RRR

ASSOCIATION OF RRR CONSTRUCTION SYSTEM

GRS integral bridge, Kyushu Shinkansen, Isahaya, 2018

RRR-A

GRS retaining wall, Yamagata Expressway, 1997

RRR-B

NRS retaining wall, Tohoku Sinkansen, Morikoka, 2000

RRR-C

GRS structure to prevent water-front disasters, Sanriku Railway, Tanohata, 2015

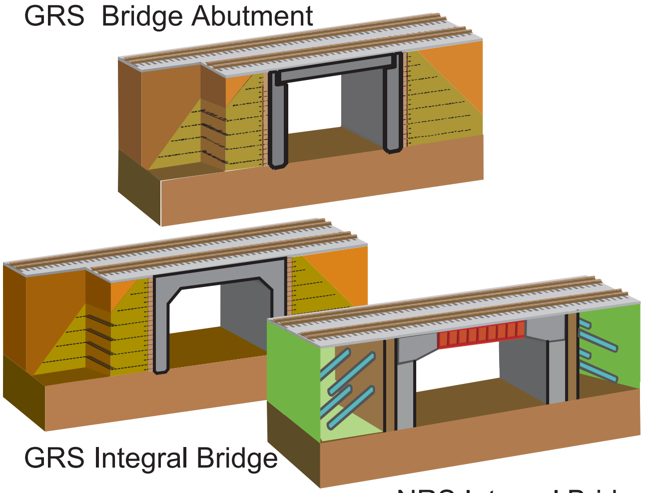
RRR-D

RRR

RRR stands for "Reinforced soil Road structures with Rigid facing".

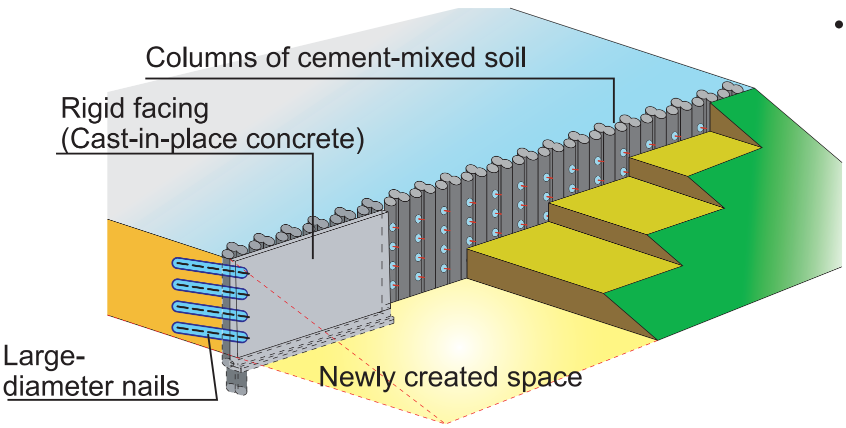
RRR reinforced soil structures comprises four sub-systems, A - D:

RRR-A
Reinforced soil bridge abutment & bridge



- GRS Bridge Abutments, using bearings to support a simple girder.
- GRS Integral Bridges and NRS Integral Bridges structurally integrate the girder, respectively, to the top of full-height rigid (FHR) facing connected to GR backfill, or to the top of RC abutment connected to nailed backfill.

RRR-C
Nail-Reinforced Soil (NRS) retaining wall

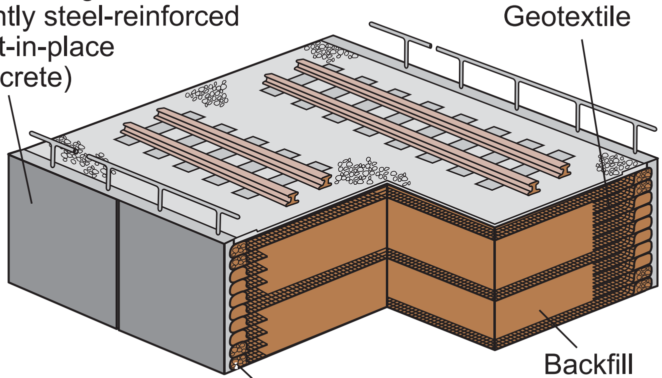


- Natural slopes and embankment slopes cut to vertical walls by reinforcing slopes with medium to large diameter nails using full-height rigid facing.

RRR reinforced-soil structures include embankments, retaining walls, water-front structures, bridge abutments, bridge systems etc. constructed for railways, highways and others.

RRR-B

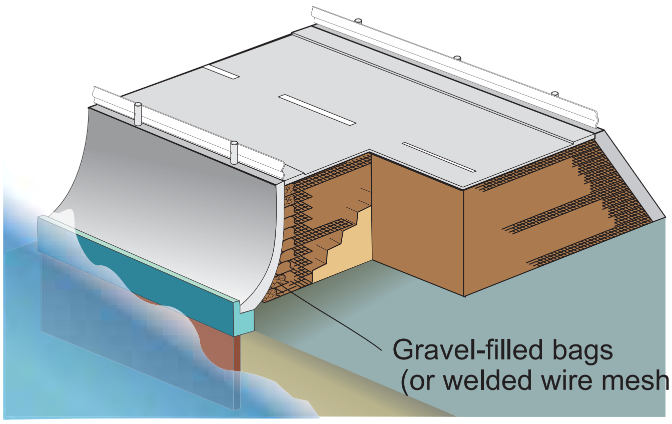
Geosynthetic-Reinforced Soil retaining wall



- GRS retaining walls (RWs) with full-height rigid (FHR) facing.
- GRS RWs with FHR facing can support railway tracks or roads arranged close to the wall face. They can also support continuous RC slab railway tracks and external loads acting on, or close to, the facing.

RRR-D

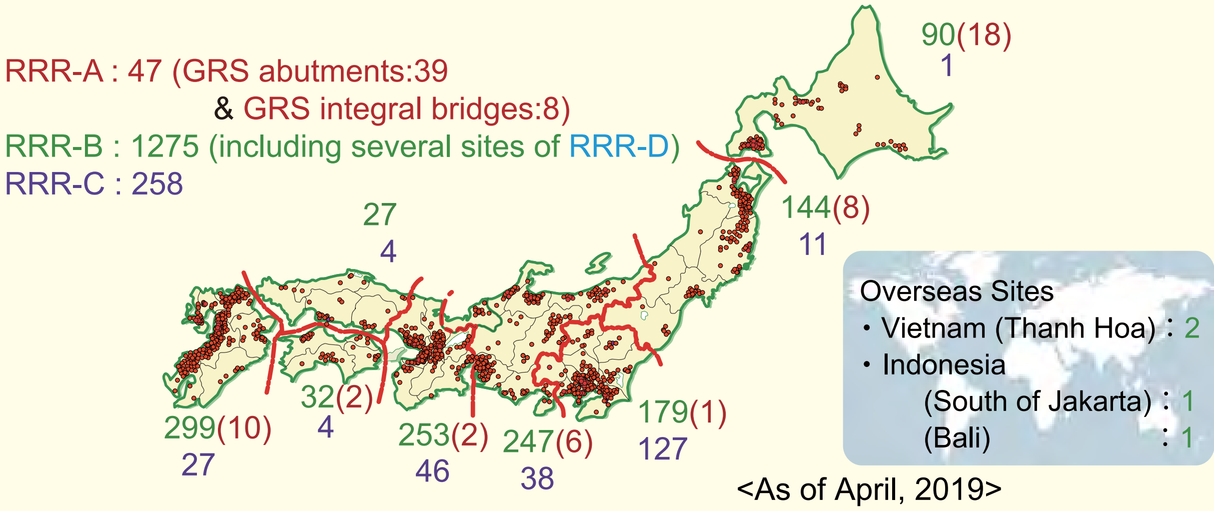
GRS structures to prevent water-front disasters



- Water-front GRS structures to prevent and mitigate disasters caused by scouring, erosion and overtopping flow by flood, storm and tsunami.

