Accelerated Constructions of the Viaducts on the Second Keihan Expressway

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Abstract

The Second Keihan Expressway located between Kyoto and Osaka has been constructed as a bypass of the existing national route. Since the expressway is located in the suburban residential area, cost saving, accelerated construction, environmental protection for the surrounding residential area as well as improving the safety were required for the construction of the expressway. To meet these requirements, unique rationalized construction methods were applied for the different site conditions in two viaduct projects, the viaducts in Nasu-dukuri Area and in Aoyama Area.

This paper describes these new erection methods.

1. Introduction

The Second Keihan Expressway linking Kyoto and Osaka has been constructed as a bypass of the existing national route (Fig.-1). Since the expressway passes the suburban residential area, accelerated construction and reduction of the environmental impact during construction as well as improving the safety etc. are required for the construction of the expressway. To meet these requirements, two kinds of rationalized construction methods were newly developed and applied in two viaducts in Nasu-dukuri Area and in Aoyama Area, which are suitable for their own site conditions.

In Nasu-dukuri Area, since some degrees of construction area could be used in the construction site, the areas were used as casting yard and a unique U-shaped precast girders were adopted. It was not as the conventional erection method that uses muli-number of small precast segments divided longitudinally. It was possible to have some casting yard along the viaduct and to transprt the segment from the casting yard to the below area of the viaduct. The erection method was called "U girder lifting erection" in which site-fabricated U-shaped precast girders were used.

On the other hand in the viaduct in Aoyama Area, it was impossible to have enough construction yard around the viaduct, and also it was impossible to use the area under the superstructures due to the topographical conditions. The segments were fabricated at the concrete factory and transported to the site. The

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girder was devided into several segments longitudinally and the already completed deck surface was used as the assembling yard of the segments. The transported segments were lifted up, put on the deck and jointed as a girder. Then the girder was transported on the deck to the newly erecting span with the erection girder. This erection method is called “Span-by-span erection with rear assembly system”.

In both viaducts, accelerated construction could be achieved by developing the conventional erection methods, which are suitable for their own construction conditions. It could shorten the erection cycle and could also save the construction cost.

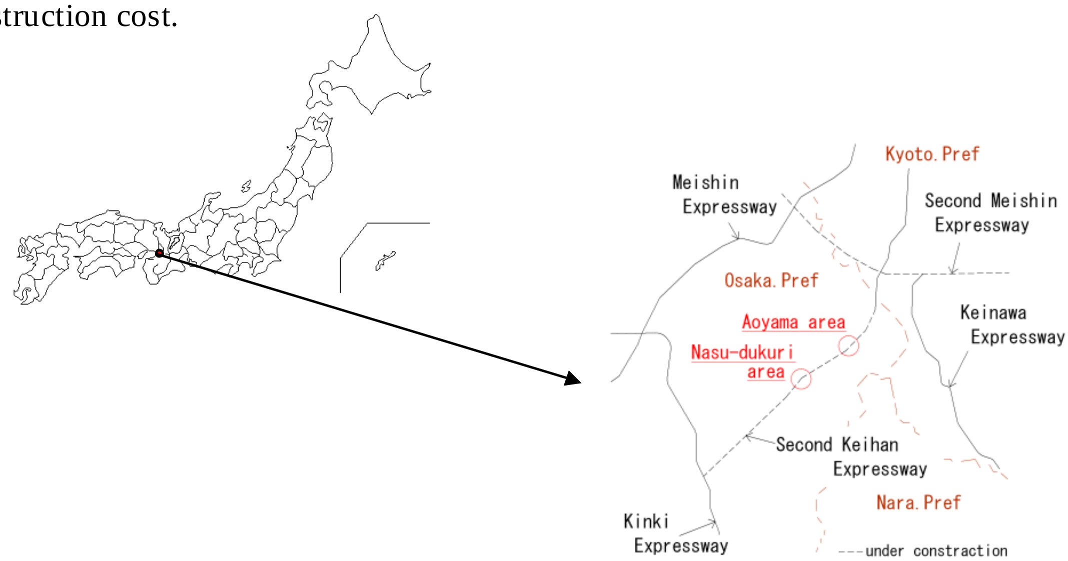


Fig.-1 The Second Keihan Expressway,

2. Project summary

2.1 General features

General views of the viaducts are shown in Fig.-2 and Fig.-3, and the cross sections of the girders are shown in Fig.-4 and a Fig.-5, respectively. The project summary and the viaduct properties are also shown in Table-1. The configurations of these two viaducts such as width, total length, span length and the structural type are quite similar. The design-built biddings were applied, and the construction methods were proposed by the contractor.

