Initiatives for the use of FRP materials in Non-metallic Bridges

West Nippon Expressway Company Limited

Shikoku Branch

Keijiro Tsurukawa

Table of Contents

Situation of deterioration of concrete structure in Japan

■ Poor Condition for Concrete Structures

Anti-freezing Agents in Winter (Soil)

Salt Exposure from Sea

Slab on Bridge

Flange

Overhanging Beam

Concrete deterioration due to **steel corrosion** becomes apparent

⇒ Increase in frequency and cost of maintenance

Situation of deterioration of concrete structure in Japan

■ Background of ultra-durable bridge development

Current Tasks

Increase in

- Number of deteriorated bridges
- Frequency of maintenance
- Repair costs

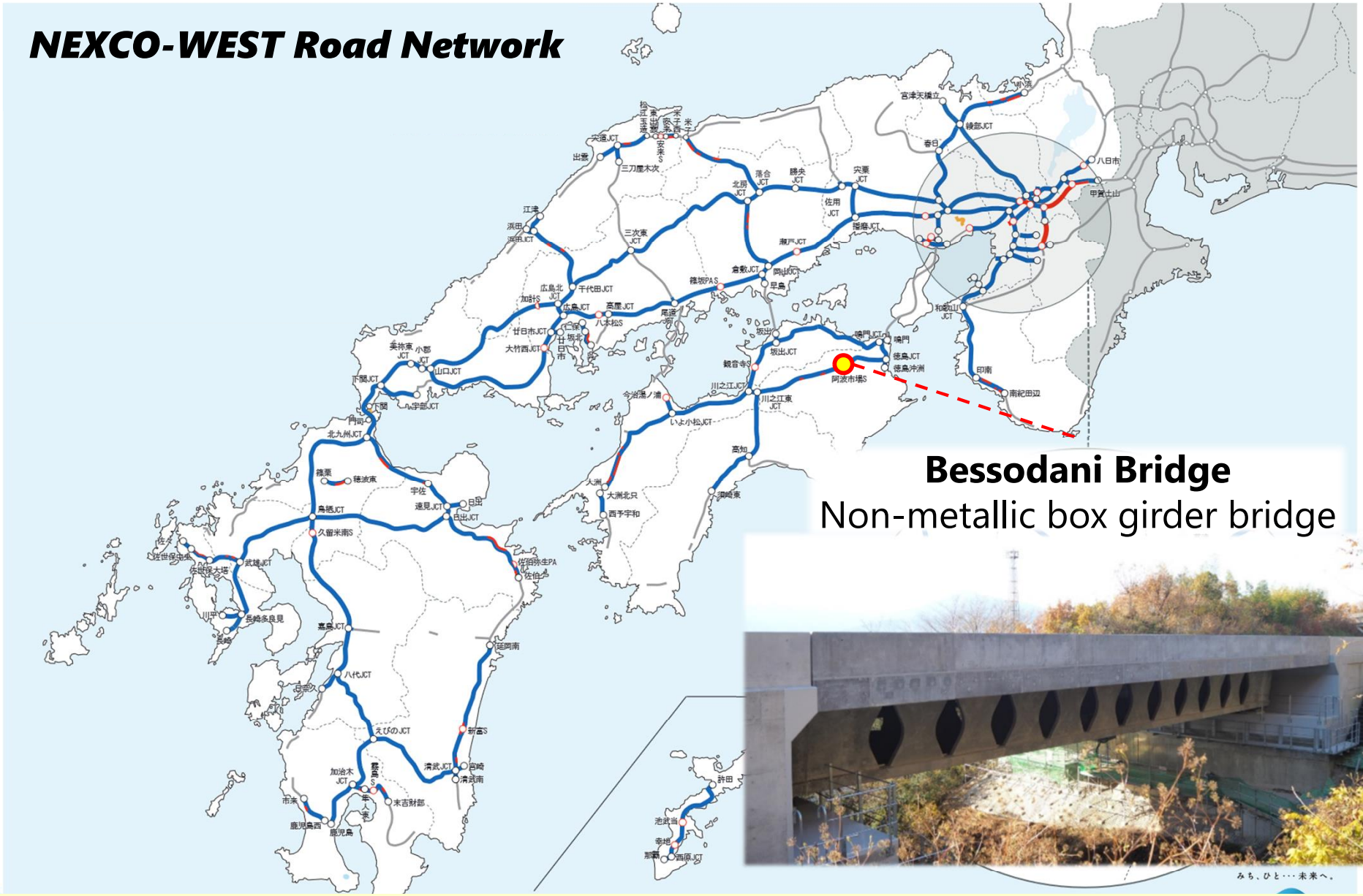
On-site Needs

- ✓ Prolonging the lifespan of existing bridge through preventive maintenance
- ✓ Higher durability of bridges to be newly constructed or renewed