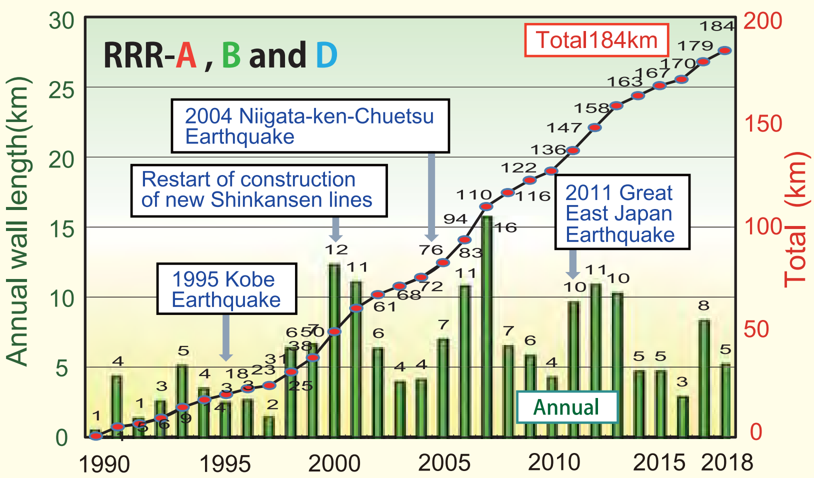
RRR Statistics

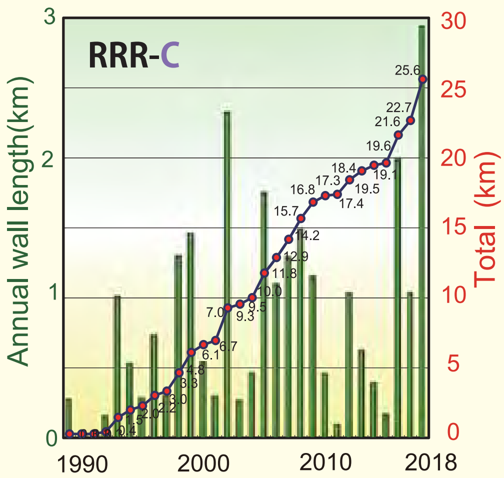
- Number of construction sites



<As of April, 2019>

- Annual and total lengths of constructed walls



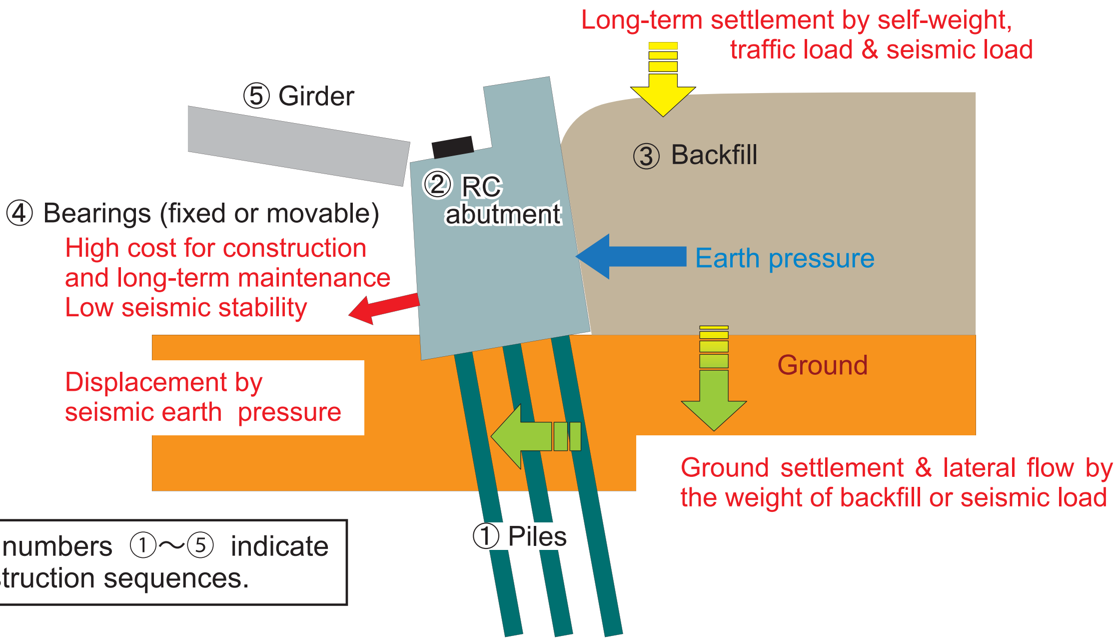


RRR Brief history

1981 : Start of basic research at Institute of Industrial Science, the University of Tokyo
1987 : Start of research at Railway Technical Research Institute, Japan
1987 : Application for the first patent (15 July)
Patent No.1870191 for "Embankment stabilization method by soil-reinforcing and structures constructed by this method"
1987 : First prototype of GRS RW structure by RRR-B technology at Tennoji station, Osaka (August)
1991 : Establishment of Association of RRR Construction System (12 July)
1994 : Certificate of technical evaluation (No.0505) by Japan Institute of Country-ology and Engineering (31 March) : RRR-GRS Retaining Wall system (RRR-B system)
2002 : Certificate of technical evaluation (No.1403) by Advanced Construction Technology Center (28 November) : Radish Anchor (Large-diameter nails) method (RRR-C system)
2005 : Publication of "All of the new reinforced soil retaining walls" by General Civil Engineering Institute Co.,Ltd. [Sougou Doboku Kenkyujo] (25 October)
2009 : Establishment of Radish Anchoring Section (June)

RRR-A Reinforced Soil Bridge Abutments & Bridge

Conventional simple girder bridges are basically not cost-effective while vulnerable to disasters by earthquakes, floods etc. due to a number of technical deficiencies , as shown below:



The numbers ①～⑤ indicate construction sequences.

RRR-A technology allows the construction of reinforced-soil bridge abutments that alleviate the above- mentioned problems. RRR-A comprises two sub-technologies:

1) **RRR GRS Bridge Abutment**

2) **RRR Reinforced Soil Integral Bridge**

- a) **RRR GRS Integral Bridge** to construct new bridges
- b) **RRR-NRS Integral Bridge** to reinforce existing old simple girder bridges

Awards conferred to RRR-A:

2003 Japan Society of Civil Engineers (JSCE), Innovative Technique Award to “Development of a seismic bridge abutment using reinforced cement-mixed backfill”

2004 Japan Chapter of International Geosynthetics Society (JC-IGS), Outstanding Geotechnical Achievement Award to “Loading tests on full-scale model of bridge abutment using reinforced cement-mixed backfill”

2008 Japan Chapter of International Geosynthetics Society (JC-IGS), Continuing Award to “Structural advantages and Problems of Integrated Geosynthetic-Reinforced Soil Bridge”

2010 International Geosynthetics Society (IGS), One of the best papers published in Geosynthetics International (IGS official journal) in 2009, “A new type of integral bridge comprising geosynthetic-reinforced soil walls”

2011 Japan Chapter of International Geosynthetics Society (JC-IGS), Excellent Research Paper Award to “Construction and field observation of the full scale test Integral GRS Bridge”

2014 Japan Society of Civil Engineers (JSCE), Tanaka Award for outstanding bridge technology to “Haipezawa Bridge (the Sanriku Railway North Rias Line) ”

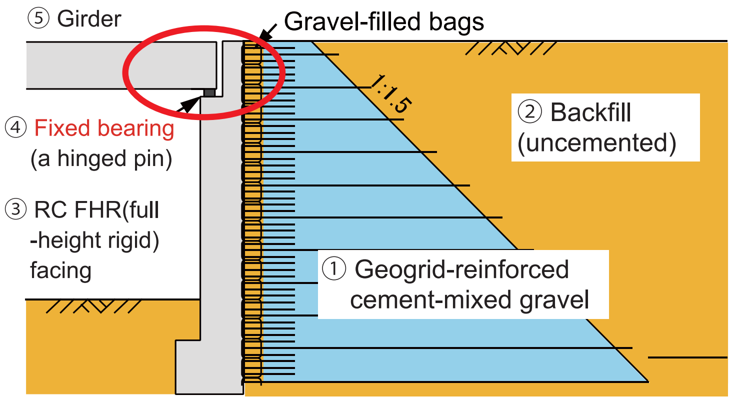
2019 Japan Society of Civil Engineers (JSCE), Innovative Technique Award to “Development of GRS Integral Bridge fusing soil reinforcement and bridge technologies”

RRR-A

1) **RRR GRS Bridge Abutment**
2) **RRR Reinforced Soil Integral Bridge**
   - a) **RRR GRS Integral Bridge** to construct new bridges
   - b) **RRR-NRS Integral Bridge** to reinforce existing old simple girder bridges

1) RRR Geosynthetic-Reinforced Soil (GRS) Bridge Abutments

This type of abutment supports one end of a simple girder by using a fixed bearing arranged on the top of the RC full-height rigid (FHR) facing that is firmly connected to geogrid layers reinforcing the backfill

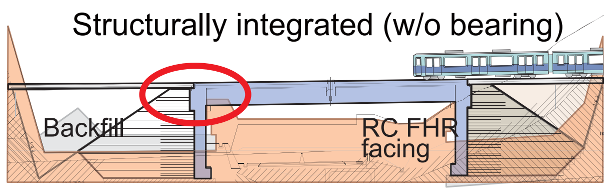


The numbers ①～⑤ denote construction sequences.

