

**Zeitschrift:** IABSE reports = Rapports AIPC = IVBH Berichte  
**Band:** 63 (1991)

**Artikel:** Aesthetic design on the Seto Ohashi bridge  
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**DOI:** <https://doi.org/10.5169/seals-48499>

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## Aesthetic Design on the Seto Ohashi Bridge

### Projet esthétique des ponts de Seto Ohashi

### Aesthetisches Projekt der Seto-Ohashi-Brücken

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### SUMMARY

The Seto Ohashi Bridge is a group of long-span bridges linking Honshu to Shikoku, it has been constructed in the Seto Inland Sea National Park and completed in April, 1988. This paper reports the countermeasures to preserve natural scenery in the National Park and the basic concept of the aesthetic design of the Seto Ohashi Bridge. At present, approximately 70 thousand people a day in automobiles and trains pass through the Bridge, and it has become an increasingly attracting area for sightseeing in Japan because of its structural beauty harmonizing with natural scenery.

### Projet esthétique des ponts de Seto Ohashi

#### Résumé

Les ponts de Seto Ohashi forment un groupe de ponts à grande portée reliant les îles de Honshu et de Shikoku. Ils se trouvent dans le Parc national de la Mer intérieure de Seto et ont été terminés en avril 1988. L'article présente les mesures prises pour préserver le paysage naturel du parc national et présente le concept fondamental de ce projet esthétique. Actuellement près de 70'000 personnes utilisent quotidiennement cette liaison en voiture et en train. Cet ensemble est devenu une zone attractive pour le tourisme, grâce à la beauté des structures, en harmonie avec le paysage naturel.

### Aesthetisches Projekt der Seto-Ohashi-Brücken

#### Zusammenfassung

Der Seto-Ohashi-Brückenzug ist eine Gruppe weitgespannter Brücken, die Honshu und Shikoku verbinden. Er wurde im Seto-Inland-See-Nationalpark gebaut und im April 1988 fertiggestellt. Dieser Artikel berichtet über die Massnahmen, um das natürliche Landschaftsbild im Nationalpark zu erhalten, und über das Grundkonzept des ästhetischen Entwurfs der Seto-Ohashi-Brücken. Augenblicklich benutzen ungefähr 70'000 Personen in Autos und Zügen täglich die Brücken, und sie sind zu einem attraktiven Ausflugsziel in Japan geworden, weil ihre bauliche Schönheit mit der natürlichen Szenerie harmoniert.



## 1. PREFACE

The Seto Inland Sea is known as a region that has the most representative natural scenery in Japan. It was first designated as a national park concurrently with Daisetuzan and Aso, etc., in 1934 and its natural scenery has been protected ever since.

Also, while the Seto Inland Sea has aesthetic archipelago scenery, it has been inhabited by people since ancient times. Fishing and marine transportation have long been prosperous industries.

One of the special features of Honshu-Shikoku Bridge projects, i.e. the Kobe-Naruto Route, Kojima-Sakaide Route and Onomichi-Imabari Route, pass through the Seto Inland Sea National Park.

The Kojima-Sakaide route has been completed in 1988, the Kobe-Naruto and Onomichi-Imabari route are under construction by the Honshu-Shikoku Bridge Authority. The portion of the straits of the Kojima-Sakaide route has been popularly named the Seto-Ohashi Bridge after its completion, and it consists of six long-span bridges, viaducts and tunnels, etc. for a highway with four lanes and a railway with four tracks. The long-span bridges comprise three suspension bridges with a center span length of approximately 1000 m, two cable-stayed bridges with a center span length of 420 m each and one truss bridge.

The Seto Ohashi Bridge was approved as a route to be completed earlier by the Third Nationwide Comprehensive Development Program of April 1977, it was subject to the condition that the environmental impact assessment be made without delay. In response to the condition, the Authority made the environmental impact assessment, which included procedures of opening explanation meeting for residents around the route for the first time in Japan.

This paper reports the basic concept of aesthetic design of the Seto Ohashi Bridge concerning protection of natural scenery and harmony aesthetic aspects of the structures with beautiful scenery.

## 2. BRIDGES AND NATIONAL PARK

The Seto Inland Sea National Park encompasses a wide area, stretching over 10 prefectures of Chugoku and Shikoku and surrounded by four straits, i.e. Kitan and Naruto in the east and Hoyo and Kanmon in the west.



Fig.1 Location of the three routes



The most eminent feature of the Honshu-Shikoku Bridge Project among public works is that all three routes pass through this national park region.