Development Goals

- ◆ **Eliminate deterioration caused by salt damage**
- ◆ **Development of ultra-durable bridge without using steel material**

Initiatives of Non-metallic Bridge in NEXCO-WEST



No rusting materials ⇒ Eliminate probability of deterioration caused by salt damage

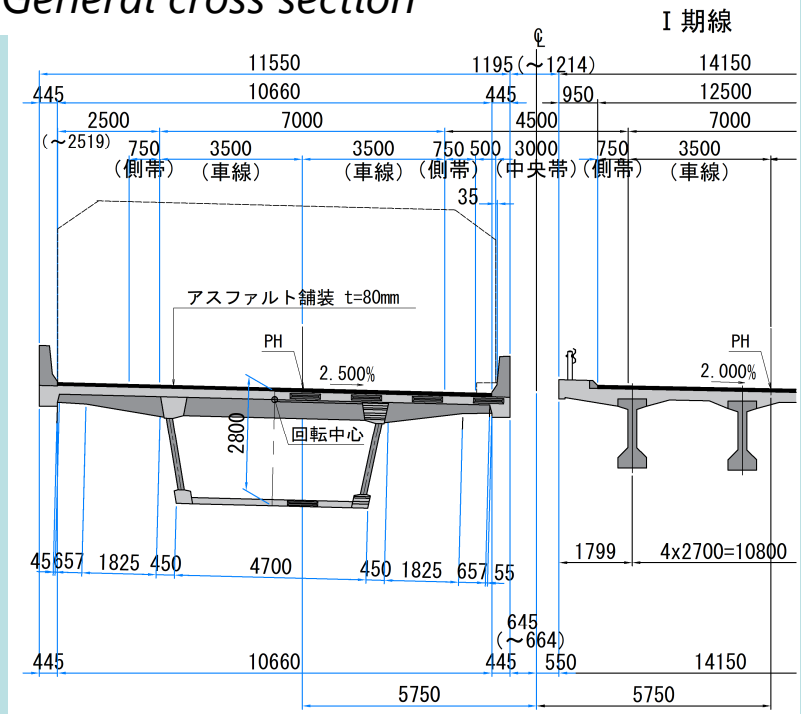
Initiatives of Non-metallic Bridge in NEXCO-WEST

Bessodani Bridge

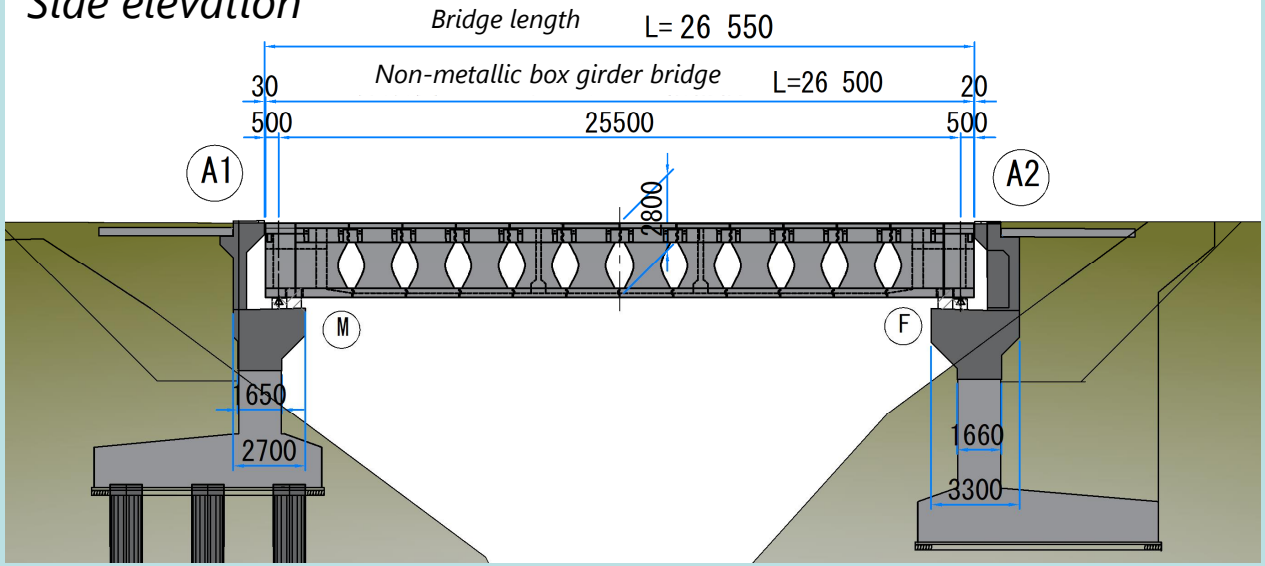
- Non-metallic box girder bridge
- Completed in December 2020
- Box girder：Using Aramid FRP
- Barrier wall ：Using Glass FRP
- Concrete：High Strength Fiber Reinforced Concrete

