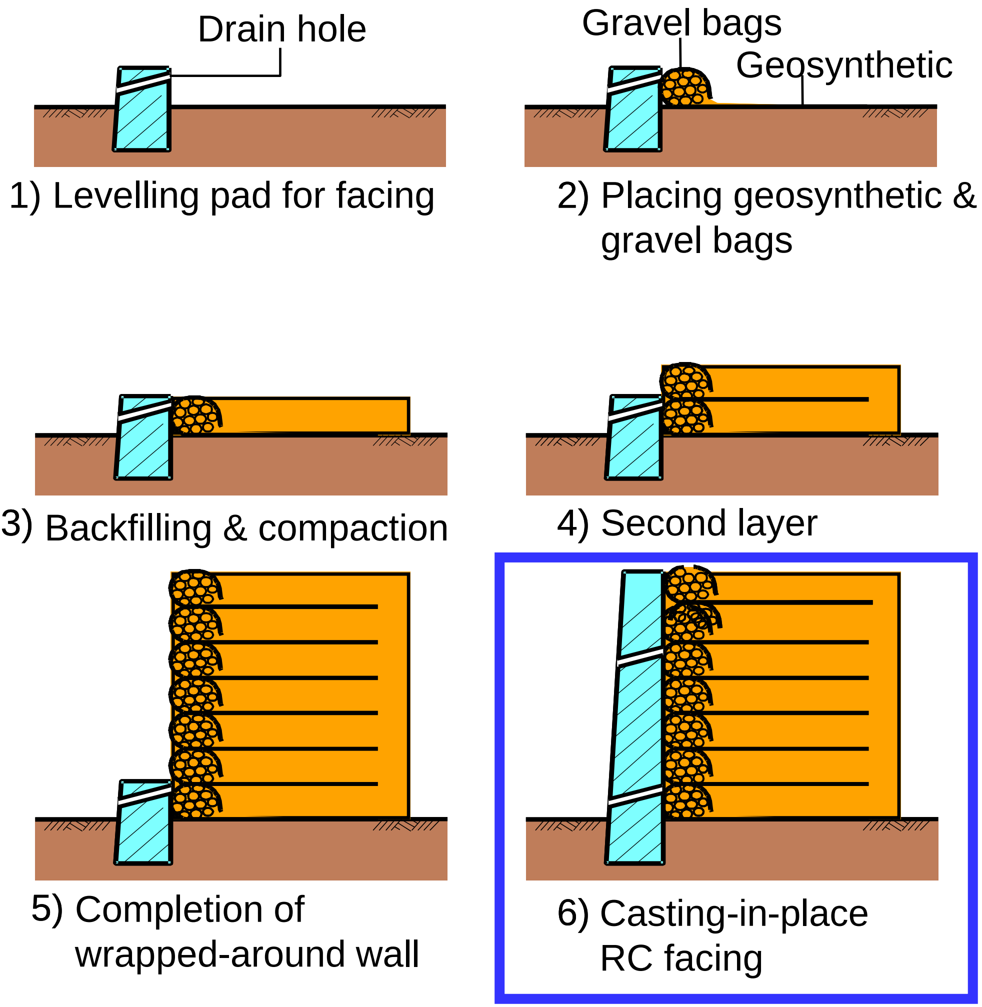


→ After step 6), the differential settlement between the FHR facing and the backfill becomes very small.

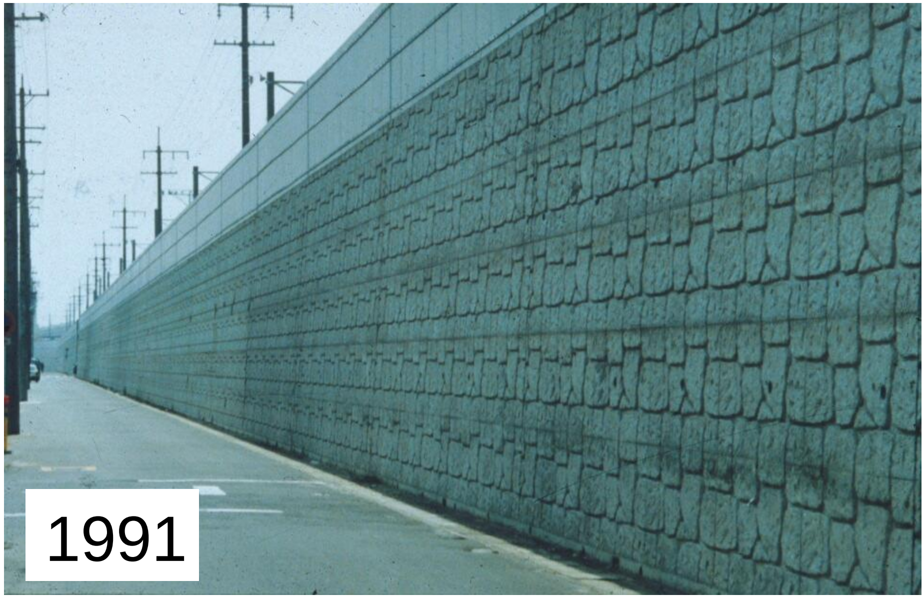
→ The facing/geogrid connection is not damaged during service of completed wall.

→ Construction using compressive backfill and/or on a compressive subsoil becomes possible.