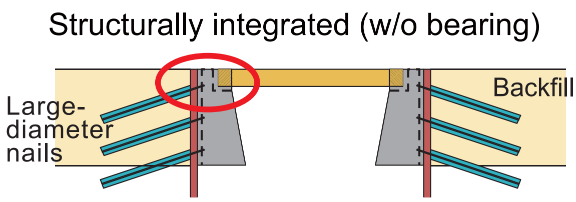
2) RRR Reinforced Soil Integral Bridges

This type of bridge structurally integrates both ends of a simple girder to the top of RC vertical walls:

a) RRR GRS Integral Bridge to construct new bridges



b) RRR NRS Integral Bridge to reinforce existing old simple girder bridges



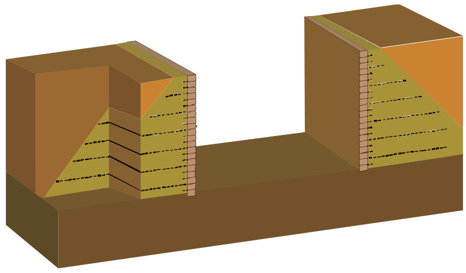
a) RRR GRS Integral Bridge

The backfill is reinforced with a number of geogrid layers that are firmly connected to the full-height rigid (FHR) facing. Both ends of a continuous girder are structurally integrated to the top of a pair of FHR facings. In this way, the girder, the FHR facings and the reinforced backfill are all integrated. As a result, RRR GRS Integral Bridges become much more stable than conventional simple girder bridges, in particular against severe seismic loads.

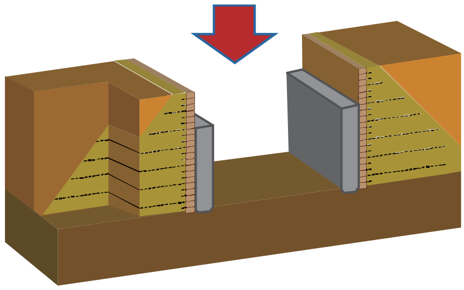
As the bearings are not used to support the girder, the top of the FHR facings is laterally displaced cyclically by seasonal thermal expansion and contraction of the girder. This may result in settlements in the active zone of the backfill and the development of elevated passive earth pressure. With RRR GRS Integral Bridge, however, as the backfill is reinforced with geogrid layers connected to the FHR facings, these phenomena are effectively restrained and associated harmful problems do not take place. The development of a bump at the back of the abutment due to settlement of the backfill caused by traffic loads and seismic loads is also effectively restrained.

The girder and FHR facings become slender due to structural integration. Moreover, as the FHR facing and girder are constructed after the deformation of supporting ground and backfill has taken place, pile foundations becomes unnecessary.

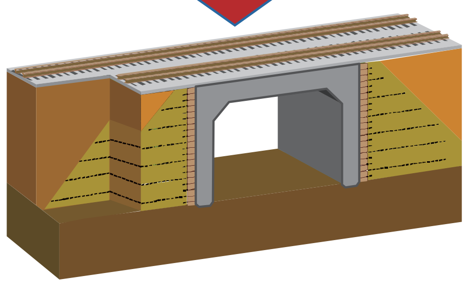
All these factors make RRR GRS Integral Bridge very cost-effective in construction and maintenance while very stable during long lifecycle service and against severe natural disasters by seismic loads and scouring and over-flow by floods and tsunami.



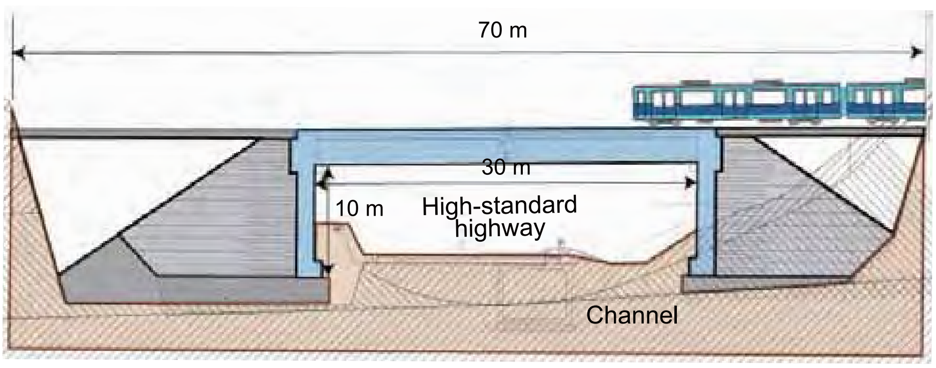
Construction of a pair of GRS retaining walls



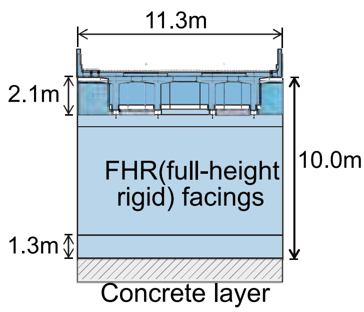
Construction of FHR(full-height rigid) facing connected to geogrid layers

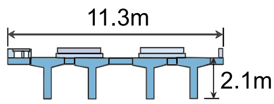


Construction of a continuous girder with both ends integrated to the top of the FHR facings



GRS Integral Bridge at Genshu for Kyushu Shinkansen, completed 2018





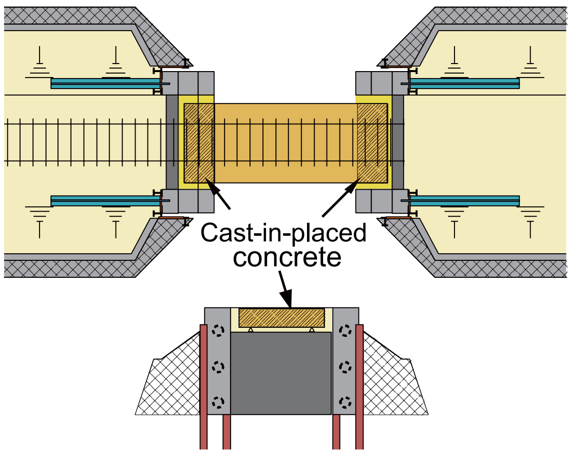
Four PPC T-shaped girders

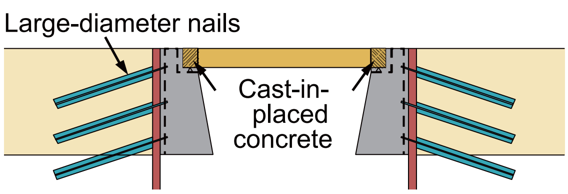
b) RRR NRS Integral Bridge

This technology reinforces existing simple girder bridges maintaining the service of the bridge while not constructing temporary detour bridges and approach roads.