On-site photo

General cross section

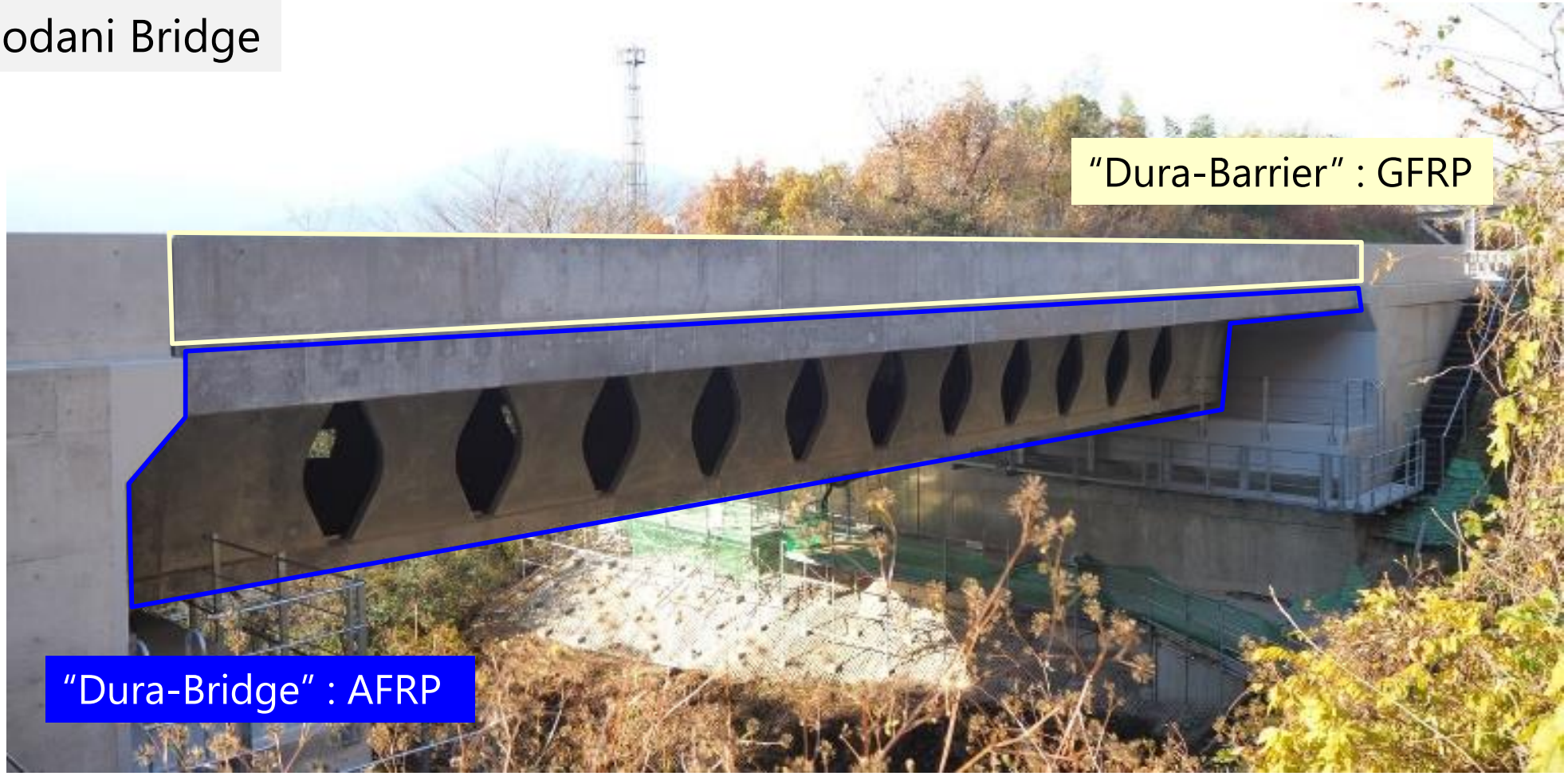


Side elevation



Bessodani Bridge (High durable bridge)