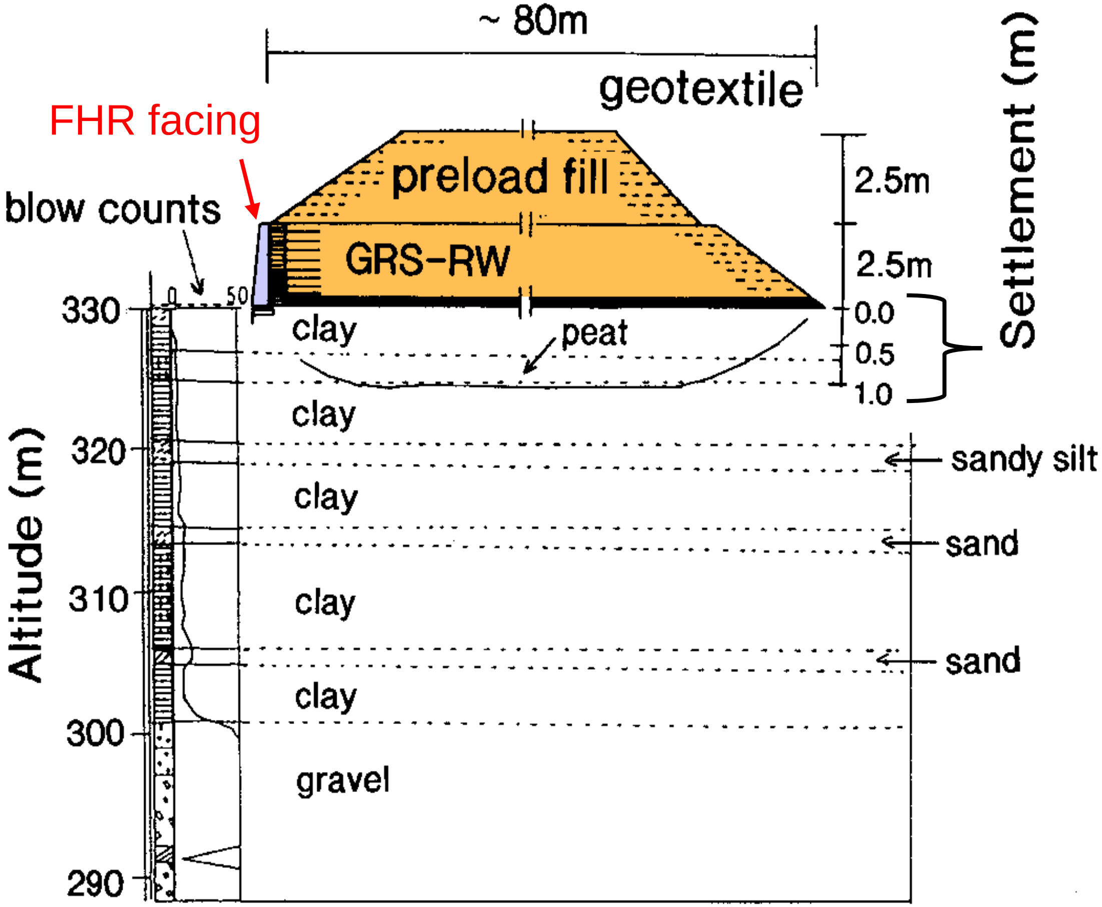
Staged construction – 6)
Competition



A typical case:
Re-construction of a gentle slope to a vertical wall for a yard of Shinkansen at Biwajima, Nagoya



Nagano wall:
- for a yard for Shinkansen
- 2.0 m-high & 2 km-long
- constructed 1993 - 1994



a) Backfill: nearly saturated soft clay

b) Constructed on a thick very soft clay deposit
- no pile foundation
- staged construction:
1) GRS RW w/o FHR facing
2) preload fill
3) settlement (about 1 m)
4) removal of preload fill
5) construction of FHR facing

Preloading

<u>wall height</u>

before preloading: 3.0 m

after preloading: 2.0 m

Construction of FHR facing after removing the preload fill.

20 years after construction, 6th July 2014

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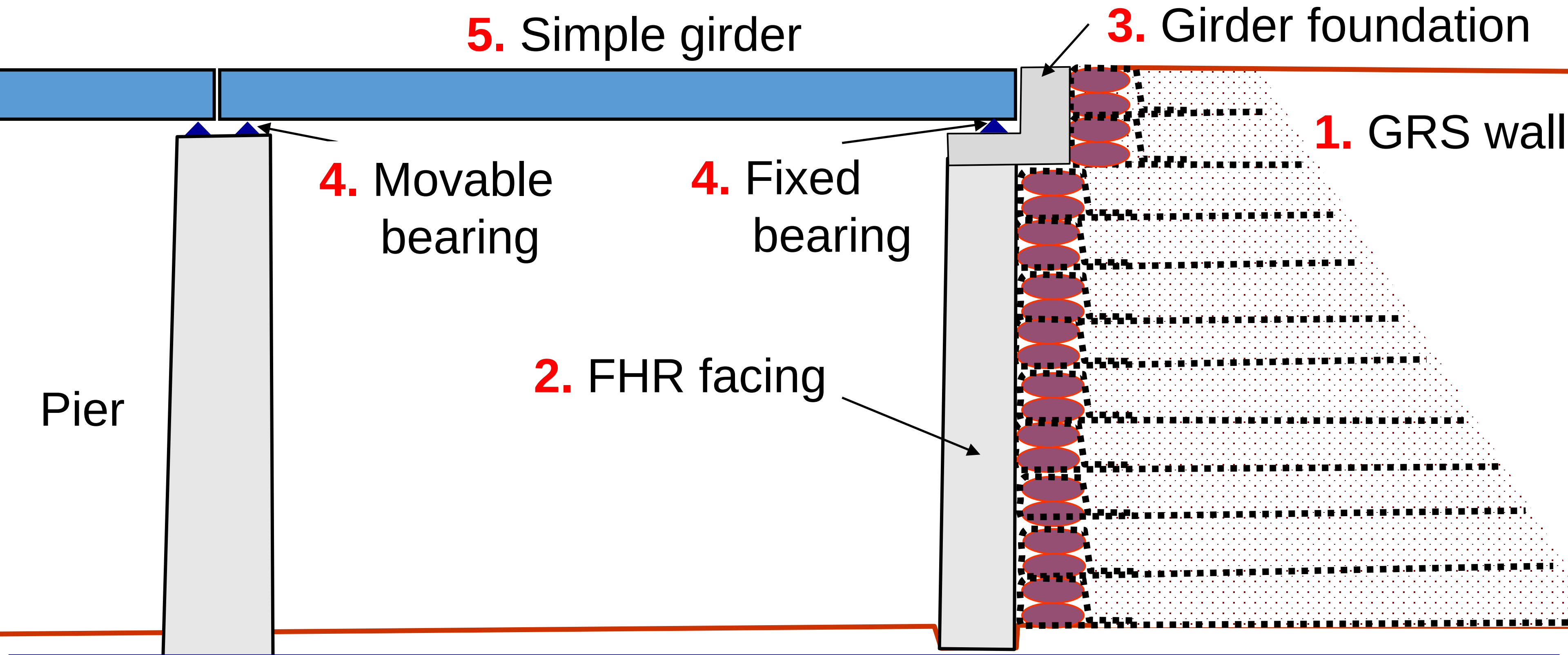
5. **GRS Bridge Abutment and GRS Integral Bridge**

6. Collapse of soil structures by earthquakes, floods and tsunami
   and restoration to GRS structures

7. Concluding remarks

GRS Bridge Abutment

The girder foundation becomes much more stable by structural integration to the top of the FHR facing ….