The Natural Parks Act was promulgated in 1957 for the purpose of preserving natural scenery in the natural parks, which were under jurisdiction of the Environmental Agency since the establishment of the Agency in 1977.

When someone needs to construct a structure such as building within natural park special region, he is subject to the permission of the Director General of the Environmental Agency under item 3 of Article 17 of the Natural Park Act. However, since Honshu-Shikoku Bridge Authority is regarded as a national administrative organization, the project was subject to consultation with the Director General of the Environmental Agency under item 1 of Article 40 of the Act, and did not have to obtain the permission of the Director General of the Environmental Agency.

According to the Natural Parks Act, the Environmental Agency shall respect the opinions of the Committee on Preservation of Natural Environmental, which is established in the Environmental Agency under Article 13 of the Natural Environmental Preservation Act in exercising its right of jurisdiction. The opinions of the Committee was substantially made through the "Subcommittee on Examination of Problem on Honshu-Shikoku Bridges" which was established as a division of the Committee.

Members of the Subcommittee at the time of consultation concerning the Seto Ohashi Bridge consisted of experienced scientist and professionals, ranging from lawyers, authority of science of fishery, and journalist to designer, etc. The Subcommittee met four times on the construction of the Seto Ohashi Bridge, and summary of the conclusion of which was that it was inevitable to proceed the project with the condition that through measures be taken to preserve the natural environment.

### 3. PRESERVATION OF NATURAL SCENERY

Mt. Washu area, where the Seto Ohashi Bridge route pass through in Honshu side, is famous for sightseeing spot at which people can command the beautiful scenery of archipelago and is designated as a Type 1 of National Park Special Region where is most valuable to preserve natural scenery.

In the construction plan of the Authority, the open cut method of construction was initially planned in the Mt. Washu area.

However, the opinion of the Environmental Agency was that the plan should be reconsidered to minimize the alteration of the topography of Mt. Washu area as technically possible as the Authority could.

In response to this opinion, the Authority had begun to reconsider the initial construction plan of open cut method in Mt. Washu area.

From the viewpoint of preservation of natural beauty of Mt. Washu area, a tunnel definitely excels as the method of construction. However, as the tunnel is adjacent to the Shimotui-Seto Bridge, which is a suspension bridge with a double-deck structure, the section of the tunnel had to be as same as of the suspension bridge. Consequently, the tunnel would become an unprecedented large section tunnel if it was to be a single section including a four lane highway and a four-track railway line. If it was to be separated into four tunnel sections, it would be tunnels that are considerably close to each other in the upper and lower direction and in the horizontal direction, making it extremely difficult to construct.

As it was also judged that the overburden was thin and geology was of weathered granite with extensive cracking, which posed extreme technically difficult



ulties, the open cut method of construction was planned initially. However the Authority had begun the technical examination of the tunneling method to minimize the alteration of topography due to the opinion of the Environmental Agency.

The technical examination was undertaken by the committee composed of experienced scientist and professionals of the Japan Society of Civil Engineers, etc. The examinations and evaluations were repeated based on the knowledge of tunnel engineering and underground stress analysis with computer, which has remarkably progressed in recent years. As a result of these examinations, it had been clear that the tunneling was technically feasible through N.A.-T.M. method and new in-situ surveying technologies. Also, a double section tunnel plan had been selected finally. This finally determined that the highway and railway pass through Mt. Washu by tunnel, suiting the intention of the Environmental Agency for preservation of the scenery. (Refer to Fig.2)

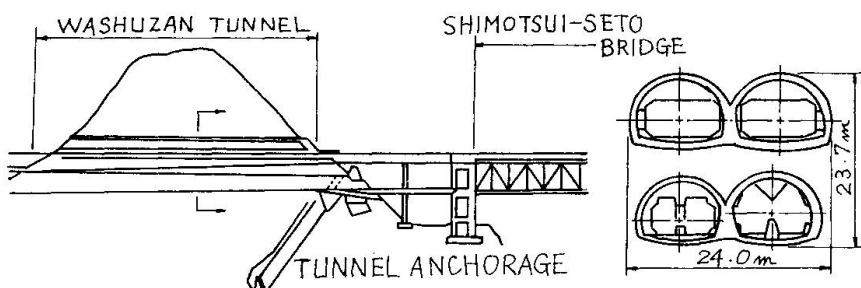


Fig.2 Side view and cross section of Washuzan Tunnel

#### 4. SCENERY OF BRIDGES

To examine the aesthetic aspects of a continuous group of large bridges that span the straits on the delicate and graceful archipelago scenery of Shimotsui and Bisan-Seto, the first problem would be to determine where the vista points should be located.