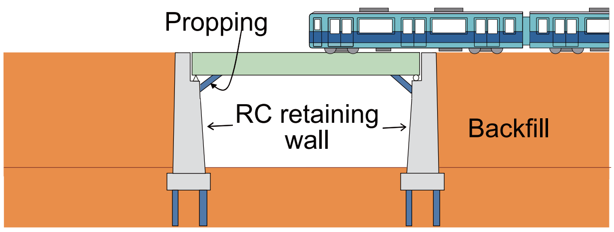
Firstly the existing girder is propped and the backfill of the approach fill is reinforced by installing large-diameter nails from, and connected to, the RC retaining walls of the abutments. The girder is then structurally integrated to the top of the RC retaining walls. As a result, the whole bridge system is fully structurally integrated. The integrated bridge exhibits very high stability against seismic loads, floods and tsunami.

By removing the bearings for the girder, the top of the RC retaining walls of the abutments are laterally displaced cyclically by seasonal thermal expansion and contraction of the girder, which may result in settlements in the active zone of the backfill and development of high passive earth pressure. With RRR NRS Integral Bridge, however, as the backfill is reinforced with nails connected to the retaining walls, these phenomena are effectively restrained. In particular, backfill settlement by long-term traffic loads and seismic loads and associated development of bump at the back of the retaining walls are effectively restrained.

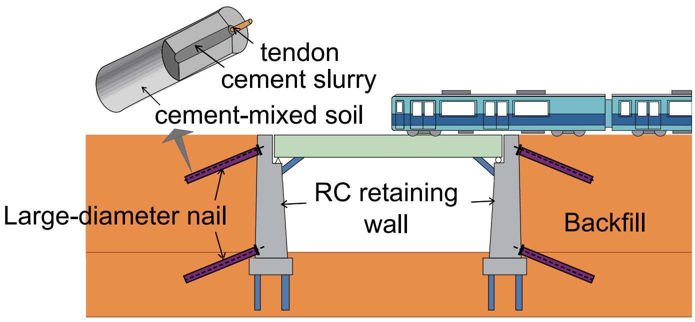




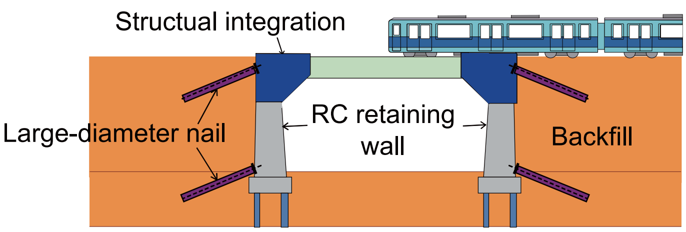
① The simple girder of an existing old bridge is stabilized with a propping extending from the abutment.



② The backfill is reinforced with large-diameter nails connected to the RC retaining walls of the abutments



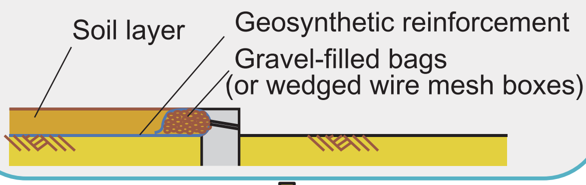
③ The girder is integrated to the RC retaining walls of the abutments by casting-in-place concrete.



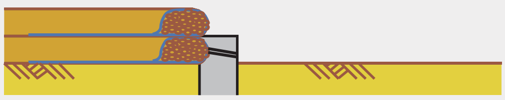
RRR-B Geosynthetic-Reinforced Soil (GRS) Retaining Walls

RRR GRS retaining walls (RWs) are constructed by reinforcing the backfill with geosynthetic reinforcement that is firmly connected to full-height rigid (FHR) facing. Many RRR GRS RWs performed very well during recent major earthquakes, including the 1995 Kobe E.Q., the 2011 Great East Japan E.Q. and the 2016 Kumamoto E.Q. Besides, RRR GRS RWs have a high resistance against river floods and ocean storm waves.

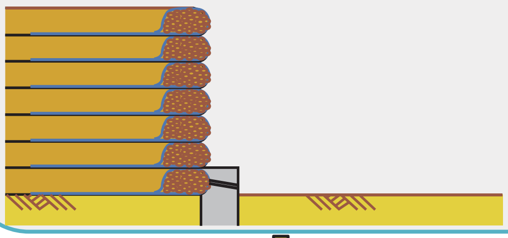
Place the first layer of geosynthetic reinforcement and gravel-filled bags (or welded wire mesh boxes), then place and compact the first soil layer.



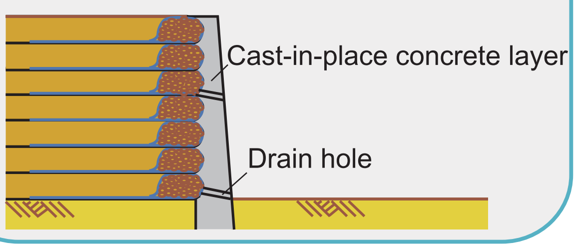
Construct the second layer in the same way as the first layer.

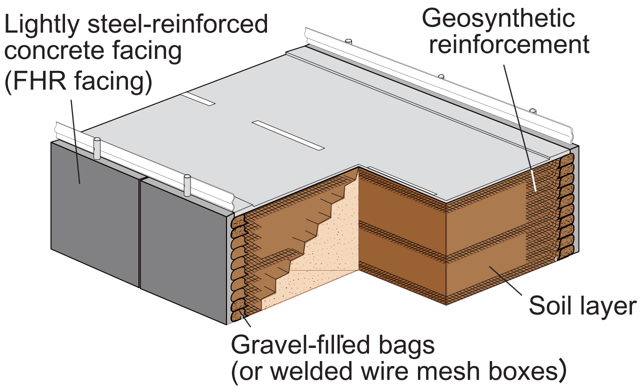


Complete the full-height geosynthetic-reinforced soil wall by repeating the procedure shown above .



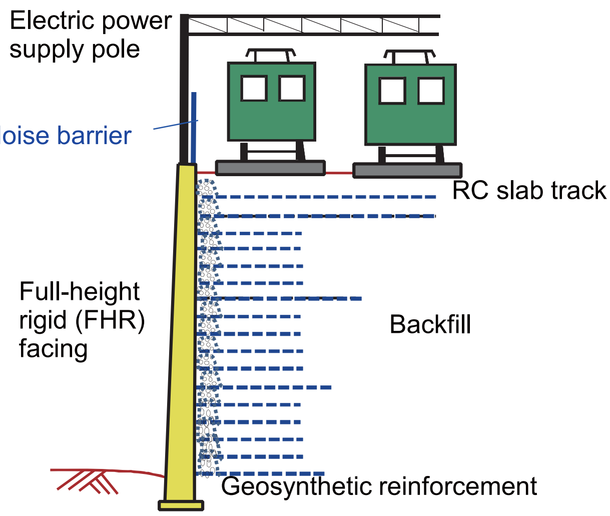
Cast-in-place concrete layer directly on the wall face, ensuring a firm connection between the facing and the geosynthetic reinforcement layers.