Bessodani Bridge

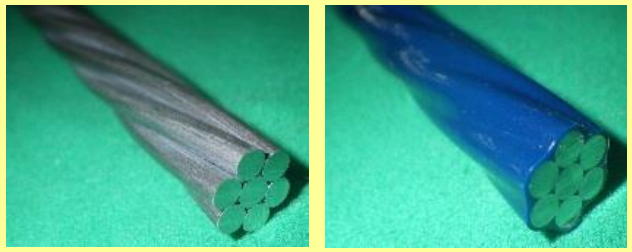


◆ Characteristic of Bessodani Bridge

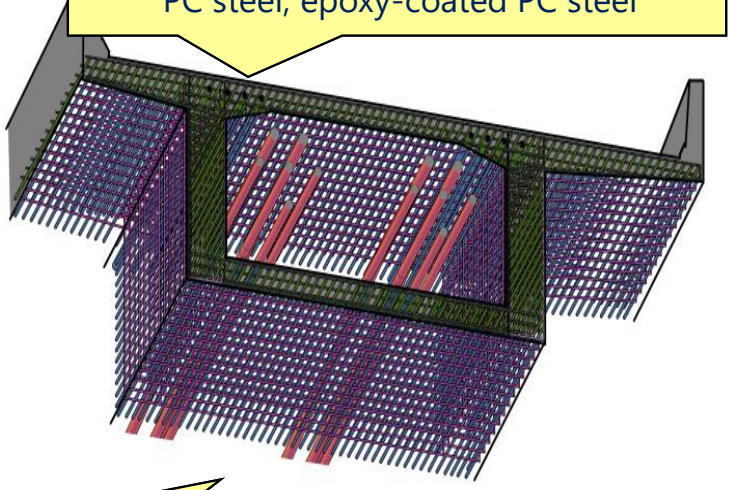
Non-metallic “Butterfly” web	Reduction of dead load and clarification of resistance mechanism against shear stress
Precast Segment	Quality control and on-site labor saving

“Dura-Bridge”（AFRP）

Conventional bridges



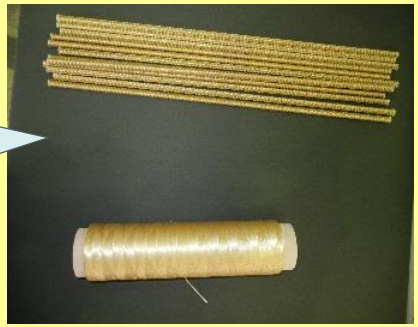
PC steel, epoxy-coated PC steel



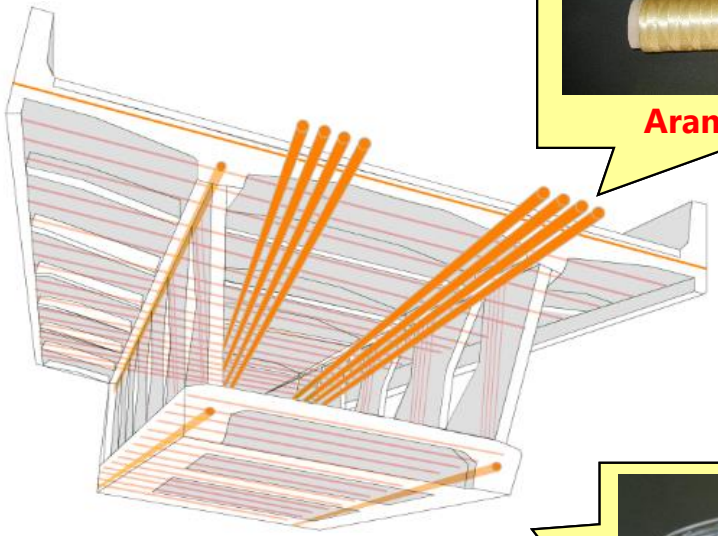
Steel Rebar

Ultra-durable bridges（Dura-Bridge®）

Fiber：Technora fiber
Resin : Vinyl Ester Resin



Aramid FRP rods

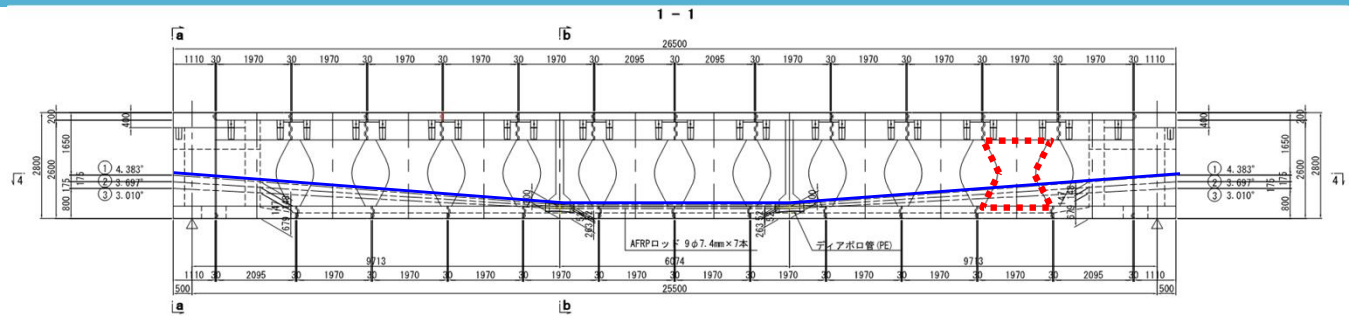


High strength steel fiber

*PC steel : prestressed concrete steel

“Dura-Bridge”（AFRP）

Prestressed outer cable



Butterfly Web
（Reduce Weight）

Deployment of aramid FRP rods for outer cables

Aramid FRP rod placement
(Butterfly Web)