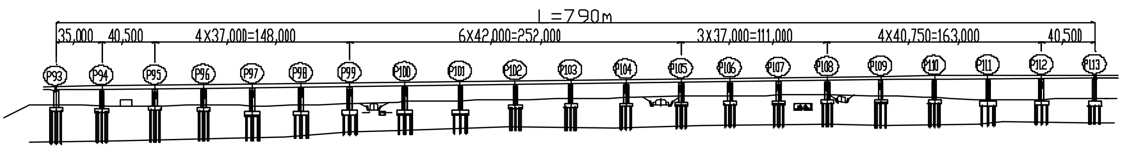


Fig.-2 Nasu-dukuri Viaduct

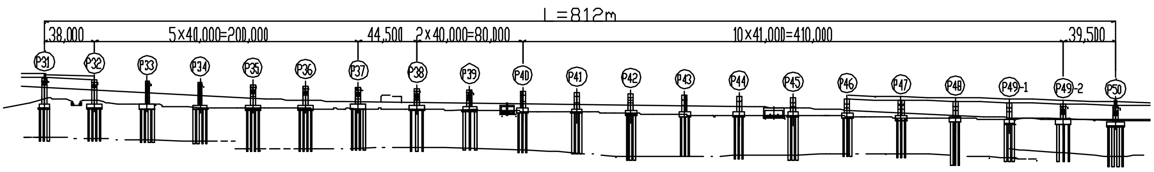


Fig.-3 Aoyama Viaduct

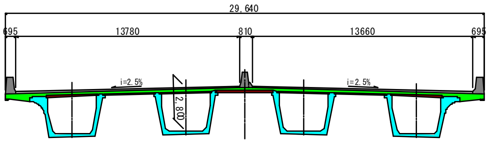


Fig.-4 Cross section of Nasu-dukuri Viaduct

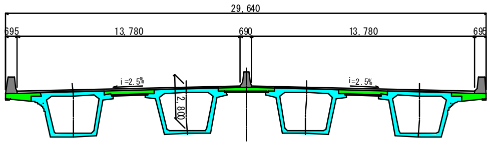


Fig.-5 Cross section of Aoyama Viaduct

Table-1 Project outlines and properties

Project	Nasu-dukuri Viaduct	Aoyama Viaduct
Profile	(20,2@2,2@7)spans prestressed concrete viaduct	20 spans prestressed concrete viaduct
Period	Mar.2007-Mar.2009	Sept.2007-Dec.2009
Length	790m	812m
Spans	37m, 40.75m, 42m	40m, 41m
Effective Width	2@13.780m	13.780m,13.660m
Alignment	R=1950-A=650-R=∞	R=∞-A=500
Vertical Alignment	1.240%-0.300%	2.966%-2.366%
Horizontal Alignmen	2.500%	2.500%

2.2 Requirements for the projects

During construction periods in both projects, following requirements were imposed.

1) Each construction period is about two years. However, considering the time for the detail design and other preparation work, only 18 months were remained as the direct construction periods. Therefore, strong time reduction was required.

2) Both viaducts are located in the quiet residential area, especially in Aoyama Area. Therefore, the environmental impact had to be strongly reduced.

3. Construction of the viaduct in Nasu-dukuri Area

3.1 Outline of the erection method

In Nasu-dukuri they could use some degrees of construction yard at the site and precast girders were selected. After fabrication the precast girder, the girder was transported to the erected span and lifted using erection girder. The U-shaped girder with no upper slab was first applied in Furukawa viaduct on the New Meishin Expressway (2002)[1)]. This erection method is called “U girder lifting erection method” (Fig.-6).

The procedures of the U girder lifting erection are shown in Fig.-7. Maximum weight of a U girder is 2,400kN, and the girder was lifted with the erection girder.

Since the precast girders were lifted near the supports of the erection girder on the piers, the bending moment acting on the erection girder could be quite small. Furthermore, applying the U-shaped girder without upper slab could also reduce the weight of the erection girder. As results, the bending moment acting on the erection girder could be reduced up to 1/6 compared with the conventional span-by-span erection, and the erection girder could be lightened drastically (Fig.-7, 8 and Table-2).

