Construction of Space Truss Bridge
— Nagata Bridge —

スペーストラス橋の施工
— 永田橋 —




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Synopsis
Nagata Bridge, crossing over the Tama River, connecting Fussa City and Akiruno City in Tokyo, Japan, is a four-span continuous pre-stressed concrete composite truss bridge that employed a special structure called "space truss" for the first time in Japan (**Fig. 1** and **Fig. 2**). The bridge must have been completed in only one dry season of the Tama River, which is only 7 months. Due to the tight construction schedule, assembling tests were repeated beforehand in order to eliminate any waste of reassembling or nonconforming works to shorten the actual construction period.
This paper reports remarkable points on the structure and technical examinations of Nagata Bridge.

Fig. 1 The whole view

Structural Data
Structure: Hybrid truss bridge (space trussed structure)
Bridge Length: 244.3m
Span: 62.1m + 60.3m + 60.3m + 60.0m
Width: 16.0m
Girder Height: 3.10m
Designer: Central Consultant Inc.
Contractor: Kawada Construction Co., Ltd.
Construction Period: January 2009 - August 2010
Location: Between Fussa City and Akiruno City, Tokyo

1. Introduction
Nagata Bridge was reconstructed over the Tama River to solve the problem of chronic traffic jam that the old bridge had not been able to solve due to its narrow width. Since the old bridge, constructed in 1961, had only two traffic lanes, it was not able to accommodate the current increased traffic volume. In addition, the design conditions for the new bridge were given by focusing on the followings:
- The bridge has to be a landmark for the people who visit the neighbor recreational facilities and/or playgrounds.
- The bridge must be harmonized with the surrounding landscape.
- The bridge must be constructed in low construction cost.

To realize these points, the new Nagata Bridge was

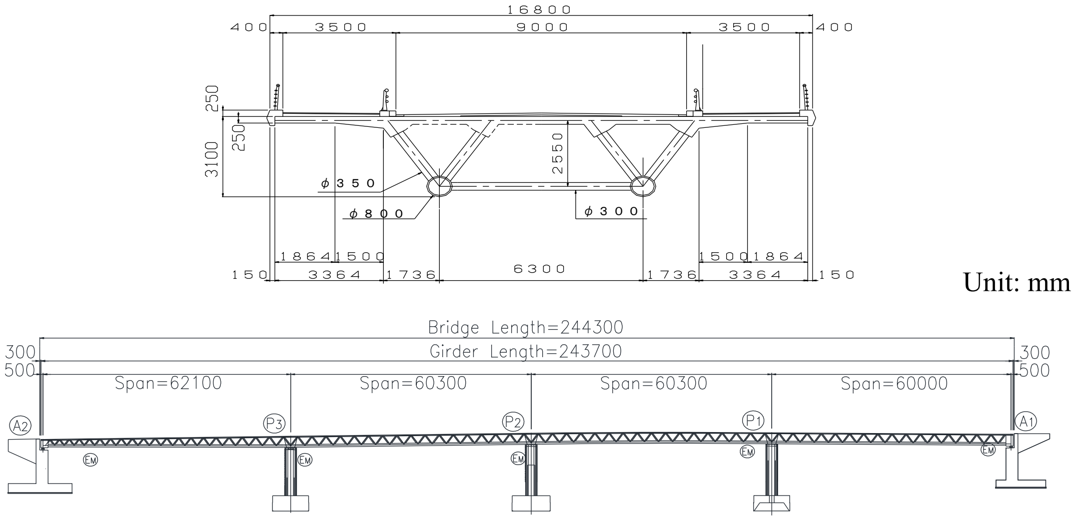


Fig. 2 Cross section and side view

planned to be a composite structure comprises concrete upper slab deck and lower three-dimentional truss assembled by steel pipes. This structure is called as "space truss". The space truss structure projects an image of harmonization with the surrounding environment and structural transparency of somewhat fading away into the surrounding background (**Fig. 1**). Besides the scenic effects, the lighter weight than conventional concrete bridges also realizes the cost saving. The schedule of the construction was as follows:

