

# Shin-Meishin Mukogawa Bridge

Client: West Nippon Expressway Company

## 1. Abstract

The Shin-Meishin Mukogawa Bridge is an extradosed bridge with butterfly webs on the Shin-Meishin Expressway in Japan. Butterfly panels are used for main girder webs to improve seismic resistance and increase the ease of construction. Together with the extradosed structure and constant girder height, this web design also contributes to a significant reduction in the weight of the superstructure. The bridge piers were built using half-precast form components (SPER method) for reducing the labour required in the field, thereby achieving a short construction schedule. Other new techniques were employed in the project to meet locational and other restrictions. For construction of the pier head at great height, precast segments were used for the cross beam in part to reduce the need for **labour** and scaffolding. A new separated anchorage system for the main towers, consisting of a single steel plate and two independent columns, has been developed to meet dimensional restrictions.



Photo 1 Completion view

## 2. Overview of the bridge

The bridge has a **unified transverse section across the two travelling directions**. The bridge has been constructed initially for a four-lane expressway, but is designed for future expansion to accommodate six lanes. The future width expansion will entail installing cantilever decks that add about 5.6 m on each side, supported on struts. Figure 1 gives a general outline of the bridge, Fig. 2 shows a cross section of the main girder, and **Table 1** presents the specifications of the bridge

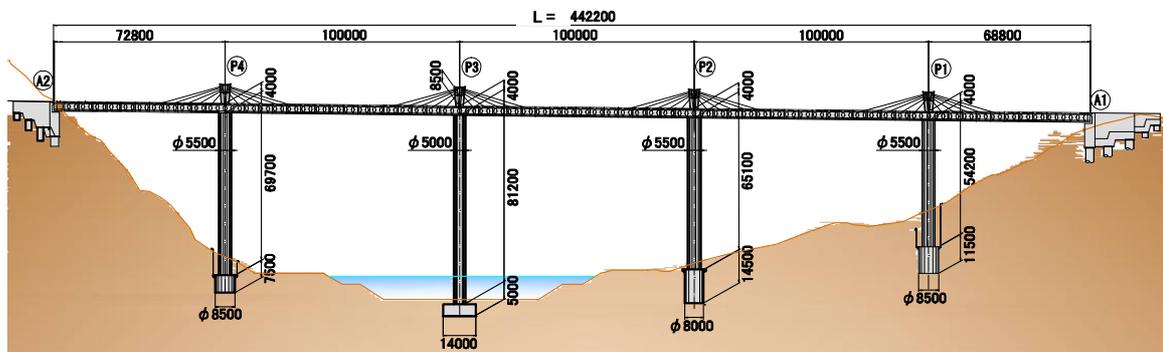


Fig. 1 General view

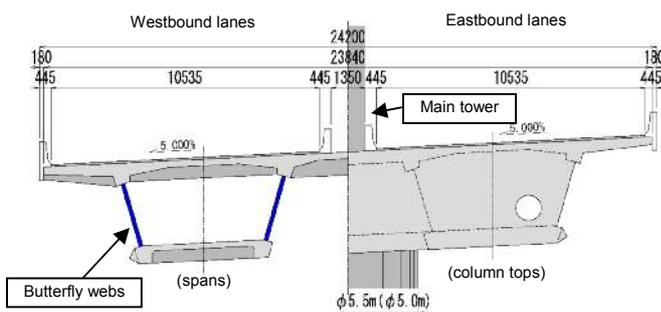


Fig. 2 Cross-sectional view of the main girder (as constructed)

Table 1 Specifications of the bridge

Project name	Shin-Meishin Expressway Mukogawa Bridge Construction
Structure	Five-span continuous prestressed reinforced concrete rigid frame extradosed bridge with butterfly webs
Bridge length	442.2 m
Span lengths	71.800 m + 3 x 100.000 m + 67.800 m
Effective width	21.500 m (temporary), 32.500 m (final)

### 3. Features of the bridge

#### 3.1 Extradosed structure with butterfly webs

The superstructure of the bridge consists of butterfly webs combined with extradosed cables. The butterfly web structure consists of butterfly-shaped concrete panels that replace the webs in an ordinary prestressed concrete box girder. The panels are precast components prefabricated using high strength fibre-reinforced concrete with a design strength of  $80 \text{ N/mm}^2$ . No reinforcing steel is used. This design allowed the web thickness to be reduced to 150 mm throughout the bridge length, thereby reducing weight. Dimensional restrictions during transport of the butterfly webs required that the girder depth be a constant 4.0 m. In order to achieve this fixed girder depth for all the 100 m spans, extradosed cables were employed to stiffen the butterfly web structure with diagonal tendons at the pier head areas. The use of butterfly webs resulted in a reduced number of construction blocks and thus a shorter construction period. The extradosed design with a constant girder height in conjunction with reduced-weight butterfly webs led to a reduction in superstructure weight of about 20% as compared with a standard design, thereby successfully reducing seismic inertia forces. The total weight of superstructure and substructure at the detail design stage was about 35% lower than for a standard plan. Figure 2 gives details of the butterfly web.

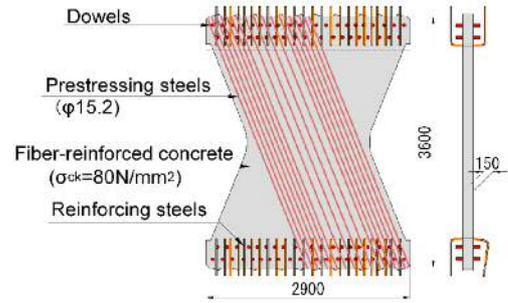


Fig. 2 Detail of butterfly web

#### 3.2 Main tower structure

A decision was made to employ a separate single-plane anchorage at the centre of the cross section, but the space available for the tower was insufficient for a conventional hollow separate anchorage structure consisting of a steel shell or concrete. Tower width was limited to the width of the median strip, which was only 1.35 m. To overcome this dimensional restriction, a new separate anchorage structure was developed in which a single steel plate is combined with two concrete columns. The steel plate in this anchorage structure is unified with the concrete using dowel reinforcement. Photo 2 shows an overall view of the main tower.