For the examination of the aesthetic aspects of the group of the long-span bridges, main vista points were selected, i.e. two points on the Honshu side and two points on Shikoku side for the people who come to view the scenery of the National Park.

On the Honshu side a noted Mt. Washu vista point in this region and Ojigadake, to make a vista point of distant view a slightly away therefrom, were selected. On the Shikoku side, Shosujisan, located on the opposite shore of Washuzan, and Goshikidai, which is slightly away therefrom, were selected. Also, as a representative vista point from the islands in the neighborhood, Honjima was selected and Marugame-Shimotsui ferry boat route was selected as a vista point from aboard a ship. The examination was conducted using color photo montages from these vista points to determine whether the structure type and color of each bridge are in harmony with the scenery of the National Park.

##### 4.1 Bridge Type

Although it is difficult to imagine having a structure type other than a suspension bridge for the bridges that span Shimotsui-Seto straits and Bisan-Seto straits, Hitsuishijima Bridge and Iwakurojima Bridge located in the middle of these two suspension bridges make an important point from the viewpoint of scenery of a group of long-span bridges of the whole route; the selection of bridge type presented important problem.

Considering the conceivable center span of about 400 m of the two bridges due to the topography and the geology, types of the bridges to be examined were narrowed to suspension, truss, arch and cable-stayed bridges.

First, the suspension bridge plan was judged unfavorable as it was disadvantageous economically and given the immense complexity of forming a miniature version of Shimotsui-Seto Bridge and Bisan-Seto Bridge also from the viewpoint of the scenery. The arch bridge plan was eliminated from among the candidates due to the topography and geology and because the arch rib forms a reverse symmetry with cables of the suspension bridges.

On the other hand, the cable-stayed bridge plan was considered a good plan from the viewpoint of scenery as the tower and straight line cables accentuate the whole route as well as maintain continuity of the horizontal line. However, the construction of large-scale cable-stayed bridge such as this was unprecedented in the world technically, and many problems were pointed out in terms of structure and design. In the case of the truss bridge plan, there are many experiences of making the bridge a cantilever-truss type and less problems technically, and the chord members opening up and down accentuate the center of the whole route also from the viewpoint of scenery giving the feeling of profound and solemn beauty. (Refer to Fig.3)

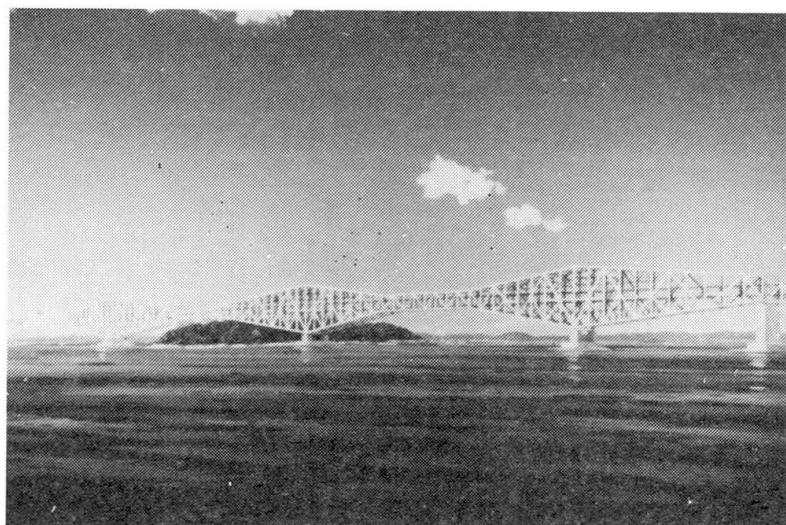


Fig.3 Proposal of cantilevered truss bridge

Through these examinations, the cantilevered truss bridge with a bilateral symmetry was submitted as a first plan for Hitsuishi-jima and Iwakuro-jima Bridges. However, the Environmental Agency imposed the condition "to make the bridges cable-stayed bridge unless it is impossible technically" based on the opinions of the Subcommittee to the plan of the Authority. In response to this condition, the Authority, in an effort to further enhance the accuracy of the technical results of the cable-stayed bridge accumulated thus far, continued to examine the issue with committees organized in J.S.C.E., etc. As a result of this examination, the Authority had obtained the prospect of conquering technical problems by adopting a Hi.-Am. socket that is high in fatigue strength for the cables in which fatigue became a problem due to the train load, and by providing a buffer system for corner bending of cables to protect the cables from bending fatigue, the cable-stayed bridge plan was adopted and the plan was realized.