- Planning:
  March 2003 - March 2005
- Building temporary bridge for detour:
  November 2006 - March 2007
- Breaking and removing of the old bridge:
  March 2007 - April 2008
- Construction of foundation and sub-structure:
  November 2006 - March 2009
- Construction of superstructure:
  November 2009 - April 2010

2. Construction schedule

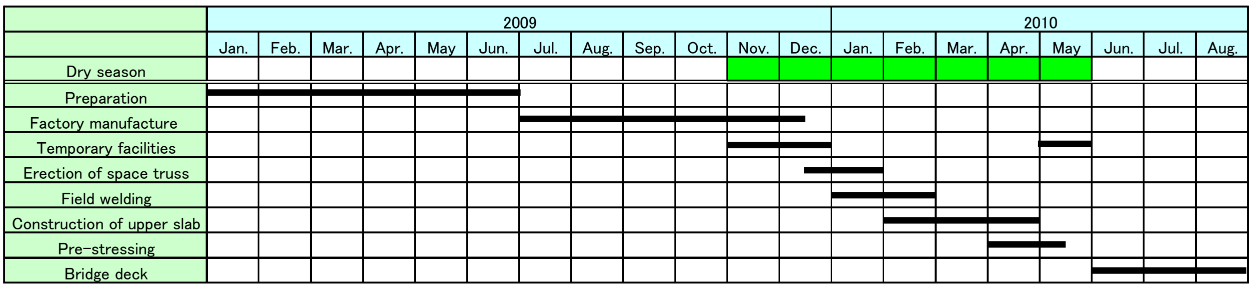
Fig. 3 shows the construction schedule of the superstructure and the period of dry season of the Tama River.

The construction can be executed in the river area only during the dry season. Structures of this type are generally built with falsework. However, since all the works in the river area had to be completed within one dry season, several examinations on the workability were conducted.

The most important work to keep up with the construction period was to join all steel pipe truss members with welding. The workability of field welding could largely affect the total construction period and thereby could be an important factor for shortening of the construction period.

Accordingly, several mockup assembly tests were implemented to confirm the workability and quality specifically as follows:

- Welding workability and welded joint quality from inside of lower pipes.



Main works in dry season	Quantity	Main works in dry season	Quantity
Construction of support	20,910 m^3	Placement of concrete slab	1,833 m^3
Erection of truss member	747.5 t	Pre-stressing of internal cables	106 cables (12S15.2)
Field welding	10,875 m	Pre-stressing of external cables	24 cables (19S15.2)
Installation of concrete slab form	4,852 m^2	Demolition of support	20,910 m^3
Installation of reinforcing bar	283.7 t		

Fig. 3 Construction schedule

Fig. 4 Simulation of workability

- Quality of steel pipe material suitable for field welding.
- Operability of setting external pre-stressing steels.

3. Examination of field welding

To ensure the good welding quality, the joints of lower members were welded from inside of the pipes. However, the pipes' diameter was 800mm at outside and 666mm in inside, it was impossible for welding operator to freely move and handle the welding instrument inside such narrow pipe as shown in **Fig. 4**. Due to this problem, welding must have been done from outside attaching the backing metals inside the pipe. In this case, as it was impossible to confirm the quality condition of the welding from inside, fatigue loading test must have been implemented to appraise the accurate toughness of durability of the welded joints.