Much more cost-effective and much more stable than conventional type bridge abutments; and
statically determinate, thus not sensitive to residual displacements of the FHR facing ⇒ rather simple to design

GRS Bridge Abutment

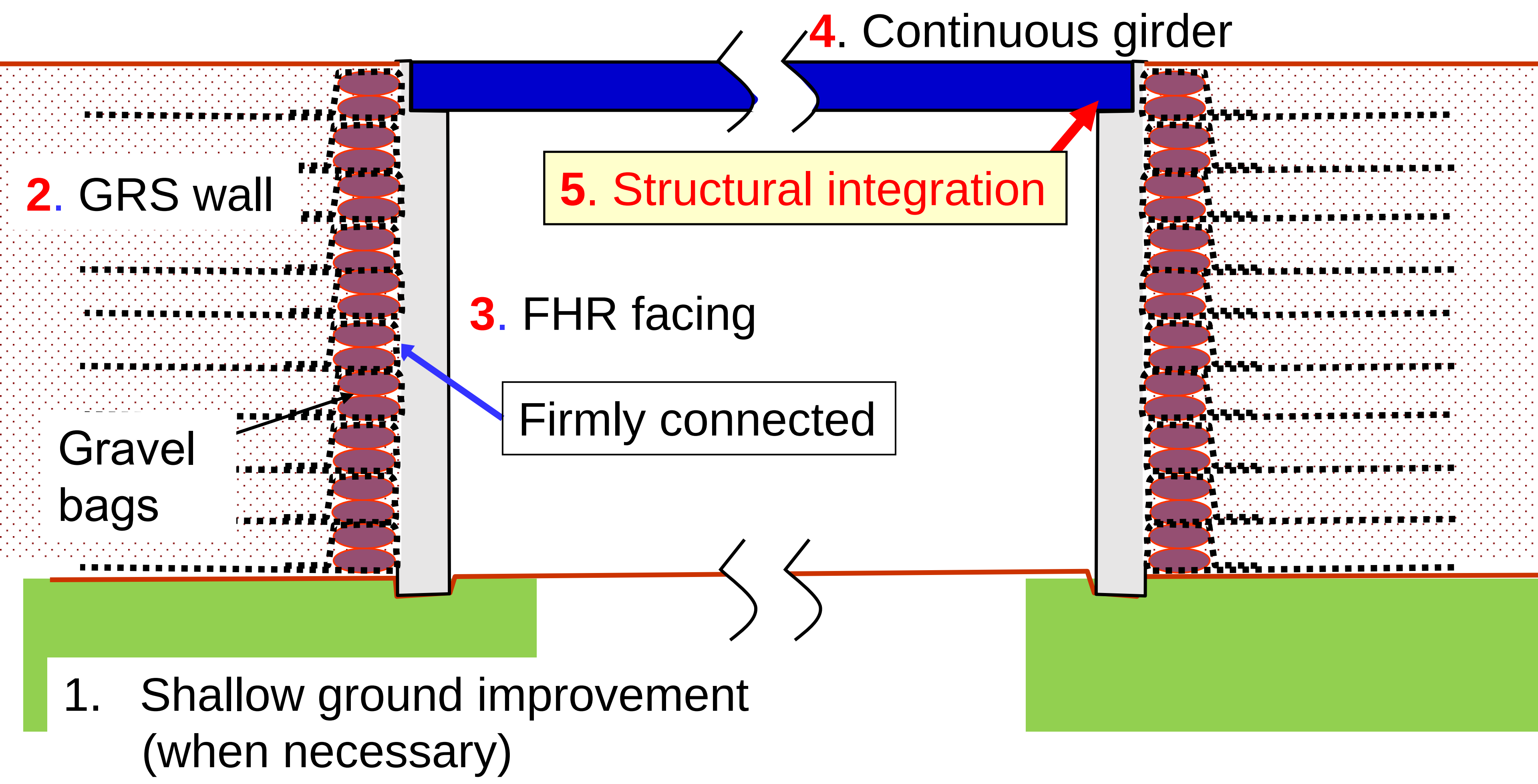
First GRS Bridge Abutment
at Takada for Kyushu Shinkansen

GRS Bridge Abutment at Mantaro
for Hokkaido Shinkansen

After the construction of the first one at Takada in 2003,

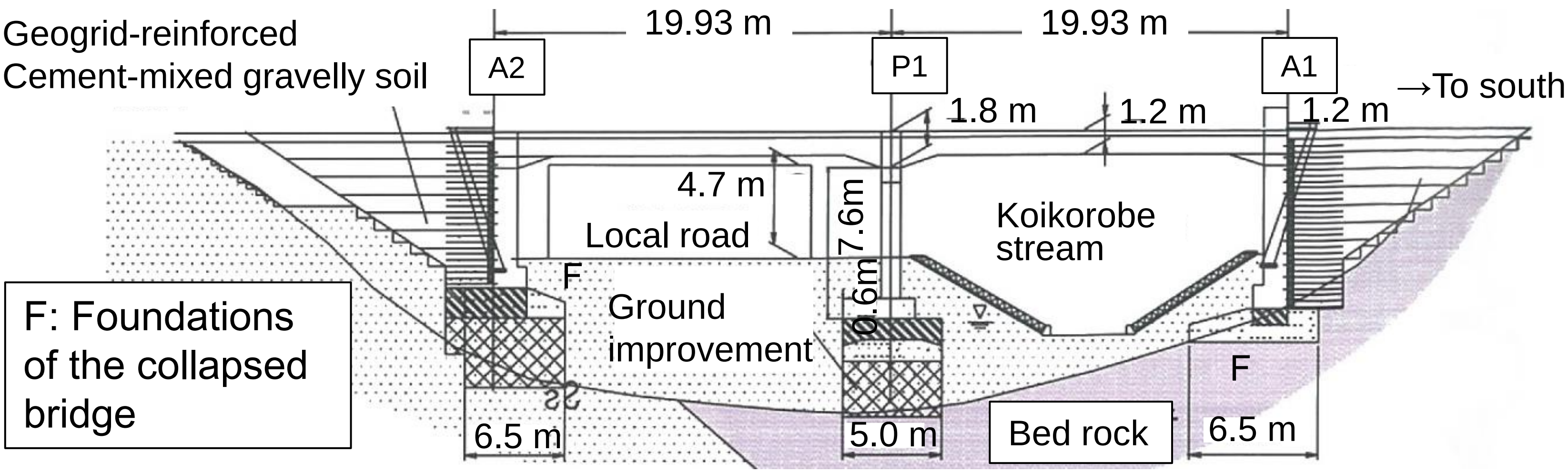
- by 2018, 36 have been constructed and are in service; and
- many others are at the design stage or under construction, including 80 for Kyushu Shinkansen Nagasaki Route.