#### 4.2 Configuration of Tower

Towers of the suspension bridge and the cable-stayed bridge can be positioned as a symbol of each bridge as they can be viewed easily from many vista points regardless of distance. For this reason, the configuration of the tower was examined in the various plans not only from the viewpoint of functions but also from that of scenery.

There are many types of tower columns, such as straight, inclined, and bent towers, and further from the configuration of loop material there are truss type and rigid-frame type, which have good features from the viewpoints of structure and scenery. Also there are triangular, convex, and crossforms in the sectional configuration of the towers which have both advantages and disadvantages from the viewpoints of scenery and structure. By combining these configurations of tower columns, loop materials and sections and taking into consideration the position of each bridge from the viewpoints of scenery, economy and workability, the basic configuration was determined.

##### 4.2.1 Shimotsui-Seto Bridge

By taking the vista point at Mt. Washu where more than one million tourists visit a year, the tower becomes the most prominent structure, which is positioned as a gateway on the Honshu side to the Seto Ohashi Bridge. For the aesthetic design, a questionnaire survey was conducted on the evaluation items from the viewpoint of scenery by preparing sketches of twenty different types of towers. As a result of the questionnaire, the rigid-frame type tower, unlike the one that could not be seen in the case of Innoshima and Ohnaruto Bridges, became influential, and as there was not too much difference in the economical comparison with the truss-type tower, the vertical tower with rigid frame type was adopted. As the tower is shorter by about 50m compared with the tower of Minami and Kita Bisan-seto Bridges, the characteristics are that it is more streamlined as it has no diagonal members as compared with the truss-type tower. (Refer to Fig.4)

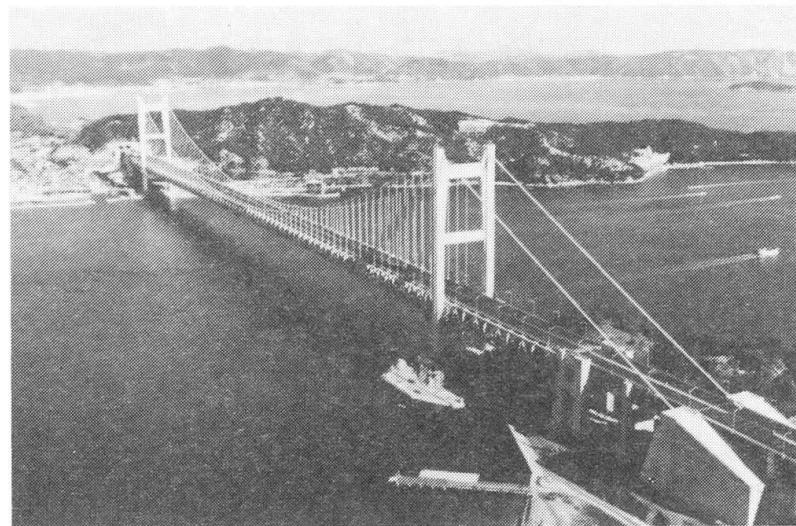


Fig.4 Shimotsui-Seto Bridge

#### 4.2.2. Minami and Kita Bisan-seto Bridges

A duplex suspension bridge that has a common anchorage is located in the wide sea area of Bisan-Seto, and tourists can not view the suspension bridges closely as in the case of Washuzam. Therefore, the evaluation of tower configuration was made from both distant and intermediate views. The selection of the basic configuration was made by preparing sketches of 32 plans that combined the types of the towers and various types of loop materials and by evaluating from the viewpoints of scenery and economy, thus selecting the inclined tower with diagonal chord. The horizontal chord and the diagonal chord of the tower were determined to be finer than the tower column to prevent them from appearing too labyrinthine. (Refer to Fig.5) It was also taken into considerations in the design that the configuration of the top of the tower, the angles of diagonal members of the truss and the ratio between height and width of the space above the roadway surface were unified.

#### 4.2.3 Hitsuishijima Bridge and Iwakurojima Bridge

Compared with the suspension bridges at the end of this route, as these two bridges was close to the islands and there were bus stops provided on the upper road surface between the bridges, scenery closer to the island itself and from the highway was seriously considered in the aethetic design of the tower. Consequently, the basic form prepared based on the various Japanese motives such as a shrine or temple, the roof of a traditional farmhouse, etc., near this route were applied to the towers of these cable-stayed bridges. To provide a visual imression of continuity, the basic form was employed to the piers of the viaducts which is adjacent to the cable-stayed bridges. The group of bridge piers and towers harmonize with each other and create a sense of rhythm in the visual flow of the entire bridges. (Refer to Fig.6)