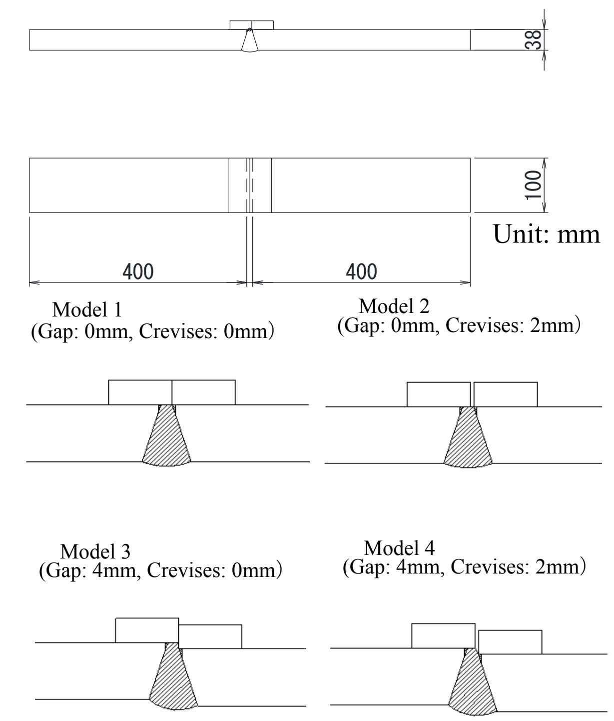


Fig. 5 Welding condition of test piece

The specifications of Japanese Society of Steel Construction (hereinafter referred to as "JSSC") require that the welded joint portion with backing metals shall have the toughness of grade G, which equals the toughness of durability to pass 2.0 million times repeated loading test with 50 N/mm^2 stress.
Fig. 5 shows welding conditions. Three test pieces for each of four typical cases of base metal alignment error were prepared with the method of gas-shielded arc welding with pure CO_2 gas under the same field welding conditions. Then, the aforementioned loading test was implemented for the total twelve test pieces.
Fig. 6 shows the results of repeated loading test. After 1.5 million times of loading, a short crack occurred near the welding zone on Model 3 and Model 4, although all of test pieces were not broken even after over 3.0 million times repeated loading test. All of the results of repeated loading test are above the grade G line and almost close to the grade F line.
According to the above results, durability grade of this method was not less then the grade G.

4. Examination of steel materials

Generally, welding for thick plates needs heat input to prevent cold cracks. There were two time-consuming tasks during field welding work; one was to give an accurate heat input to the base metal, and the other was to weld the conventional and standard grooves of such thick plates with many welding passes.
To solve these problems, the steel for Bridge High-performance Structures (SBHS) was used. SBHS is

	Model 1			Model 2		
	Gap: 0mm Crevises: 2mm			Gap: 0mm Crevises: 2mm		
	1	2	3	1	2	3
Cycles	3,150,000	3,510,000	3,800,000	3,000,000	3,450,000	3,800,000
Crack Existence	not exist	not exist	not exist	not exist	not exist	not exist
	Model 3			Model 4		
	Gap: 4mm Crevises: 0mm			Gap: 4mm Crevises: 2mm		
	1	2	3	1	2	3
Cycles	3,000,000	3,600,000	3,350,000	3,310,000	3,010,000	3,680,000
Crack Existence	exist	exist	exist	exist	exist	not exist

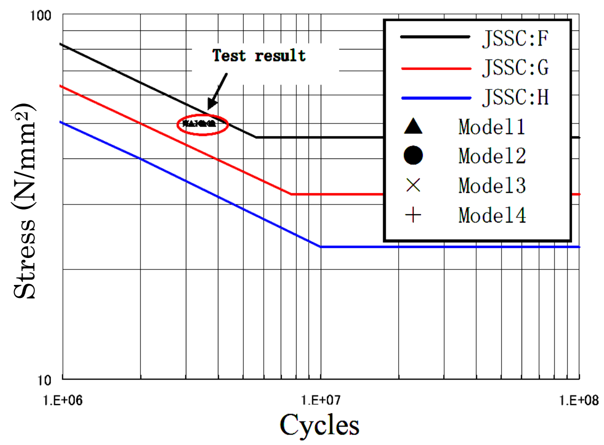


Fig. 6 Result of repeated loading test

highly strong and tough, and has excellent weldablity and cold formablity compared to the conventional rolled steel materials for welded structures.