GRS Integral Bridge
(not using girder bearings)



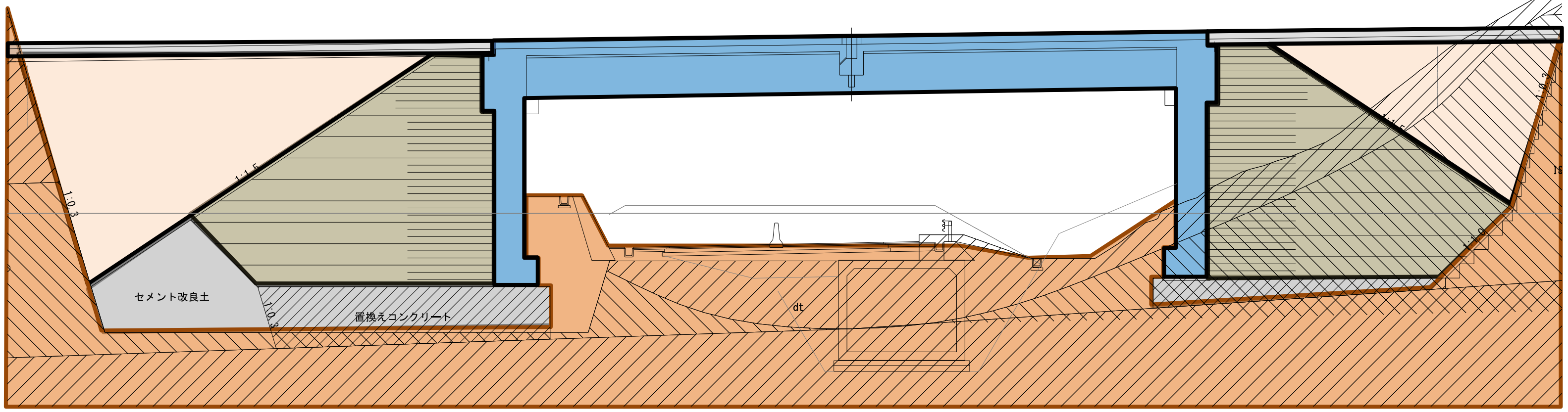
20 days after the 2011 Great East Japan E.Q. (11 March 2011) Koikoreobe, Sanriku Railway.

GRS Integral Bridge at Koikorobe, Sanriku Railway



The latest GRS Integral Bridge

at Genshu, Kyushu Shinkansen (Nagasaki Route)



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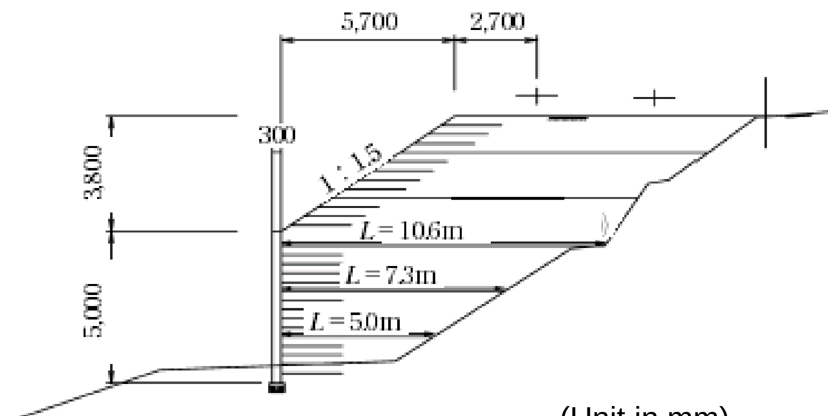
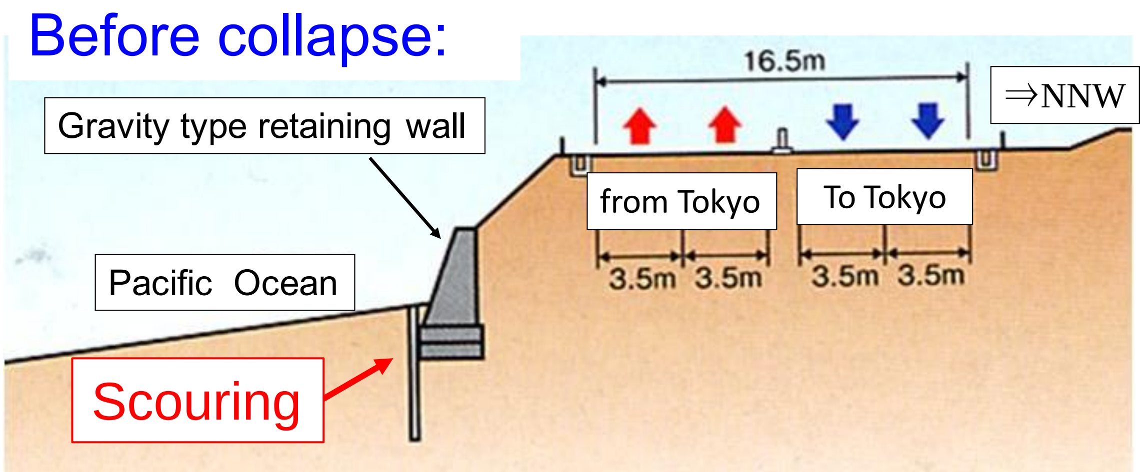
2004 Niigata-ken Chuetsu EQ, October 2004