“Dura-Bridge”（AFRP）

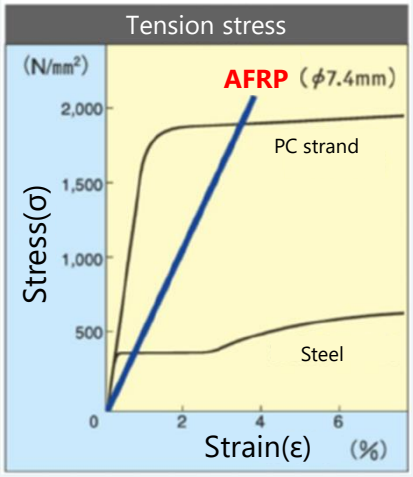
Dura-Bridge Comparison of Material

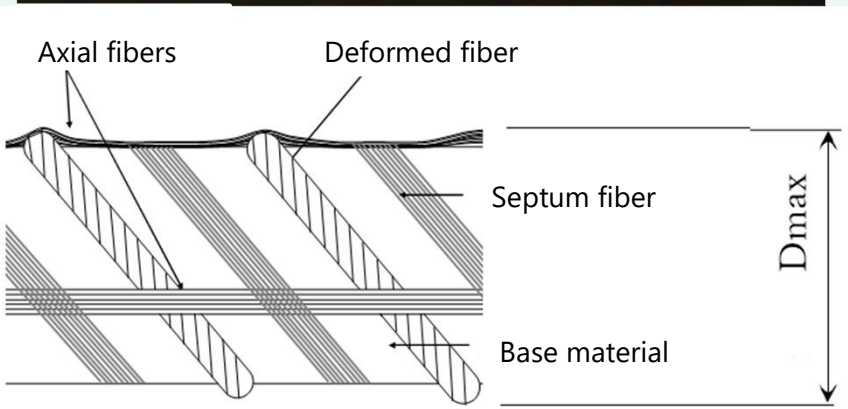
	Conventional Prestressed Concrete Bridge	Dura-Bridge (No rusting material)
Concrete	Design Strength 36N/mm^2	Design Strength **80N**/mm^2 ＋ **High strength steel fiber**（Tension stress 2,000N/mm^2）
Rebar	Steel Rebar SD345 （Tension stress 490N/mm^2）	No uses of steel rebar
Prestressed tension material	PC steel strand SWPR7BL 15.2mm （Tension stress 1,850N/mm^2）	**Aramid FRP Rods** φ7.4mm （Tension stress 1,670N/mm^2）

What is AFRP?

AFRP rods quality standards

Nominal Diameter	φ7.4mm
Effective cross-sectional area	42.4㎟
modulus of elasticity	53.0kN/㎟
Guaranteed Strength	1920N/㎟
Deformation	3.6%





Form of AFRP rods

Large elongation compared to steel rebar and PC steel

Why do we choose “AFRP” in Dura-Bridge?

(1) Low sensitivity on Prestress

Table3.4.2（Guidelines for the Design and Construction of Concrete Structures Reinforced with Fiber Reinforced Polymer (FRP) :JPCI）*

	AFRP	CFRP	BFRP	GFRP
modulus of elasticity（kN/mm2）	**53.0～66.8**	100.0～165.0	52.6	30.0

- AFRP is used as prestressed material due to its high tensile strength
- AFRP has low modulus of elasticity compared to CFRP （= Greater strain for the same stress）

→**AFRP: Low sensitivity on Prestress**
(Prestress loss is insensitive to PC fixture slippage or single wire rupture, even if it occurs)

(2) Higher Ductility

Material Properties（Guidelines for the Design and Construction of Concrete Structures Reinforced with Fiber Reinforced Polymer (FRP) :JPCI）

	AFRP	CFRP
Rupture elongation（%）	**4.5**	1.2~2.1

- Higher rupture elongation in AFRP comparing to CFRP (= AFRP is more ductile)