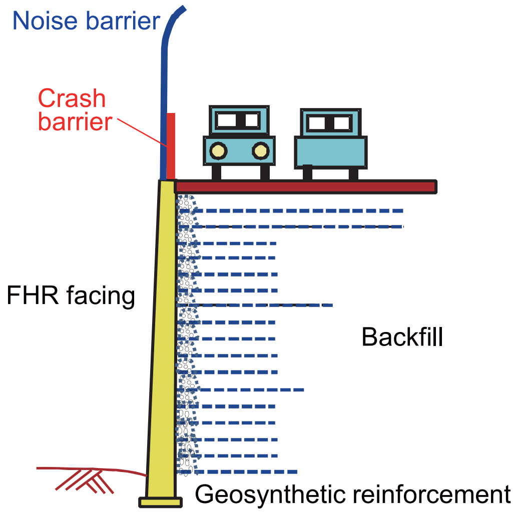




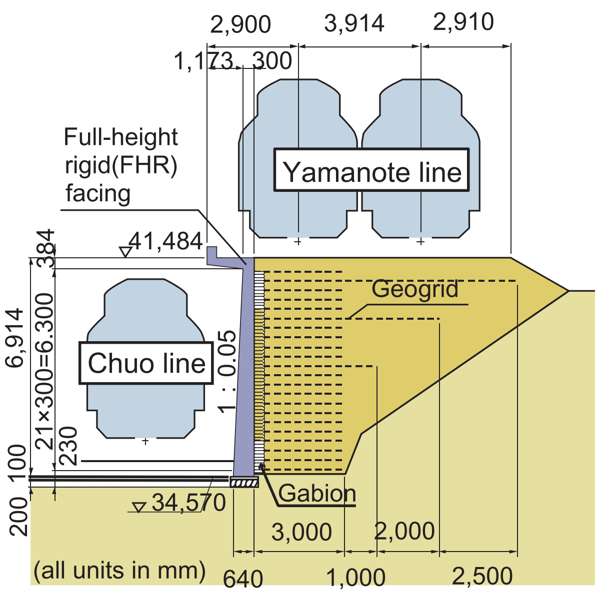
For RRR GRS RWs, the backfill is first constructed reinforced with planar geosynthetic reinforcement layers (usually geogrid layers). After the deformation of the supporting ground and the backfill due to the construction of backfill has sufficiently taken place, lightly steel-reinforced full-height rigid (FHR) facing is constructed by casting-in-place fresh concrete on the vertical geosynthetic-wrapped-around wall face in such that the FHR facing is firmly connected to the geosynthetic reinforcement layers. Hence, the facing and the facing/reinforcement connection are not damaged by relative vertical settlement between the facing and the backfill. Besides, a pile foundation for the facing becomes basically unnecessary.

RRR GRS RW is highly cost-effective because of no use of pile foundation; no use of heavy construction machines; use of relatively short reinforcement; no strong restriction to the backfill type; use of FHR facing as foundation for other structures; use of the backfill crest close to the wall face; and no need for a space in front of the wall for propping of concrete form for the FHR facing construction.





The full-height rigid (FHR) facing confines effectively the backfill by developing high earth pressure. Therefore, high connection forces and high tensile forces in the reinforcement layers develop. As a result, the backfill, in particular in the zone immediately behind the wall face, becomes very stable. Even if part of the wall is damaged locally, it does not develop into the failure of the whole wall.



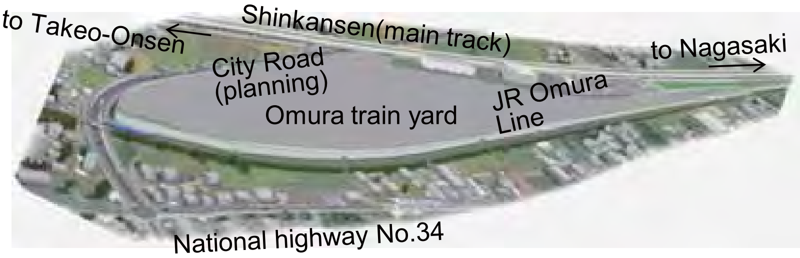
RRR GRS retaining wall with FHR facing for very busy urban railways near Shinjuku Station, Tokyo, constructed during 1995 – 2000

Created area : about 10.9 ha

Embankment volume : about 680,000 m^3

GRS retaining wall

Wall length : about 1,700m
Wall area : about 7,200m^2
Wall height : about 12.4m (max.)
about 9.0m (ave.)
Geogrid area : about 240,000m^2




Completed GRS retaining wall

Omura train yard of Kyusyu Shinkansen under construction 2018

Moreover, the FHR (full-height rigid) facing can be used as a foundation for other structures, such as crash barriers, noise/wind barriers, electric power supply poles etc. Unlike reinforced soil RWs having facing that is not FHR (e.g., discrete panels or modular blocks), road and railway can be arranged very close to the wall face relying on high stability of the reinforced backfill immediately behind the FHR facing.

Recently, many railways (including high-speed railways) use continuous RC slab tracks because of a high lifetime cost-effectiveness resulting from very low maintenance cost despite relatively high construction cost. However, RC slab track cannot be constructed on ordinary embankment and the backfill retained by conventional RWs due to their potentially high residual deformation. On the other hand, RC slab tracks are constructed without any problem on RRR GRS RWs because of very small residual deformation of the backfill that is well-compacted and stabilized by taking advantage of closely arranged geosynthetic reinforcement layers (with a vertical spacing of 30 cm) that are firmly connected to the FHR facing.

Awards conferred to RRR-B:

1988 Japan Railway Civil Engineering Association (JRCEA), Excellent Research Paper Award to “Development of a reinforced soil wall using geotextiles” (1987)

1991 The Japanese Geotechnical Society (JGS), Outstanding Geotechnical Achievement
Award (Project Award Division) to “Development of reinforced soil retaining wall having short planar reinforcement and rigid facing”

1994 International Geosynthetics Society(IGS), The IGS Award to “Development of geosynthetic-reinforced soil retaining wall system having staged-constructed full-height rigid facing”

1996 International Geosynthetics Society (IGS) and International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), The Mercer Lectureship on “Geosynthetic-reinforced soil retaining walls as important permanent structures”

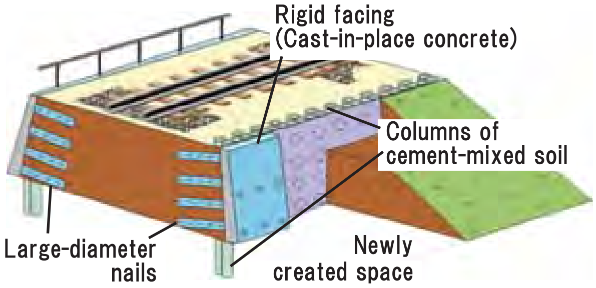
1998 Japan Chapter of International Geosynthetics Society (JC-IGS), Excellent Research Paper Award to “Field measurement of the behavior of a preloaded-prestressed reinforced soil structure and a proposal of design and construction method”

2013 The Japanese Geotechnical Society (JGS), Outstanding Geotechnical Achievement Award (Project Award Division) to “Application of various GRS (Geosynthetic-Reinforced Soil) structure for Hokkaido Shinkansen”

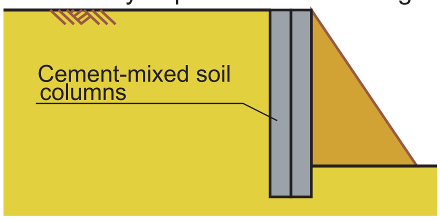

Certificate of technical evaluation (1999)
Japan Institute of Country-ology and Engineering

RRR-C Nail-Reinforced Soil (NRS) Retaining Walls

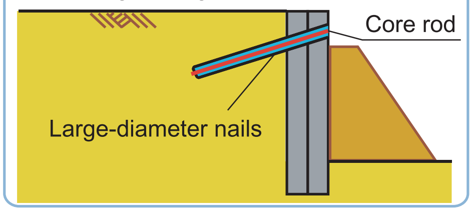
RRR-C is a new technology to cut natural slopes or embankment slopes to near-vertical walls by using large-diameter nails and FHR (full-height rigid) facing without using temporary structures (e.g., anchored sheet piles). New spaces are created in front of the wall.



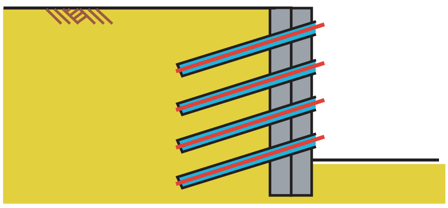
Construction of cement-mixed soil columns by in-place cement-mixing



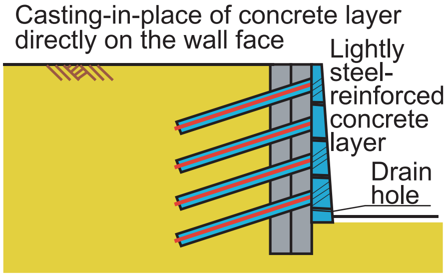
Excavation of the top soil layer and installing of large-diameter nails



Completing of cutting work by repeating the procedure shown above



Casting-in-place of concrete layer directly on the wall face



Firstly, an internal FHR wall is installed in the slope before the start of step by step cutting.
At each step, large-diameter nails are installed after partially cutting the slope.
In this way, the deformation of slope during cutting is kept very small, which allows continuous use of the slope crest for railways, highways, residences etc.
After cutting is completed, an external FHR facing is constructed by casting-in-place concrete on the wall face in such that it is firmly connected to large-diameter nails.
The completed wall is very stable. Moreover, the FHR facing can be used as a foundation for other structures (e.g., fences,traffic barriers, noise/wind barriers, electric power supply poles etc.).