The following effects to the surrounding area could be expected.

1) Noises and vibrations caused by the construction work can be reduced since the girders are fabricated at the fixed fabrication yard in the site.

2) No need to use the large trailers to pass the existing residential area for transporting the precast segments.

The standard construction cycle of the superstructures is shown in Table-3.

In Nasu-dukuri Area, no stockyard was built for the U girder. This could be achieved by that the casting cycle of four girders were set to be equal to their erection cycle. In order to achieve the cycle, four casting beds were used, and two sets of lifting girders were used in order to achieve the two weeks erection cycle of four girders per span.

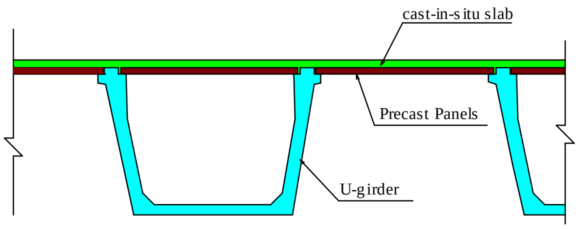


Fig.-6 Girders and slab structures in Nasu-dukuri Viaduct

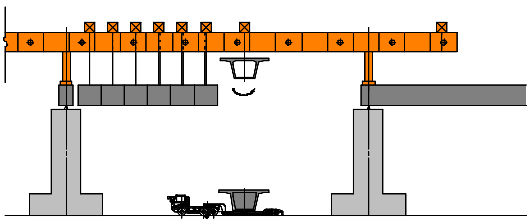


Fig.-7 Conventional span-by-span erection

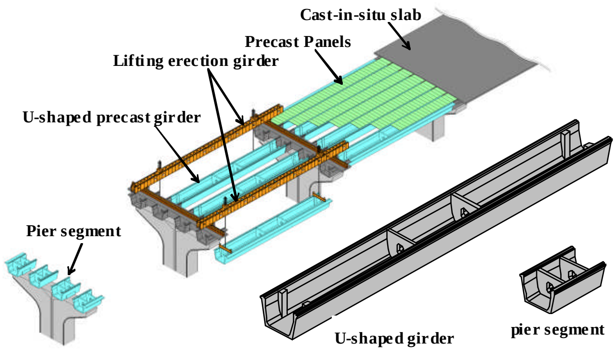


Fig.-8 Overview of the U-shaped girder lifting erection

Table-2　Erection methods and the bending moments of the erection girder

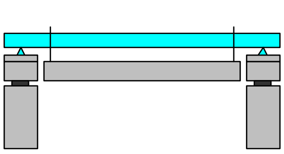
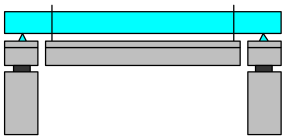
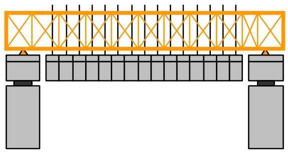
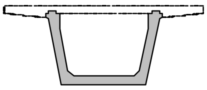
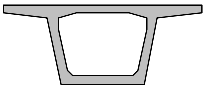
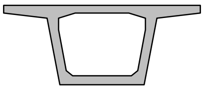
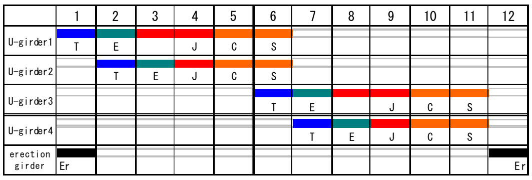
Erection Method	U-shaped girder lifting	Box girder lifting	Conventional span by span
			
Cross Section at Erection	U-girder 	Box girder 	Box girder 
Max Bending Moment in Erection girder	4100 kNm 18%	6800 kNm 30%	23000 kNm 100%

Table-3 Construction cycle of Nasu-dukuri Viaduct



T : Transportation　E : Erection　J : joint concreting

C : Curing　S : Stressing　Er : Erection Girder Equipment

3.2 Fabrication and erection of the U girder

Considering the limited construction area and the way to transport the construction materials as well as the construction cycle work, four sets of casting bed were arranged in line longitudinally along the viaduct (Photo-1).