AFRP is used as Prestressed Material

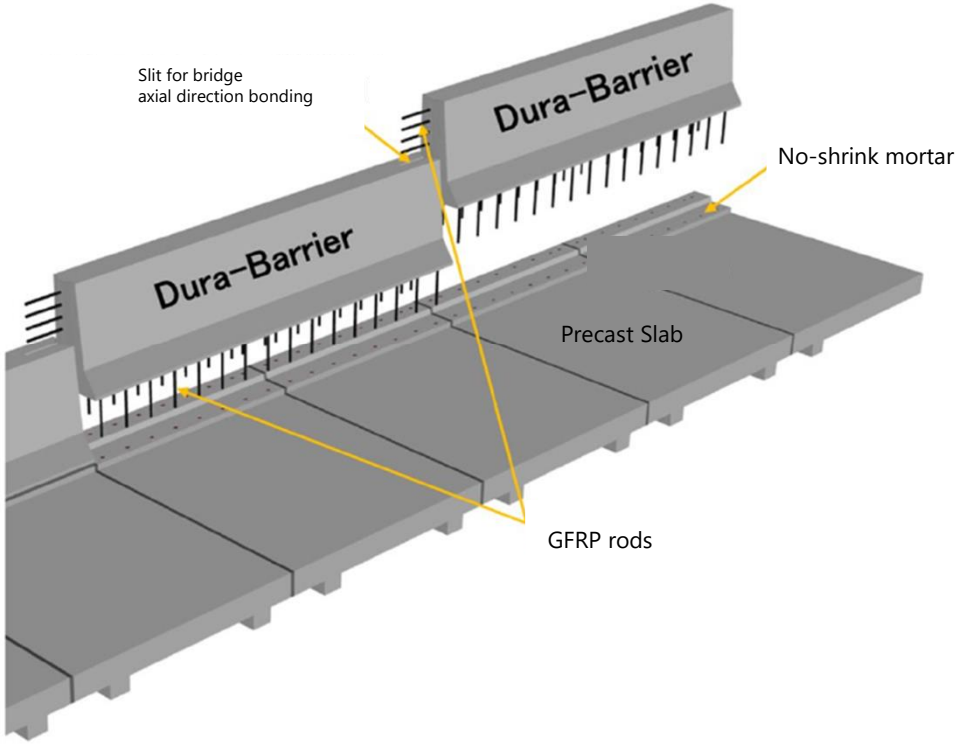
JPCI :Japan Prestressed Concrete Institute）

“Dura-Barrier”（GFRP）

Ultra-durable barrier wall（Dura-Barrier®）

- GFRP is selected for barrier wall instead of steel rebar
- Precast barrier wall : on-site labor saving
- Impact test was conducted for verification of load resistance
- Effective for not only Dura-Bridge but slab replacement project which has shorter construction period