RRR-C is very cost-effective, because of no use of temporary structures and a short required length of nails due to their high pull-out resistance resulting from a large-diameter.

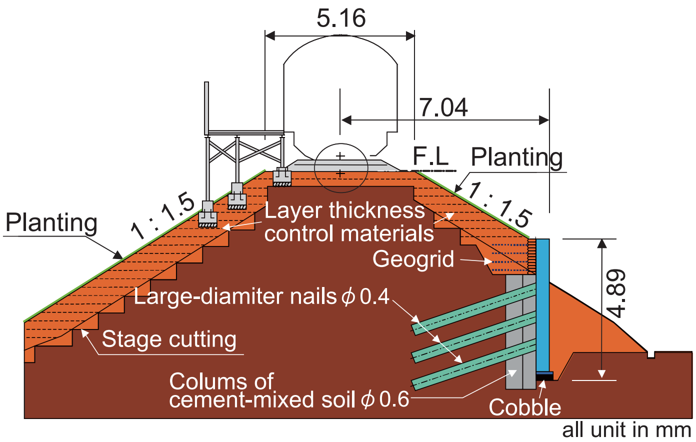
Typical examples:

< Shinkansen (bullet train) >

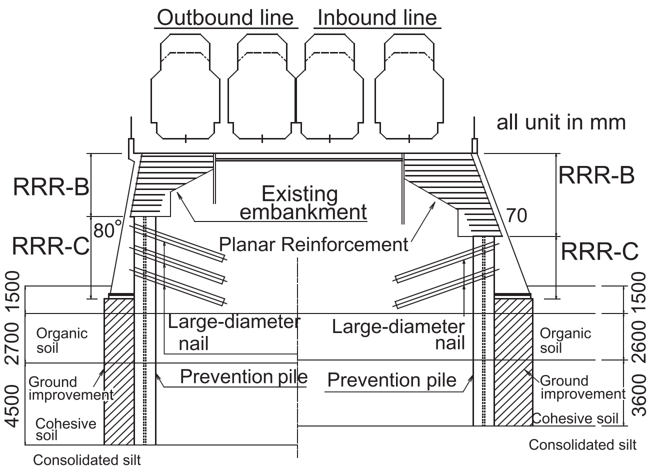
Nail-reinforced soil wall under construction, Kyushu Shinkansen, 2000

Nail-reinforced soil wall under construction, Tohoku Shinkansen, 2000

< RRR-C and RRR-B >



Completed Nail-reinforced soil wall, Chojabaru Station, JR Kyushu Sasaguri Line, 1999



Installing of large-diameter nails, 2004

Quadruple-track work between Musashikosugi and Hiyoshi on Tokyu Toyoko Line, constructed 2004

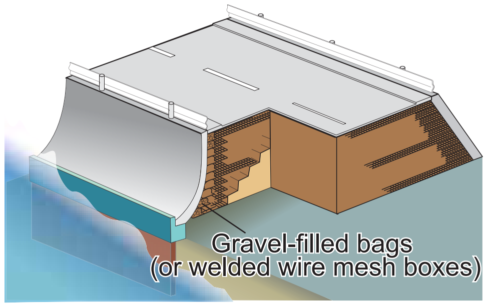
Awards conferred to RRR-C:

2001 Japan Society of Civil Engineers (JSCE), Innovative Technique Award to “Development of a natural slope reinforcing method using large-diameter reinforcing materials ” (Radish Anchor Method)

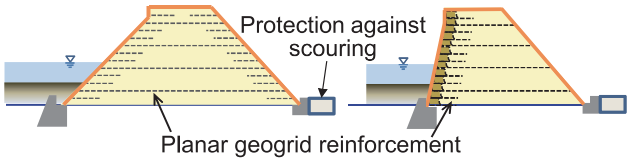
Certificate of technical evaluation (2007)
Advanced Construction Technology Center

RRR-D GRS Structures to Prevent Water-Front Disasters

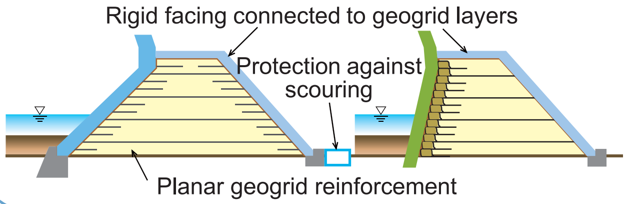
RRR-D technology allows the construction of GRS river and coastal dykes that prevent and mitigate disasters by floods, storms and tsunamis. The lightly steel–reinforced concrete facing is firmly connected to geogrid layers reinforcing the backfill to ensure a high stability against strong earthquakes and strong over-flows.

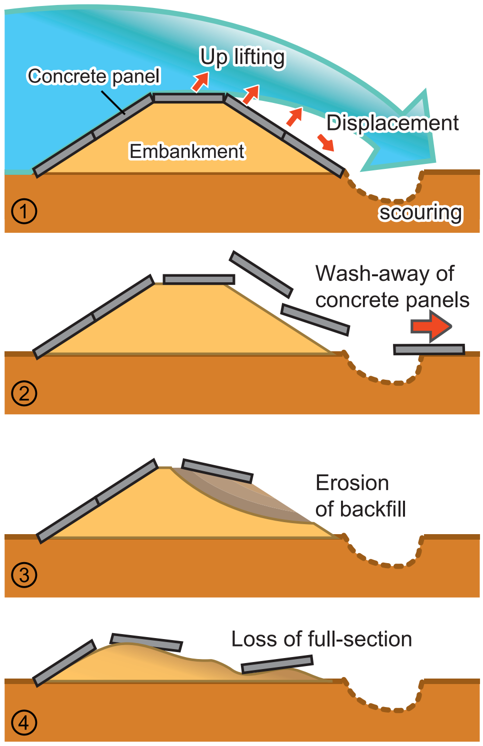


Construction of geogrid-reinforced embankment: nearly vertical walls can be constructed by taking advantages of RRR-B construction method.



Rigid facing is constructed firmly connected to geogrid layers. Filter layers are installed on the back of facing to prevent erosion of the backfill by seepage forces and sucking out of the backfill by over-flowing current.



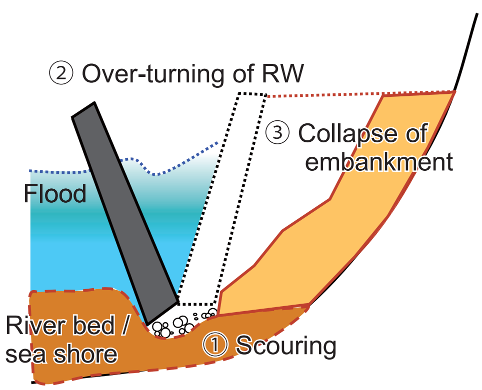


Collapse mechanism of costal dyke by tsunami

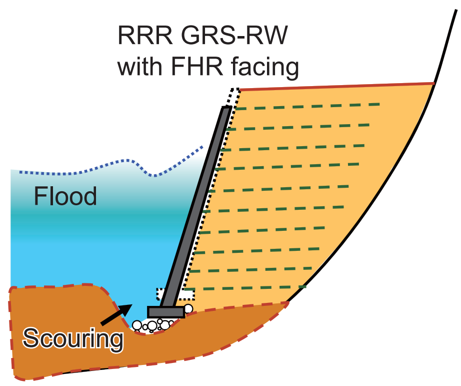
The collapse by floods and tsumanis is effectively prevented by:

1) stabilizing the facing against wave forces and shear and uplift forces by over-flowing current in addition to slope deformation by scouring in the supporting ground; and

2) increasing the resistance of backfill against erosion by geogrid-reinforcing.