The U girders were transported from the casting bed to the erecting span with a large trailer (Photo-2). Photo-3 shows the erection of the U girder. Since large tensile stresses occur near the lifting points inside the webs during lifting, the vertical prestressing and the additional reinforcement were arranged for the local stress. Prior to the fabrication, a mockup test was conducted to confirm the stress and the safety during erection.

After lifting the girder, the girder was moved horizontally and transversally to the fixed location, following that the U girder No.2 was lifted by another erection girder. The U girder No.2 was then moved also horizontally and transversally (Photo-4).

150 mm closure joints were placed at both ends of the girder and the pier segments. After placing concrete, each girder was externally prestressed and then the lifting devices were released.

Segments No. 3 and No. 4 were also constructed as the same ways and the construction of one span was completed.

Photo-1 Casting yard

Photo-2 Transportation of the U-girder

Photo-3 Erection of the U-girder

Photo-4 Transversal movement of the girder

3.3 Construction of slab

For the construction of the slab, precast and prestressed panels were place on the webs of the U girder. These panels are used as structural components as well as for the formwork, and the re-bars were assembled on them. For the thermal stress and the stress caused by the deformation of the girder due to the influence of the concreting in the adjacent slab, as well as shrinkage and creep effects. Expansive admixture was used as well as additional reinforcement designed through the thermal stress analysis (Photo-5, 6).

Photo-5 Precast panels

Photo-6 Cast-in-situ slab

4. Construction of the viaduct in Aoyama Area

4.1 Outline of the erection method

Since it was impossible to have the casting yard near the construction site and it was difficult to use the area below the superstructures in Aoyama Area, existing concrete factory was utilized as the fabrication yard for the precast segments of the girder. After the factory-fabricated precast segments were transported from the factory to the construction site, the segments are then lifted and assembled on the already constructed deck surface as an assembling yard. This erection method is called “the span-by-span erection with rear assembly system”. The core segment without some length of overhang slab could save the weight of the girder (Fig.-9). Compared with the viaduct in Nasu-dukuri Area, transversal movement devices were used in order to reduce the number of erection girder, and the cost of the construction girder was reduced substantially.

Construction procedures of the erection method is shown in Fig.-10 as followed, and the standard construction cycle of the superstructures is shown in Table-4.

1) Segments of the girder No.1 are put and jointed together on the already constructed deck surface. The assembled girder is transported toward the erection girder along the deck surface and erected with the erection girder. The weight of a girder is about 3,500kN.
2) The girder No.1 is horizontally and transversally moved by the devices and then tensioned. The following girder No.2 is also assembled, transported and erected from the rear span continuously.
3) After the girder No.3 and the girder No.4 are erected in sequence and all the four girders are erected, precast panels are placed and the erection girder is moved toward the next span.
4) Slab concrete is placed.

In Aoyama Area, transporting the segments, lift up to the deck surface and joining were performed in one day, and the transportation, erection and transversal movement on the next day, while the segments of the next girder were transported to the site in 2 days later. Joining work of the next girder was performed concurrently at the rear assembling yard while the installation and tensioning were performed in the erecting span. As results, the construction cycle in one span of four girders took two weeks and was achieved as the same as that in Nasu-dukuri Area.

Compared with the conventional span-by-span erection method, this erection method with one set of erection girder could construct 1/2-1/3 faster by the number of days. In other words, 2 to 3 sets of erection girder would be needed to have the same erection speed in the conventional erection method (Fig.-11).