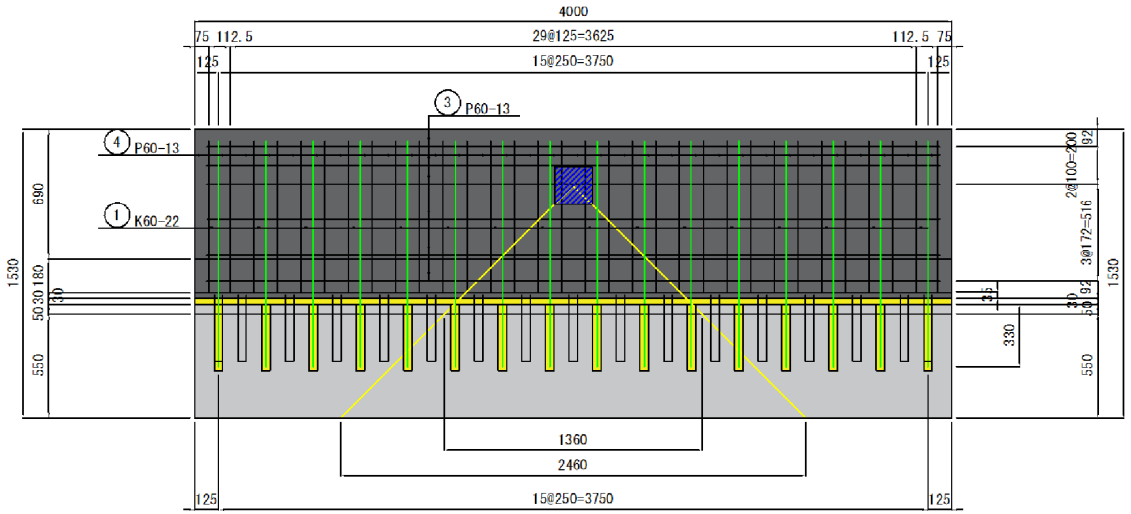
On-site photo

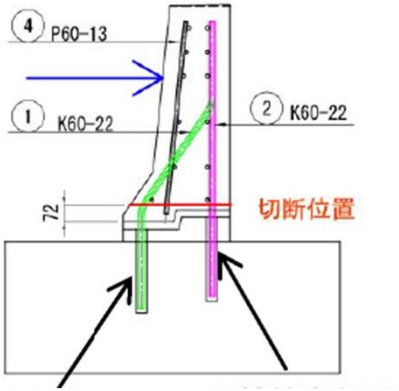


“Dura-Barrier”（GFRP）

GFRP Barrier wall

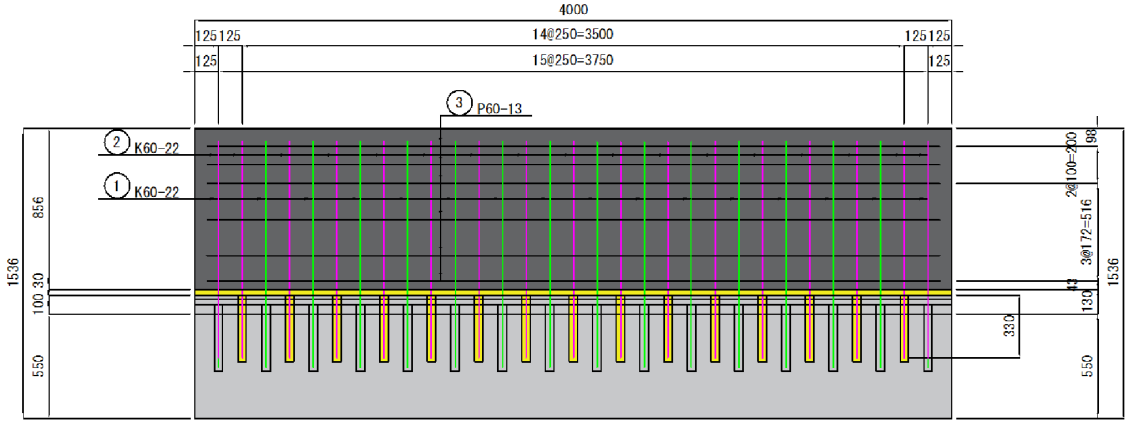
Front





Tension (Collapse)　　Compression

Back



- Validated the load capacity as a barrier wall through impact test

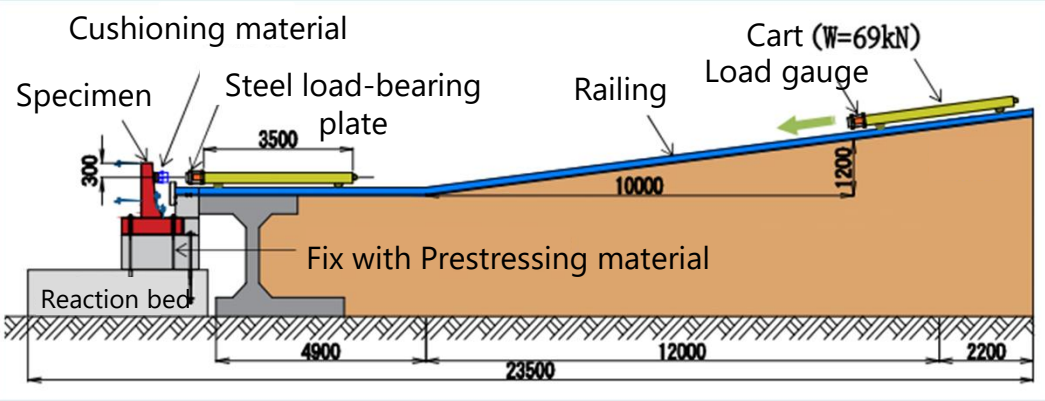
Why do we choose “GFRP” in Dura-Barrier?