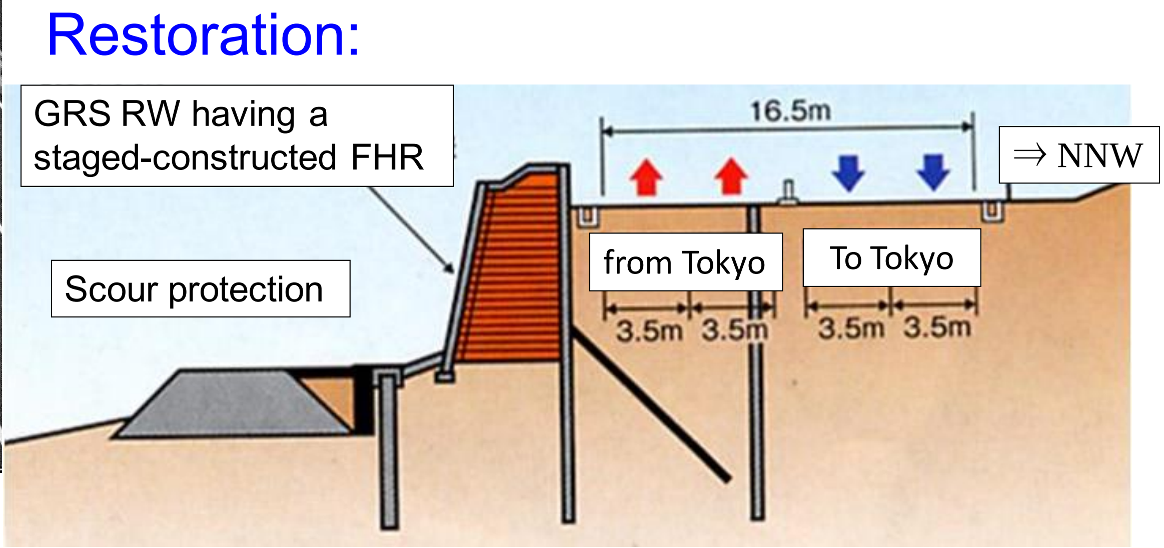


(Unit in mm)

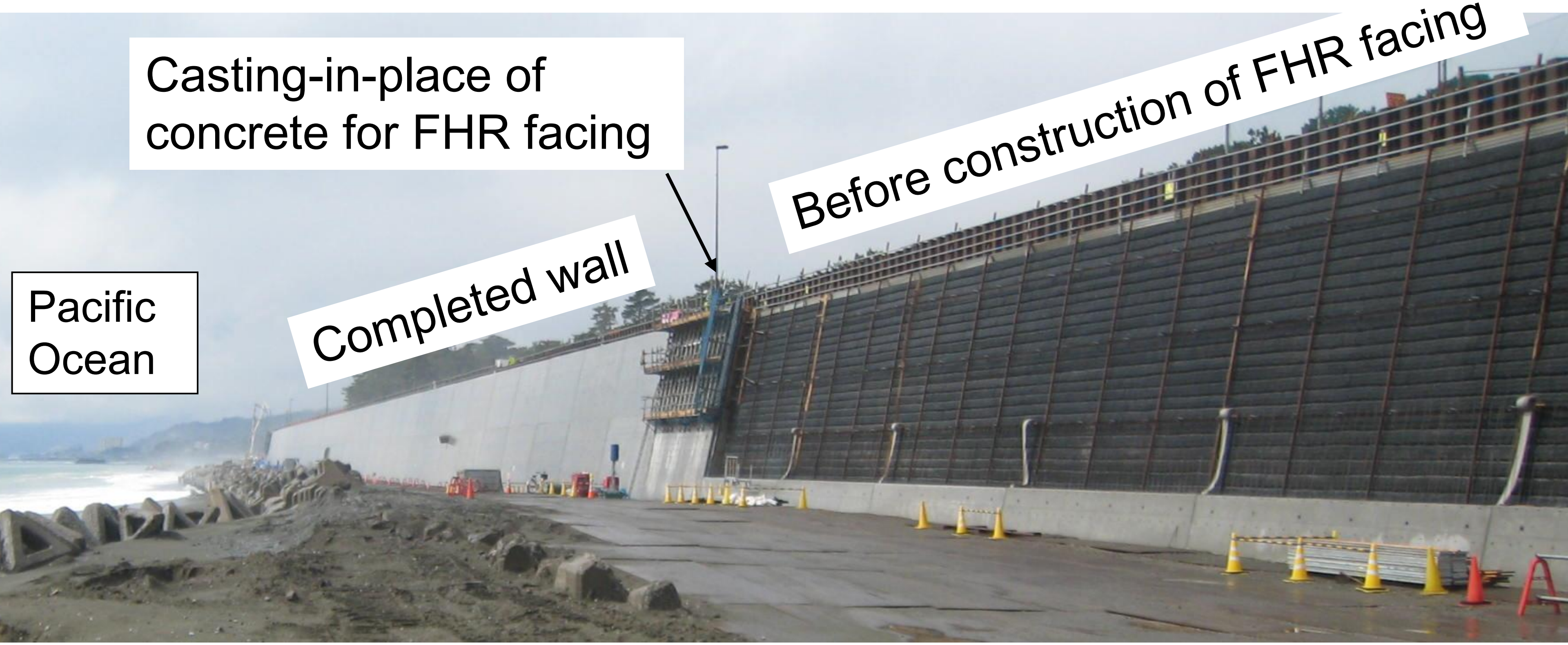
Site 3

Collapse of gravity-type seawall for a length of 1.5 km by Typhoon No. 9, 8 Sept. 2007 (National Road No. 1, southwest of Tokyo)