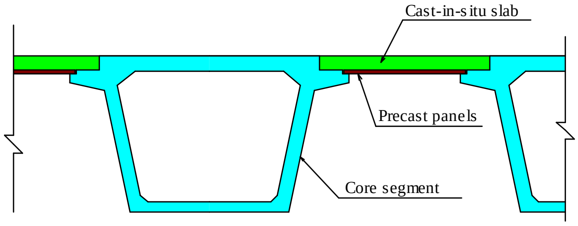


Fig.-9 Girders and slab structures in Aoyama Viaduct

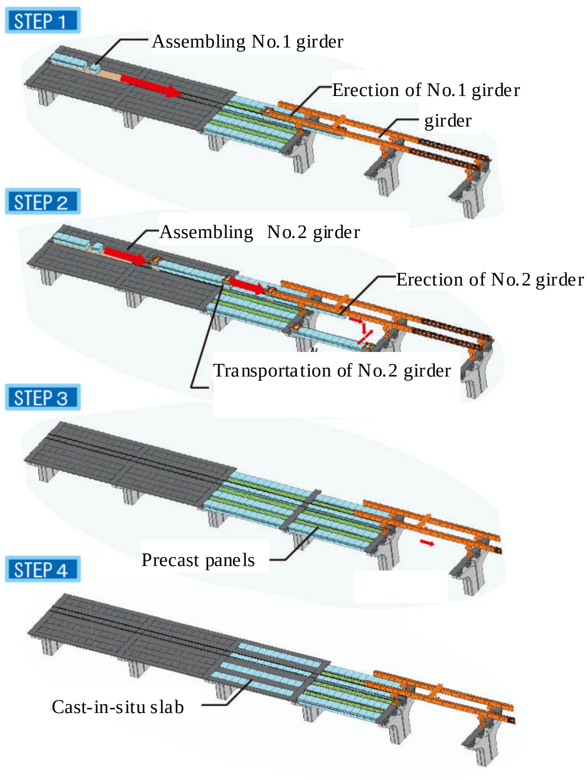


Fig.-10 Overview of the span-by-span erection
with rear segment assembly system

Table-4 Construction cycle of Aoyama Viaduct

	1	2	3	4	5	6	7	8	9	10	11	12
main girder 1		E		J	S	Er						
main girder2				E		J	S	Er				
main girder3						E	J		J	S	Er	
main girder4								E	J	S	Er	
erection girder	Er											Er

E : Erection J : joint concreting

S : Stressing Er : Erection Girder Equipment

4.2 Assembly and erection of the segments

13 numbers of segments were transported from the factory with trailers. The segments were placed on the deck surface with a crane, jointed together as a girder (Photo-7). Then the girder was prestressed and put on the carriers.

Devices for transversal movement were installed at the upper part of both ends of the girder, and the girder was transported toward the erecting span (Photo-8). Since the weight of the girder and the devices reaches about 3,500kN and they were transported on one of four existing girders, the stress of the girder due to the loading was verified and additional prestressing tendons were arranged.

After the girder was transported toward the erecting span, the girder was hung by the crane installed on the erection girder (Photo-9). The devices for transversal movement were installed on the rail on the pier segments, and the devices with the girder were moved transversally to the fixed location (Photo-10).

As the same as the viaduct in Nasu-dukuri Area, 150 mm closure joints were placed at both ends of the girder and the pier segments, supported with the transversal movement devices. After placing concrete, each girder was externally prestressed and then the supporting devices were released.

Photo-7 Assembling the segments

Photo-8 Transportation of the girder

Photo-9 Erection of the girder

Photo-10 Transversal movement of the girder

4.3 Construction of slab

Precast panels were placed between the top of the girders (Photo-11), and re-bars assembly and concrete placing were conducted (Photo-12).

By using precast panels with labor saving, the slab could be constructed at the same days of the erection of four girders in next span. These procedures were quite effective ways to achieve the required construction cycles.

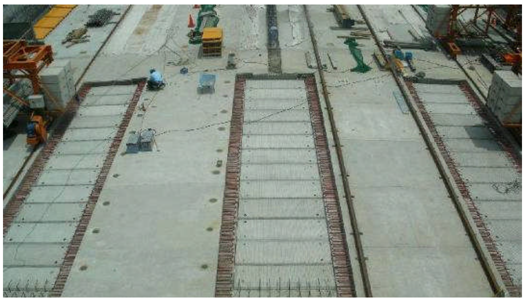


Photo-11 Precast panels

Photo-12 Cast-in-situ slab

5. Afterword

It has been considered that the conventional span-by-span erection using conventional multi precast segments is suitable for the construction of the large-scaled continuous urban viaduct project for the cost saving, achieving the high quality and for the accelerated construction. However, in the urban viaduct projects, there might be some severe site conditions as mentioned. In such cases, the construction methods adopted newly developed in the viaducts in Nasu-dukuri Area and Aoyama Area on the Second Keihan Expressway can be the good solutions in different site conditions. In both projects, the rate of construction speed of 2,400m^2 per month were both achieved.

Reference

1) Ikeda S., Ikeda H., Mizuguchi K., Muroda K., and Taira Y.: Design and Construction of Furukawa Viaduct, Proceedings of the 1st fib Congress, Osaka, 2002