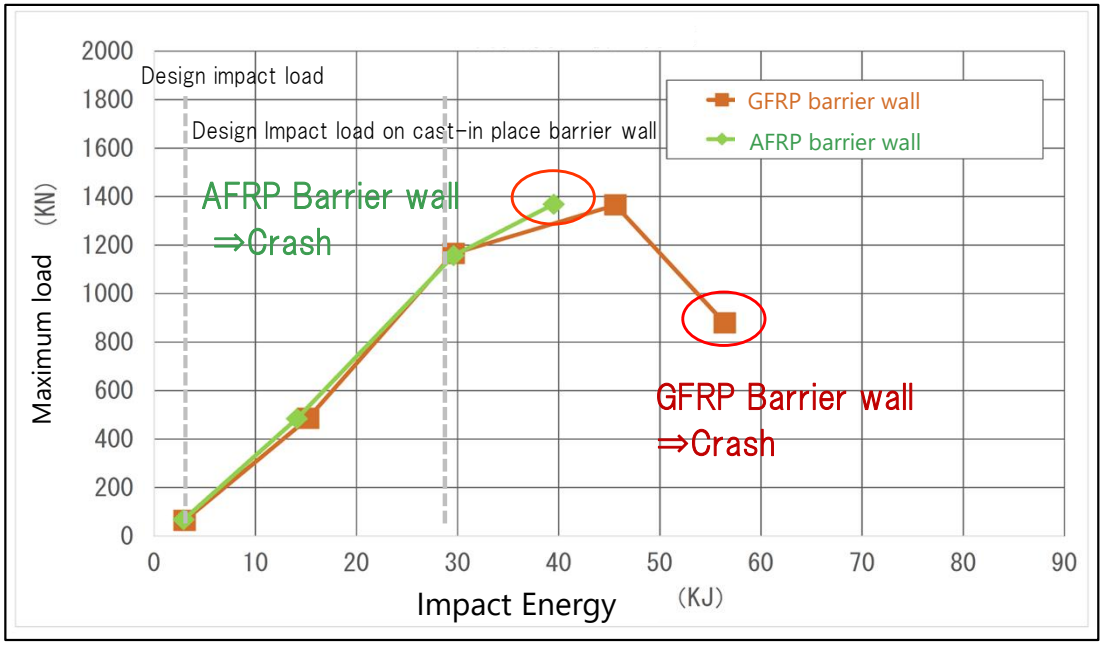
◆ NEXCO Test Method 441 “Testing method for joints of precast concrete barrier ”

Verification of appearance deformation and component strain based on NEXCO guidelines

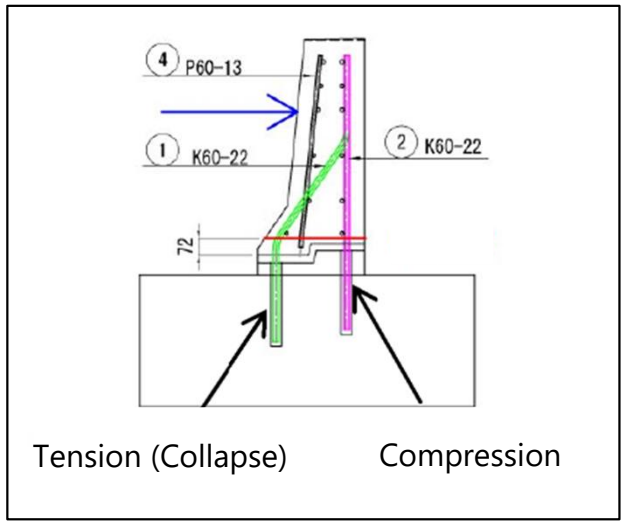
Experimental condition (Energy right before impact)

- Design impact load : 2.8kJ
- Desing impact load on cast-in-place barrier wall：28.0kJ





Result of experiment



Cross-section

- Validated much higher load capacity compared to design impact load

NEXCO WEST

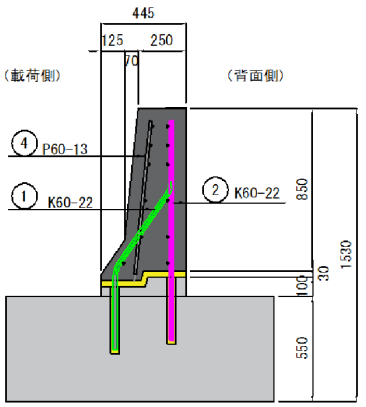
Cross section

Why do we choose “GFRP” in Dura-Barrier?

■ AFRP and GFRP were compared for the use of barrier wall

	AFRP	**GFRP**
Economic efficiency	The shorter the part length, the more uneconomical (*1.25 times)	○
constructability	Full-Prestress	Insert into hole
comprehensive evaluation	△	○

断面図

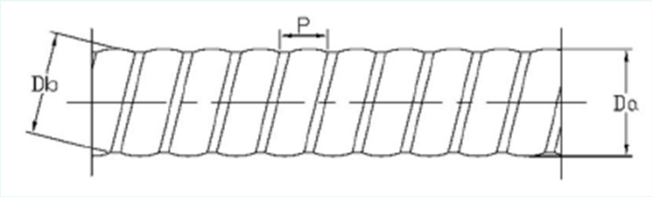


-> Dura-Barrier：GFRP was selected because of economic efficiency and constructability

What is GFRP?

GFRP rods quality standards(P60-13)

Nominal Diameter	Φ15.0mm
Effective cross-sectional area	132.7㎟
modulus of elasticity	60.0kN/㎟
Guaranteed Strength	1,000N/㎟



Form of GFRP rods