Development of Ultra-high-durability Bridge and Its Pilot Structure

超高耐久橋梁の開発と実証橋施工の概要

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1. Introduction

In Japan, annual maintenance and renewal costs for infrastructure are expected to surpass the current total annual investment after 2035. Thus, in addition to efficient and strategic maintenance of existing capital stock, new infrastructure that will be constructed needs to use structures that are very durable in order to keep the future maintenance burden to a minimum.

Motivated by these circumstances, the authors have attempted to develop an ultra-high-durability bridge (UHD bridge) that does not use steel materials, such as steel reinforcements and prestressing steel, that can cause the bridge to deteriorate due to corrosion. The UHD bridge is a concrete structure utilizing high-strength fiber-reinforced concrete and uses aramid fiber-reinforced polymer (FRP) rods for tendons as reinforcement (**Fig.1**).

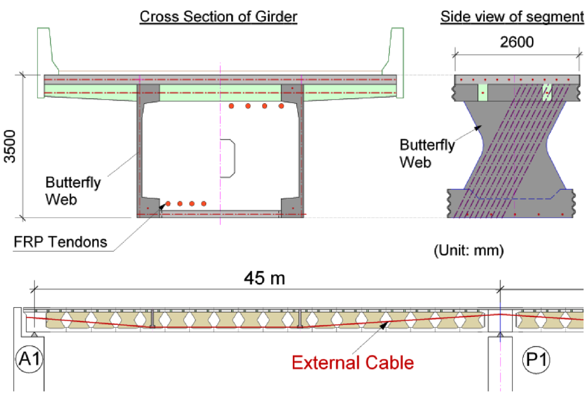

Fig.1 Outline of UHD Bridge

2. Development of UHD Bridge

(1) Butterfly Web

The UHD bridge has a new type of web structure, the Butterfly web. This structure consists of butterfly-shaped concrete panels and behaves similarly to a double Warren truss, with compression and tension forces acting diagonally in the panels. The compression forces are resisted by the compressive strength of the panel concrete, and the tension forces are resisted by incorporating prestressing steel tendons into the panels. For the UHD bridge, aramid FRP rods are used instead of prestressed steel rods. Shear force acts on the pinched areas of the panels and is resisted by the shear capacity of the concrete.

(2) Mixture Proportion of High Strength Fiber Concrete

Consequently, the concrete used for the butterfly panels needs to have high compressive strength and shear load capacity. For this reason the design strength for the compressive strength was specified at 80MPa. Trial designs using a butterfly web structure in girder bridges with spans of about 50m showed that the ultimate shear strength required for the pinched part of the butterfly web panel was 14.3MPa, thus 17.0MPa was adopted as the target for the shear strength requirement In order to determine the appropriate fiber, a comparison was conducted between the three types of steel fibers shown in **Table-1**.

Table-1 Mixture proportion and strength test results

Name	Steel Fber			Slump	W/B	Content (kg/m³)					Compressive Strength		Shear Strength
	Dia.	Length	Volume			Water	Cement	Silica Fume	Sand	Graval	7 days	28 days	
	mm	mm	%	cm	%						MPa	MPa	MPa
Base	—	—	0.00	20±2.0	25	185	666	74	815	594	102.2	129.4	11.8
DN1	0.62	30	1.50	20±2.0	25	185	666	74	776	594	93.8	116.5	20.9
DH1	0.38	30	1.00	20±2.0	25	185	666	74	189	594	95.3	120.4	19.1
SW1	0.20	22	0.50	20±2.0	25	185	666	74	867	528	97.7	126.5	18.0

(3) Experimental Study

The UHD bridge consists of precast segments, the upper deck slab incorporates ribs and has no steel reinforcement. Therefore, in order to investigate fatigue durability, a wheel load running test was conducted. The results show adequate durability (**Fig.2**).

Fig.2 Wheel load running test in progress

The structure uses the butterfly panels and the concrete itself to resist shear. The bridge is designed on the assumption of construction using precast segment structures, and thus the joints between such segments are only continuous at the upper deck and lower deck, making stresses likely to concentrate at these locations. For this reason, shear behavior was investigated using a cantilevered beam test specimen (**Fig.3**), and the structure provides a certain amount of shear strength.

(4) Pilot Structure

From these outcomes, the authors constructed an actual structure. The pilot structure is a temporary single girder bridge (span length: 14m) for a construction site (**Fig.4**). It is a precast segment bridge of eight segments. Using this pilot, the authors investigated the

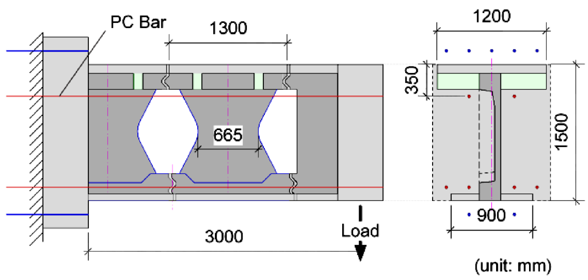

Fig.3 Outline of segment shear capacity test

Fig.4 Pilot structure

issue from the point of erection and verified agreement between design and actual structure. The bridge has been used for two years and monitored for deformation, stress, strain and prestressing force of the aramid FRP rods.

3. Conclusion

The materials and experimental tests proved the following.

- Mixing steel fibers into high-strength concrete made from ordinary Portland cement and silica fume allows creating concrete with the specified concrete strength of 80MPa and shear strength of 17.0MPa.
- Experimental results confirmed that fatigue performance of the upper slab was sufficient for 100 years of service and joints between segments can resist shear by means of the newly developed high-strength fiber-reinforced concrete alone.

The pilot structure construction allowed integrity between design and actual structure to be verified through monitoring the structural behavior of the bridge.

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