Collapse of conventional type RW by scouring



Increased resistance and high redundancy of RRR GRS-RW with FHR facing against scouring

Typical examples:

Collapsed railway embankment
by Niigata and Fukushima torrential
rains of July 2011

Train operation was recovered
in 14 days

Reconstruction of railway embankment near Tazawa tunnel, Iiyama Line, JR-East

Shimanokoshi Station
before 2011

Sanriku Railway Kitariasu Line
suffered enormous damage
by giant tsunamis caused by
the 2011 Great East Japan
Earthquake

Reconstruction of railway embankment near Shimanokoshi Station, Sanriku Railway
Kitariasu Line, 2013

Awards conferred to RRR-D:

2001 International Geosynthetics Society (IGS), One of the best papers published in Geosynthetics International (IGS official journal) in 2007, “Remedial treatment of soil structures using geosynthetic-reinforcing technology”

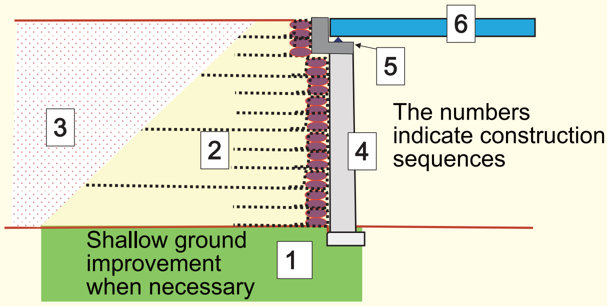
2009 Japan Chapter of International Geosynthetics Society (JC-IGS), Outstanding Geotechnical Achievement Award to
“Outstanding Geosynthetic Engineering Achievement to “Development of mitigation technology for damage to soil structures by earthquakes and floods”

2014 The Japanese Geotechnical Society (JGS), Project Award to “Restoration of soil structures of Sanriku Railway by increasing the stability against seismic load and tsunami”

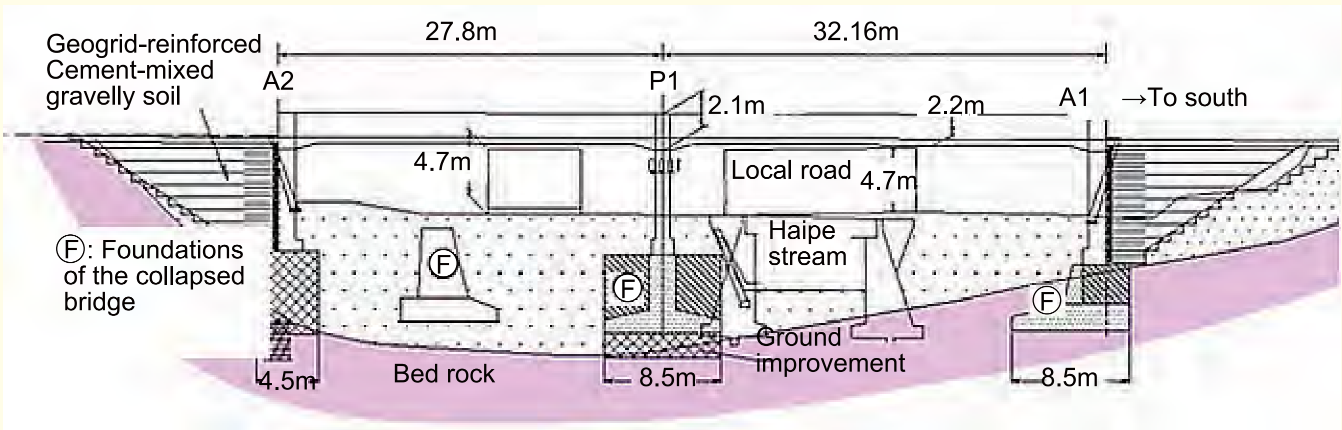
RRR Typical case histories

RRR-A GRS Integral Bridges and GRS Bridge Abutment

Under construction Oct. 2011



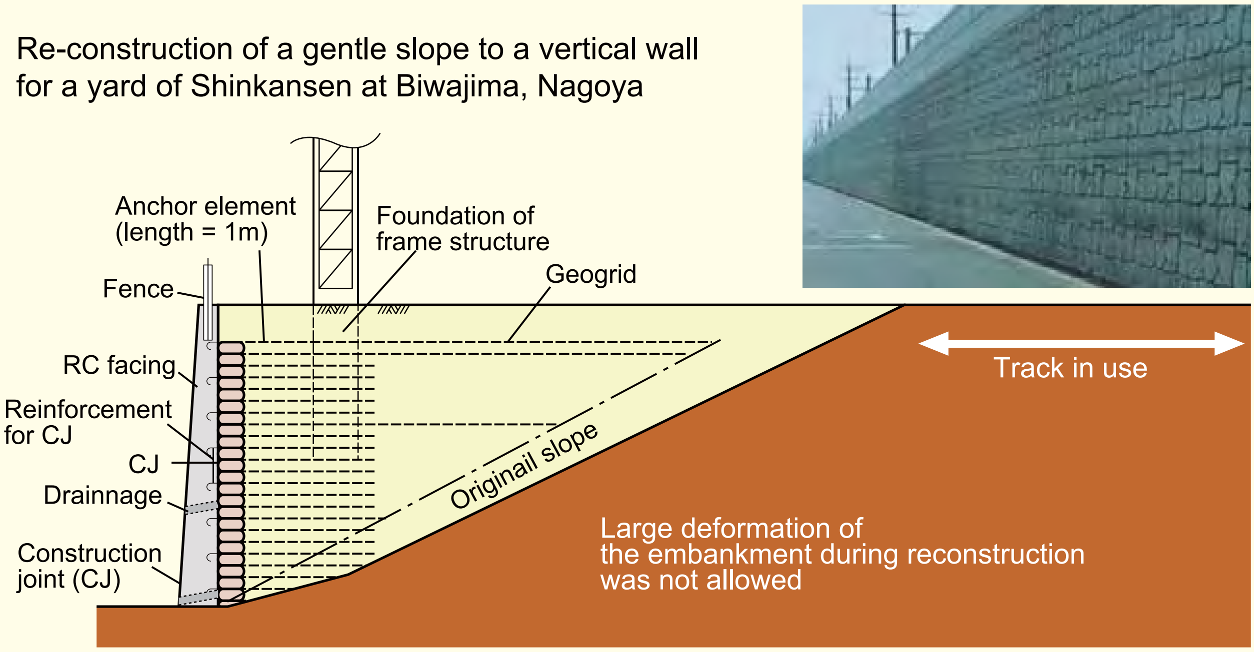
GRS Brideg Abutment (using bearings),
Hokkaido Shinkansen,
Completed Aug. 2012



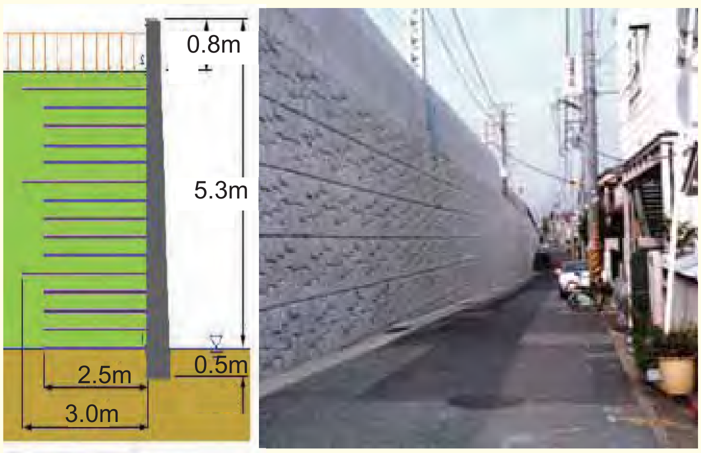
GRS Integral Bridge at Haipe, Sanriku Railway, April 2014