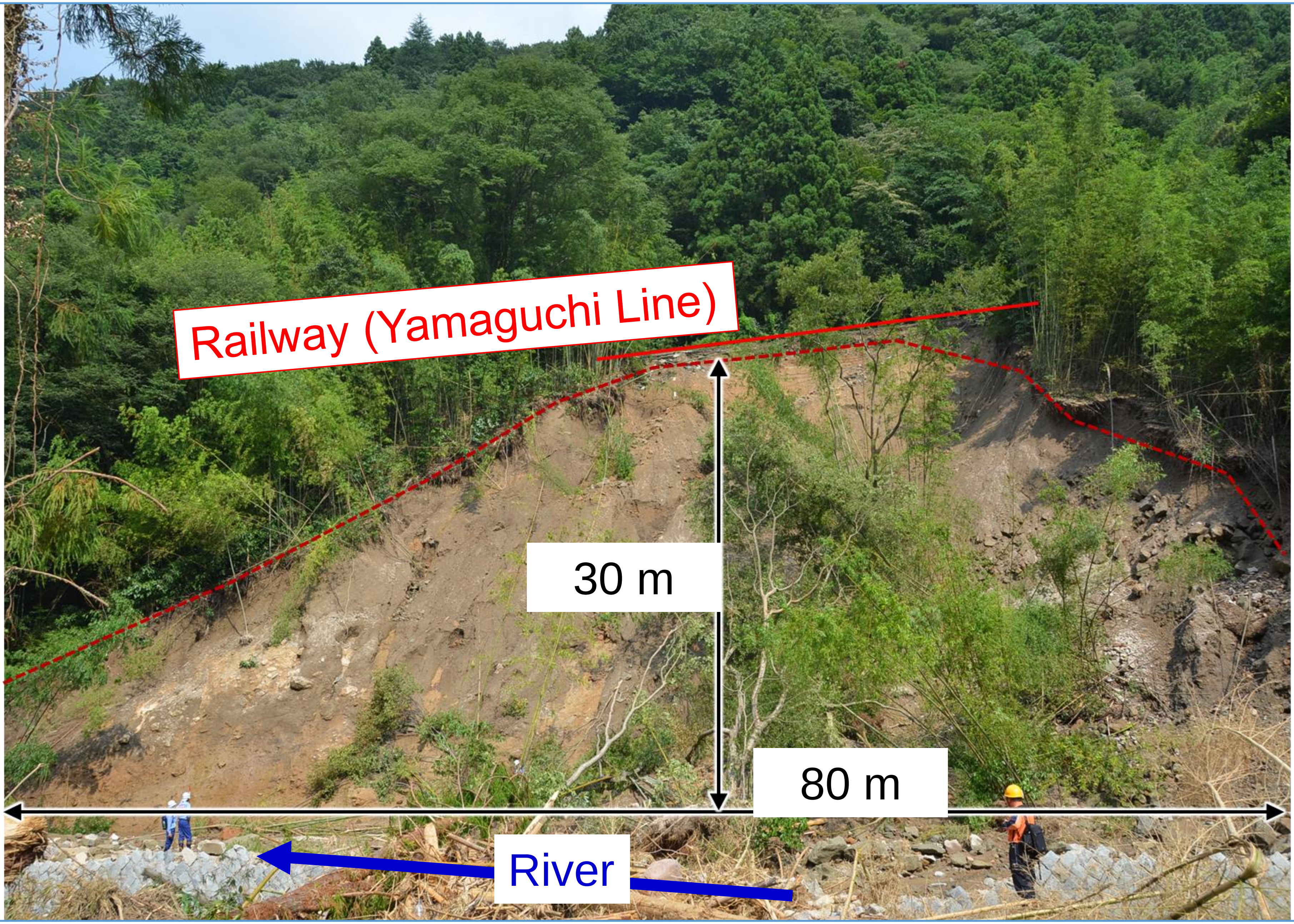


Restoration to GRS RW with FHR facing



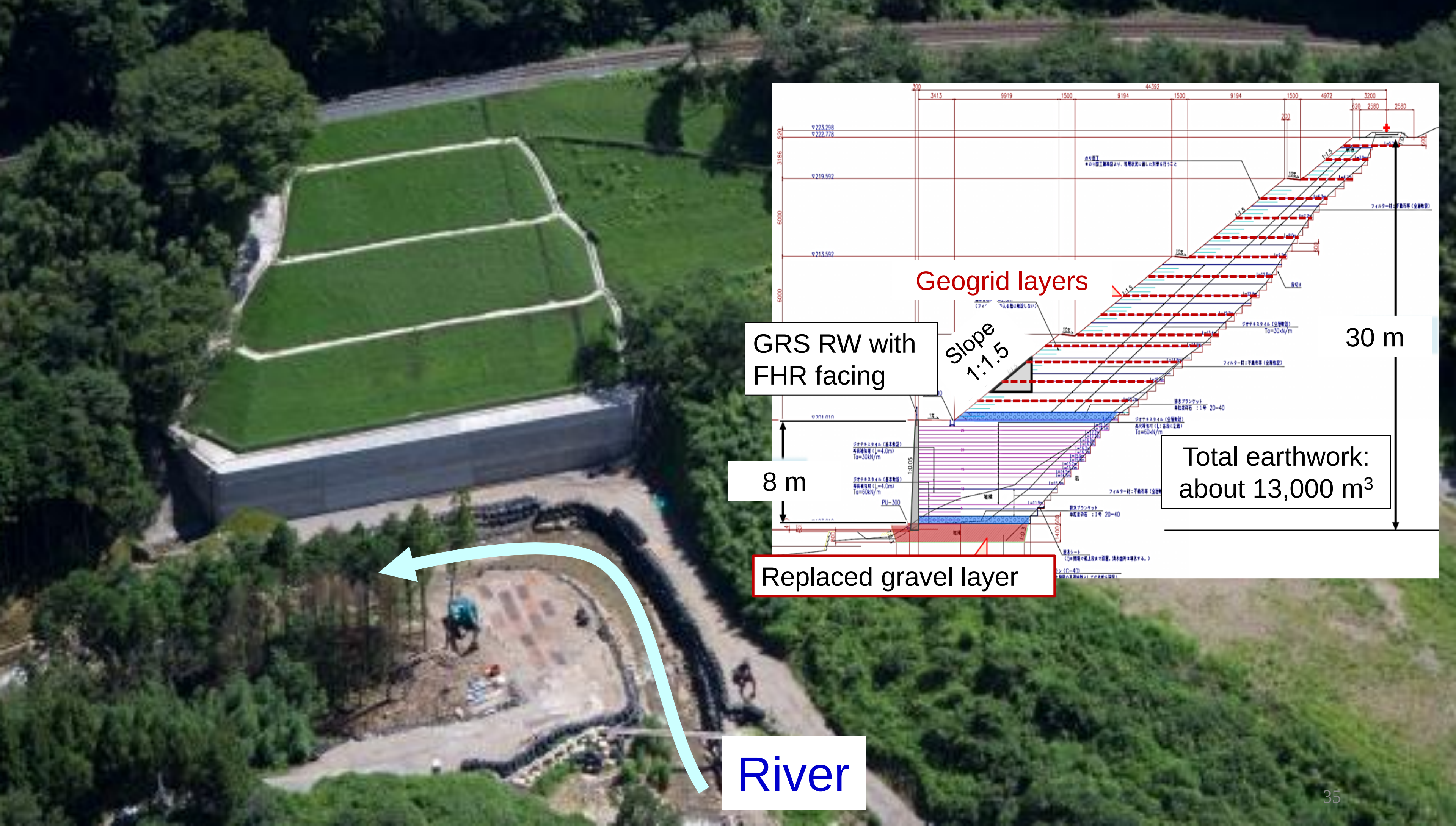
10 March 2010

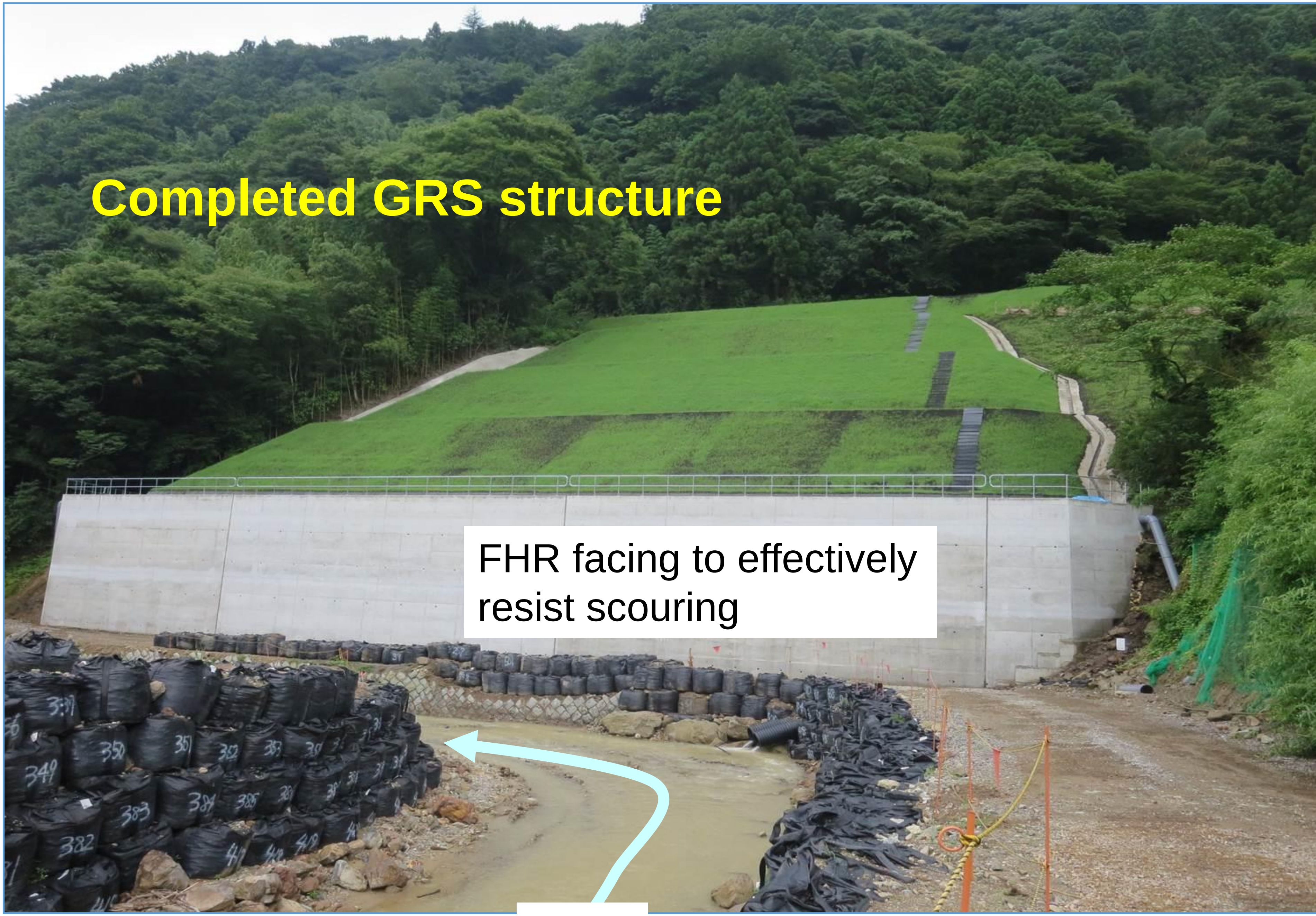
Collapse of railway embankment by scouring at the toe



GRS structure