Photo 2 Overall view of main tower

#### 3.3 Construction of bridge piers (SPER method)

The tall piers were constructed by the SPER method, a rapid technique using prefabricated half-precast components named for Sumitomo Mitsui's Precast Form for Earthquake Resistance and Rapid Construction. With this method, hoops and intermediate ties are embedded in half-precast components during fabrication, thereby reducing assembly work at site. Each half-precast component is semi-cylindrical in shape, with a height of 2.0 m in consideration of restrictions during transport and crane capacity (Fig. 3). The reduced site work required for placement of reinforcement and assembly of formwork leads to rapid construction, with components fabricated at a factory and conveyed to the site. Each component is installed by crane after first arranging the longitudinal reinforcement. The formwork components for one fill are assembled, and the pier is completed by placing the fill concrete. Through use of this method, the construction rate almost doubled compared to conventional methods. Photo 2 shows form assembly work for the SPER method in progress.

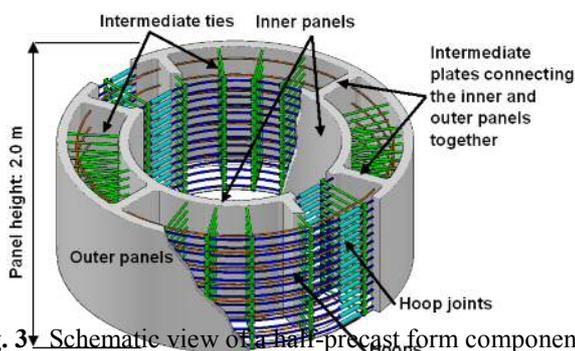


Fig. 3 Schematic view of a half-precast form component



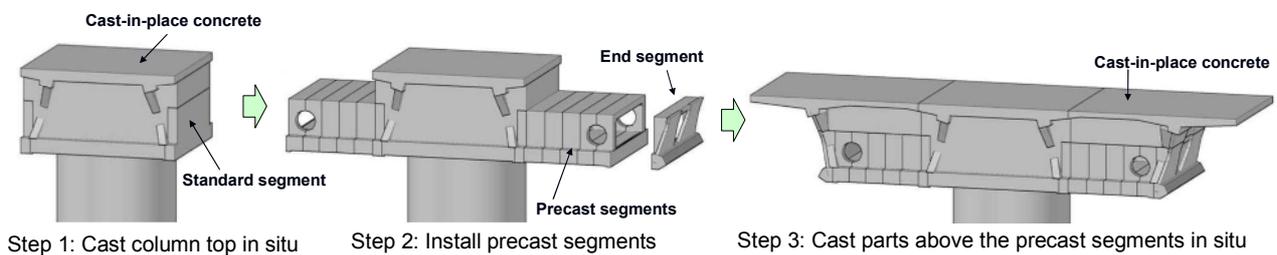
Photo 2 Installing half-precast components

### 3.4 Construction of the pier heads

The wide main girder sits on piers measuring 5.0 to 5.5 m in diameter and is 24 m across, so there is considerable overhang perpendicular to the bridge axis. Concerns were raised about the increased labour and reduced safety that working at height using a conventional scaffolding system would entail; extensive scaffolding extending up to 15 m in a radial shape would have been required. In order to reduce labour requirements and improve safety, a new method was developed for pier head work to minimize the bracket scaffolding needed.

The new method uses precast segments in part to construct the cross beam, using them in place of formwork scaffolding to carry the loads of following segments during erection. Bracket scaffolding was simplified **by making it carry only loads of the column top**. The precast segments to be erected perpendicular to the bridge axis were designed to have a unit weight of about 150 kN and a unit length of 800 to 900 mm in consideration of lifting capacity.

The use of this method reduced the size of the bracket scaffolding to one third that in the initial plan, successfully reducing the labour needed for erection and improving safety. Figure 4 shows the steps in pier head construction.



**Fig. 4** Pier head construction steps

### 3.4 Construction of the main girder

Complex work is usually required on the webs of a prestressed concrete box girder. The use of the prefabricated butterfly webs led to a significant reduction in such labour. With the main girder weight reduced by the butterfly web box girder structure, it was also possible to choose a fixed block length of 6.0 m. (Normally, the block length for cantilever erection, which is determined by the capacity of the launch gantry, is about 3.0 m near the pier head where the girder is deeper and members thicker, and about 4.0 m between the piers.) The number of blocks was thereby reduced from 14 or 15 **for this section** in the basic plan to eight at the detail design stage. The total number of blocks in the bridge was almost halved from 101 in the basic plan to 54, which greatly contributed to reducing the number of days that construction took. Photo 3 shows a view of the cantilever erection of the main girder.



**Photo 3** Cantilever erection

## 4. Conclusions

The Shin-Meishin Mukogawa Bridge was constructed using an efficient and rapid method that achieves significant labour reduction. Seismic resistance was improved by reducing the main girder weight and developing an elaborate design for pier rigidity. The bridge also has an excellent durability and maintenance costs are reduced. This has been achieved using high-strength fibre-reinforced concrete in the main girder webs and forming the outside of the piers with prefabricated precast components.

## References

Ashizuka, Kurokawa, Morohashi, Matsubara, Mizuno, & Tomiyama (2015), Design and Construction of the Mukogawa Bridge on the Shin-Meishin Expressway. Bridge and Foundation, March 2015, pp.2-11.