RRR-B Geosynthetic-Reinforced Soil (GRS) Retaining Wall with FHR facing

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



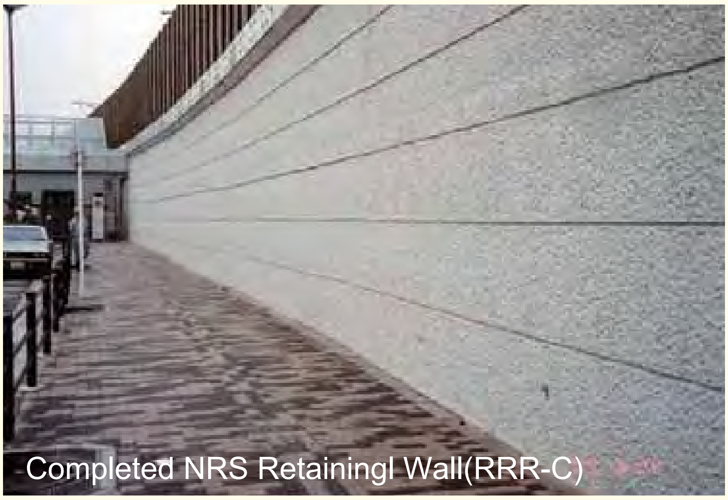
Shinkansen yard at Biwajima, Nagoya, 1989 - 1990
(average wall height= 5m & total length= 930m)



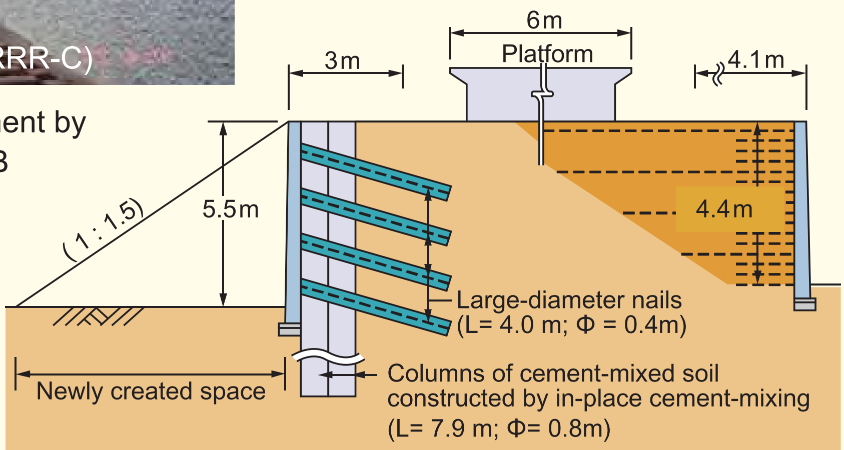
GRS RW with FHR facing for JR Kobe line,
Tanata, 1992

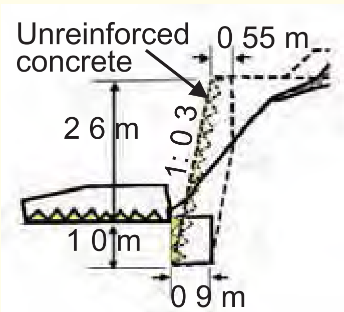
A week after the 1995 Kobe Earthquake,
24 January 1995

RRR-C Nail-Reinforced Soil (NRS) Retaining Wall

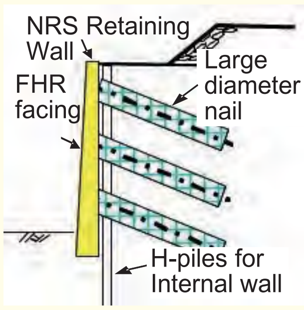


Reconstruction of railway embankment by RRR-C (on the left side) and RRR-B (on the right side), Rokuzizo Station, JR Narita Line, constructed 1992



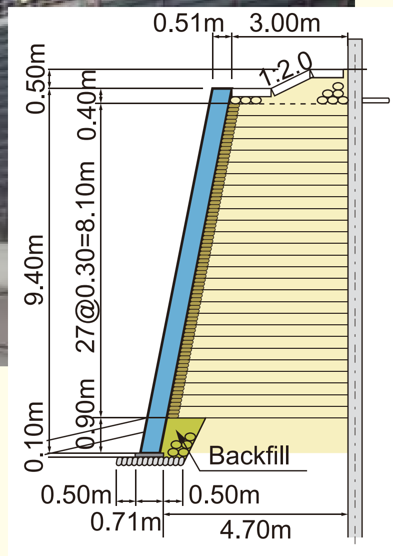


Leaning type wall, collapsed by the 1995 Kobe Earthquake, Kobe, Sumiyoshi, January 1995

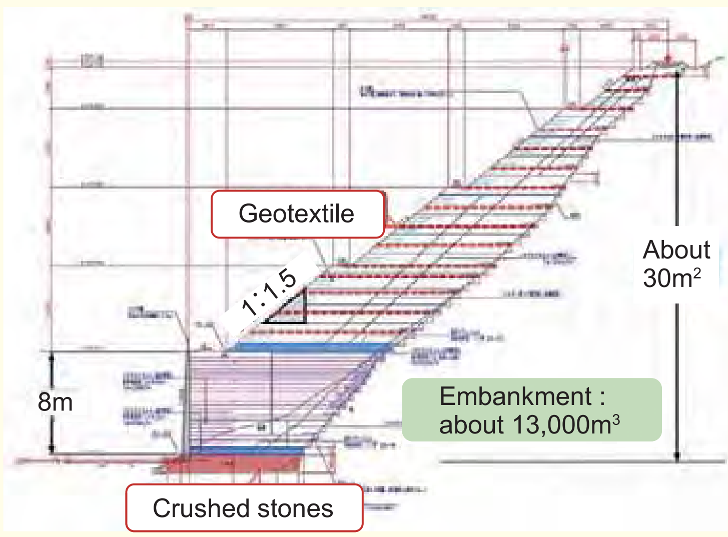


NRS Retaining Wall to restore the wall collapsed by the 1995Kobe Earthquake, Kobe, Sumiyoshi, June 1995

RRR-D GRS Structures to Prevent Water-Front Disasters



Seawall for Seisho by-pass of National Road No.1, southwest of Tokyo, to restore the gravity type retaining wall collapsed by scouring by ocean wave actions due to a typhoon, 2007



Reconstruction of railway embankment that collapsed by Yamaguchi and Shimane torrential rain of July 2013, near Nayoshigawa between Funahirayama and Tsuwano on Yamaguchi Line, JR-West, from April to May in 2014

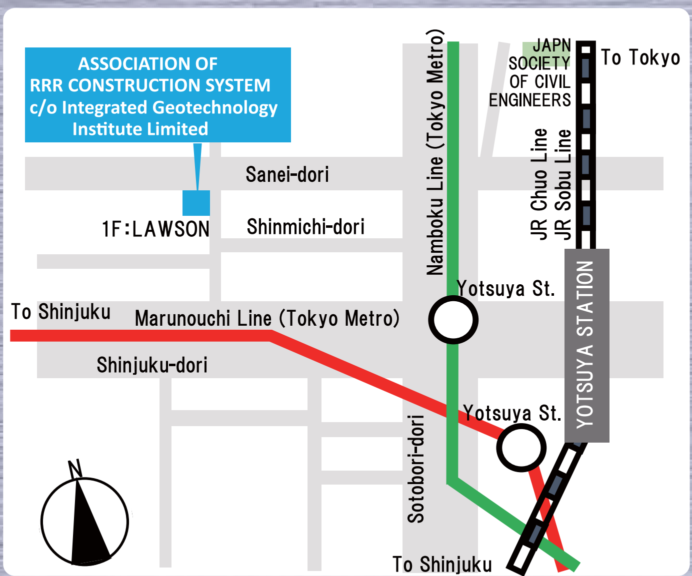
ASSOCIATION OF RRR CONSTRUCTION SYSTEM

RRR manuals

1. Manual on Design and Construction of Geosynthetic-Reinforced Soil (GRS) Integral Bridge (Original Japanese Version by Japan Railway Technical Research Institute & Japan Railway Construction, Transport and Technology Agency, March 2017)

2. Manual on Design and Construction of Cement improved Reinforced Soil Bridge Abutments (Original Japanese Version by Japan Railway Construction, Transport and Technology Agency, February 2004)

3. Manual on Design and Construction of Geosynthetic-Reinforced Soil (GRS) Retaining Wall (RRR-B) (Original Japanese Version by Association of RRR Construction System, October 2015)



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Access 5 minute's walk from
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5 minute's walk from
exit 2 of Tokyo Metro Yotsuya Station

Fisical year 2019