(before the construction of FHR facing)




Completed GRS structure
FHR facing to effectively resist scouring
River

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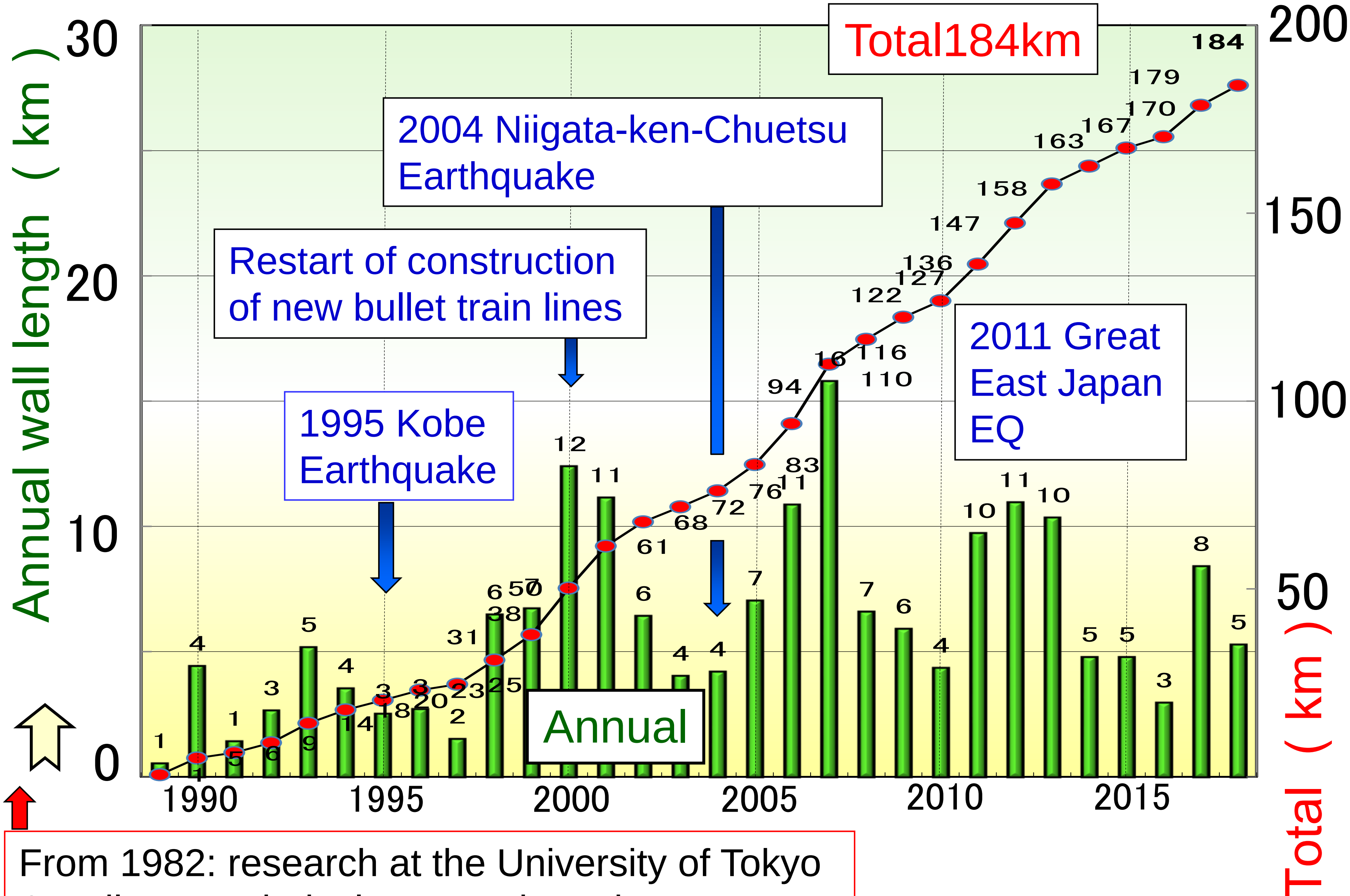
Concluding remarks – 1: Brief history