The increase of yield strength is realized by using steel microstructure makeup technology by taking advantage of the controlled cooling process, not through the addition of alloy which inhibits weldablity and formablity. Therefore, with the SBHS's excellency in weldablity, heat input can be omitted or reduced during welding and cold formablity. The upper limit of heat input for the base metal was also improved from 7kJ/mm to 10kJ/mm, and as groove angle can be sharpened from 60° to 35°, welding for a pair of steel plates was finished with less welding passes.

5. Operability of setting external cables

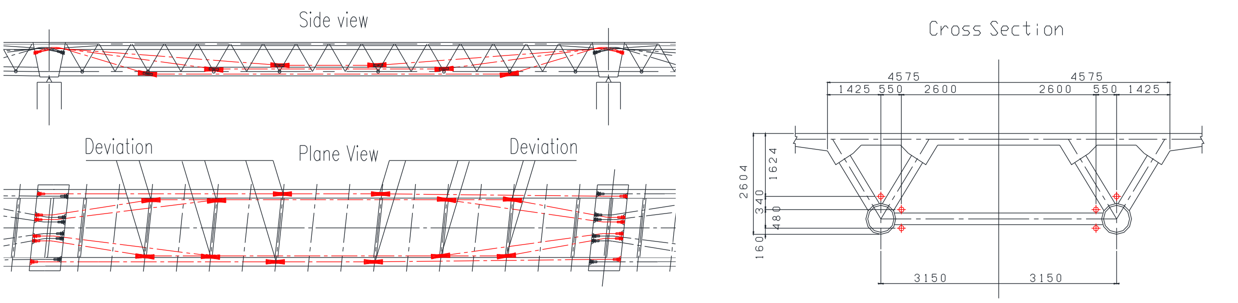
Fig. 7 shows the arrangement of external cables. To give the high weather resistance to the pre-stressing steel wires, galvanized steel wires were used, those of which were covered by polyethylene plastic tubes (hereinafter referred to as "PE tubes").

There was a risk of score marks on the surface of PE tubes or the paint coat protecting the deviating steel pipes by the work of setting the pre-stressing cables through the steel pipes. The setting of the pre-stressing cables was carried out into three types of 5m-long full-scale pipes under the actual structural condition on site. Polyamide plastic tube which has a property of more softness than PE tubes was used in the practice, putting it between the PE tubes and the deviating steel pipes as a protector for the surfaces of both the tubes and the pipes. As a result of practice, no score mark on both surfaces was detected. Furthermore, the setting of polyamide plastic tubes was successfully achieved only by manual works.

6. Conclusion

The grand-old bridge, built in 1875 as the toll bridge under the governmental permission, was hit and destroyed by a typhoon named "Kathryn" in 1947. Then, the old bridge, constructed in 1961, has been appreciated by the local citizen as one of the symbols of the Tama River for 50 years. The new bridge, opened in March 2011, will also be recognized as a symbol around the area as well with its elegant appearance and unique structure.

Finally, the authors wish to express their sincere gratitude to all of the interested members who gave the authors great advices for designing and constructing this bridge.



Unit: mm

Fig. 7 Arrangement of external cable

概　要

永田橋はスペーストラス構造が採用された４径間連続複合トラス橋であり，美観に優れたランドマークとしての役割を持つ橋梁である。スペーストラス構造とは，鋼部材である下弦材とコンクリート部材である上床版を３次元的に配置された鋼トラス材で結合したトラス構造である。本橋の上床版は主方向，横方向ともに床版内にPC鋼材が配置された場所打ち床版となっている。また，トラス内には各径間毎に外ケーブルが配置されている。

本工事は，施工実績が少ないスペーストラス橋の施工であり，橋体の施工にあたっては平成21年11月から平成22年５月までの１渇水期内での施工を要求されていた。そこで，現場溶接手法・鋼材種類の選定・外ケーブルの挿入試験等を行うことで，工程に遅延なく，品質を確保した施工を行った。