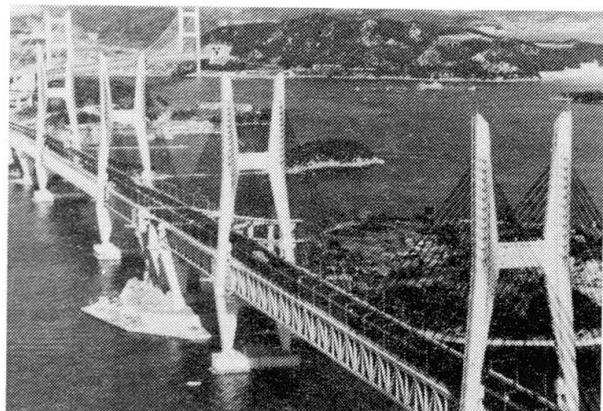
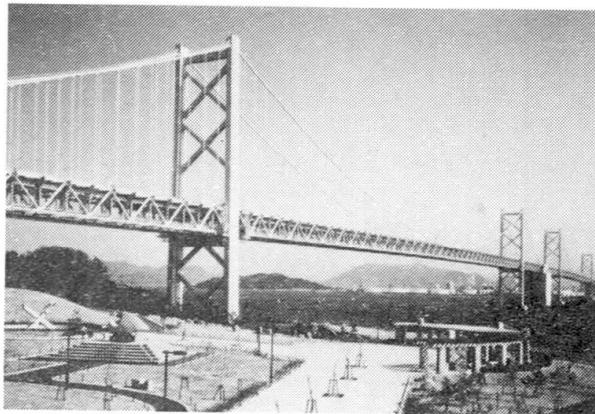


Fig.5 Minami and Kita Bisan-Seto Bridge

Fig.6 Two cable-stayed bridges

#### 4.3 Texture of Anchorage

Flat surface of the wall of anchorage for suspension bridge awes everyone around it because of its enormous size. To soften this, it was proposed to provide a texture on the wall of the anchorage.



On the other hand it was also pointed out that the flat surface of the wall of the anchorage may become a cause of radar interference for ships navigating nearby. The Authority has carried out investigations for countermeasures against radar false images through a committee which is consisted of experienced scientist, professionals and maritime interests. And it was determined that by making the surface of the wall of the anchorage a slope at a angle of more than 5° for the purpose of diverting main direction of radar waves, the radar false image could be prevented. The texture of this slope was consequently determined to be incorporated in the design from the viewpoint of the scenery. The shadow of the multi-stage slope changes depending on the position of the sun, which both accentuate the wall and softens the enormity of the anchorages. (Refer to Fig.7)

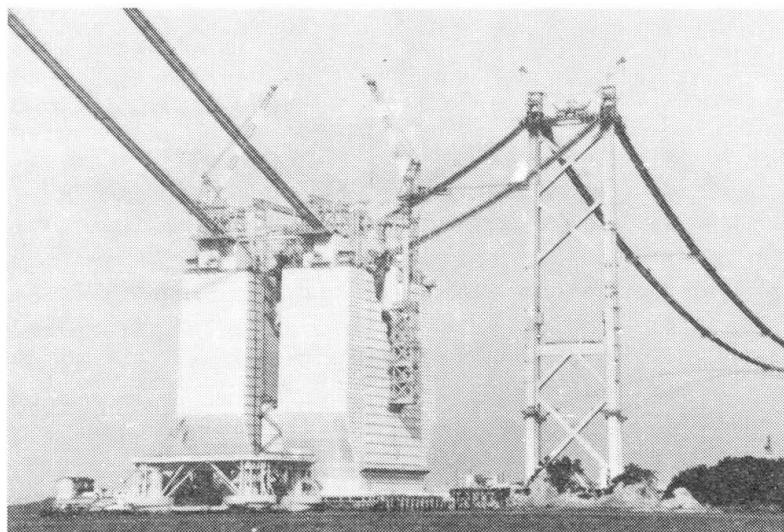


Fig.7 Texture of anchorage

## 5. POSTSCRIPT

Construction project and protection of nature are primarily contradictory. The construction of the Seto Ohashi Bridge might have been detrimental to the national park, which makes the natural scenery of archipelago as its keynote, and so it was requested that every effort be made to pursue a new scenic beauty that harmonizes with the natural scenery. We tackled this difficult task with all our energy. As a result, the Seto Ohashi Bridge has been evaluated as a new spot for sightseeing as well as a fast and safe traffic route which carry approximately 70 thousands people a day.

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