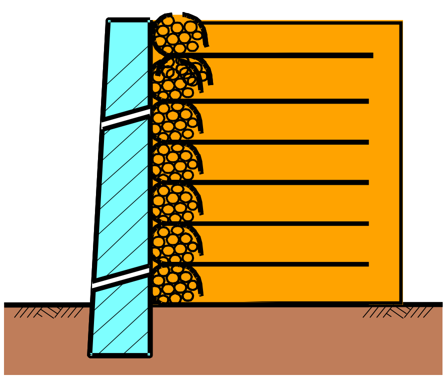
From 1982: research at the University of Tokyo & Railway Technical Research Institute

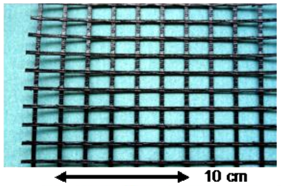
Concluding remarks – 2

GRS RWs with stage-constructed FHR facing and related GRS structures have been constructed as important permanent RWs and other soil structures for a total length of about 190 km, many for railways including high-speed railways (Shinkansen).

Its popular use is due to high cost-effectiveness by:

- **high performance** during long-term service and against severe earthquakes, heavy rainfalls etc. and
- **low cost** for construction and maintenance.



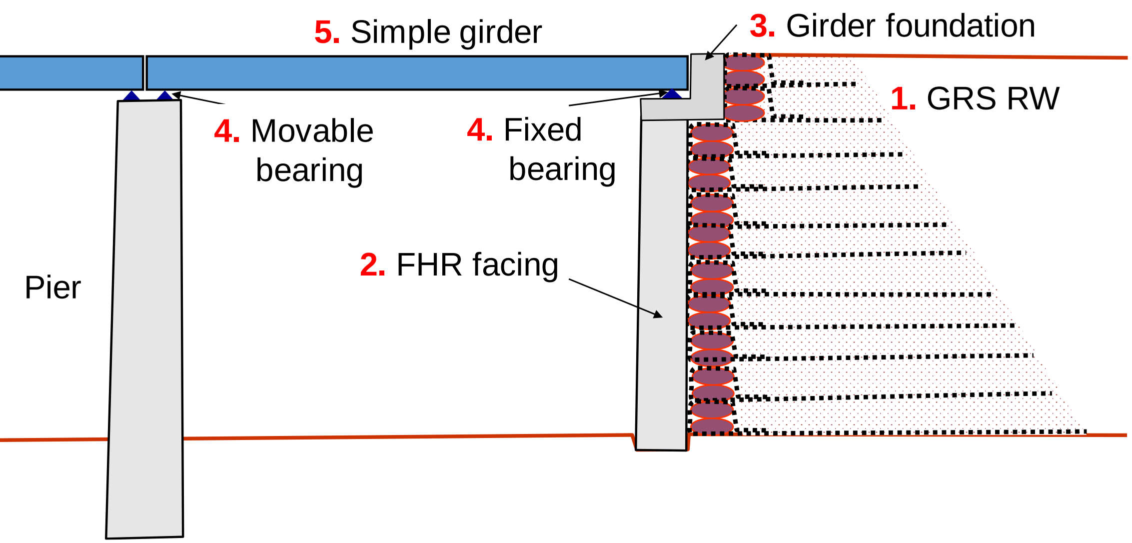


Typical polymer geogrid

Concluding remarks – 3

GRS Bridge Abutment supports one end of a simple girder with a fixed bearing on the top of FHR facing of GRS RW. This is much more cost-effective and much more stable than the conventional type abutment. Since opened to service, all exhibited practically zero bump.

GRS Bridge Abutment is now one of the standard bridge abutments for railways in Japan.



Concluding remarks – 4

GRS Integral Bridge structurally integrates both ends of a continuous girder to the top of the FHR facings of a pair of GRS RWs, not using bearing. This is much more cost-effective and much more stable than the conventional simple girder bridge.

GRS Integral Bridge is now one of the standard bridge systems for railways in Japan.

Concluding remarks – 5

A great number of conventional type embankments, RWs and bridges collapsed during severe earthquakes, heavy rainfalls, floods, tsunami etc. Many of them were restored to GRS structures with staged constructed FHR facing.

Concluding remarks – 6

The following **three breakthroughs** were necessary to develop the GRS technologies explained in this presentation:

1) **Full-height rigid (FHR) facing** for changes from low earth pressure to high earth pressure in the wall; and from the facing as a secondary non-structural component to a primary structural component for GRS structures.
2) **Staged construction** for a change in construction from the backfill last to the backfill first.
3) **Structural integration of the girder to the FHR facings** for a change from statically determinate but unstable conventional soil structures to statically in-determinate but stable GRS structures, in particular GRS Integral Bridges.