

Research Article

A Proposal for 4000m-span Cable-stayed Suspension Bridge

Haijun Wang, Anjing Lai and Hua Wei

College of Architectural Engineering, Shenyang University of Technology Shenyang,
Liaoning, 110870, China

Abstract: This study proposed a compound bridge of suspension bridges and cable-stayed bridges with 4000 m super-long-span over the Tsugaru Strait, Japan. Near to the main towers, cable-stayed bridges and prestressed concrete decks are proposed. It is helpful to enhance rigidity and endure the great axial compression force. In the center of the span, suspension bridges and steel box decks are stiffened by trusses, it can reduce self-weight and the space between girders, thus contribute to aero-elastic stability. RCFT main tower, RC shell pier and RCFT jacket foundation can enhance rigidity and reduce self-weight. As a result, the live-dead load ratio of proposal is 0.05 and it is equivalent to 2500m-span suspension bridge.

Keywords: Cable-stayed suspension bridge, super-long-span, Tsugaru Strait Bridge

INTRODUCTION

Tsugaru Strait Bridge is proposed over the Tsugaru Strait between islands of Honshu and Hokkaido in Japan. The Tsugaru Strait area is expected to play a critical role as a new pivot of the economic and traffic both domestic and international. In Japan's new Comprehensive National Development Plan "Grand Design for the 2st Century", Sapporo, Tokyo and Fukuoka have been assigned as a principal axis of Japanese islands. As a connection between the major national zone, North-Eastern Zone and Japan Sea coastal Zone, the Tsugaru Strait Axis Concept is a grand plan of significant importance to 2st century Japan that will be able to make great contributions to the shifting of the Proposed Regionally-Distributed Structure for Japan (Blair and Jose, 1997).

In the Tsugaru Strait economic zone, the Seikan region (Aomori and Hakodate) has rich natural resources. Around the Tsugaru Strait economic zone, the Northeast Asian area embraces areas rich in mineral, forestry and fish resources, such as the Far Eastern part of Russia and the north-eastern part of China. Therefore, the Tsugaru Strait area is situated at the crossroads of Northeast Asia, the Far Eastern part of Russia and North America, it has enormous potential to become an emerging economic zone in the 21st century in light of global economic dynamism and is expected to play a critical role the economic frontier of 2st century. Therefore, super long span bridge is necessary over strait. However, cable supported bridge (Niels, 1998) or cable-stayed bridge (Agrawal, 1997) is

difficult to across the strait alone. In this study, a bridge compound of suspension bridges and cable-stayed bridges with 4000 m super-long-span over the Tsugaru Strait is proposed (Brown, 1996).

Natural conditions of Tsugaru strait: By the foundation investigation of east Japan, there are two favourable bridge routes in the Tsugaru Strait. The eastern one is 19 km in width and 270 m in maximum depth. The western one is 19 km wide and 140 m in maximum depth. The sea bottom geology is both rocks (Japan Tohoku Construction Association, 1997).

The natural conditions there such as strong winds, thick fog, earthquakes, great depth of water, complicated currents, high speed tides and so on are hard. The air temperature fluctuation range is about from -22°C to 3°C; Basic wind velocity is 30 m/sec and the influence of winter monsoon is great; maximum tidal currents generally ranges from 4 to 7 knots. As an international navigation channel, many large-scaled vessels and submarines pass the channel by a 2000 m wide and 70m high international shipping lane.

Therefore, the piers are as few as possible and super-long spans are required in the centre of strait. A vertical clearance of 70 m is required over the width of the navigation channel to avoid interrupting shipping traffic.

Proposal of Tsugaru strait bridge: The longitudinal profiles of routes and the proposed bridges are shown in Fig. 1. The proposed Tsugaru Strait Bridge is a super-long span bridge with total length of 20 km, consisting

Corresponding Author: Haijun Wang, College of Architectural Engineering, Shenyang University of Technology, Shenyang, Liaoning, 110870, China

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

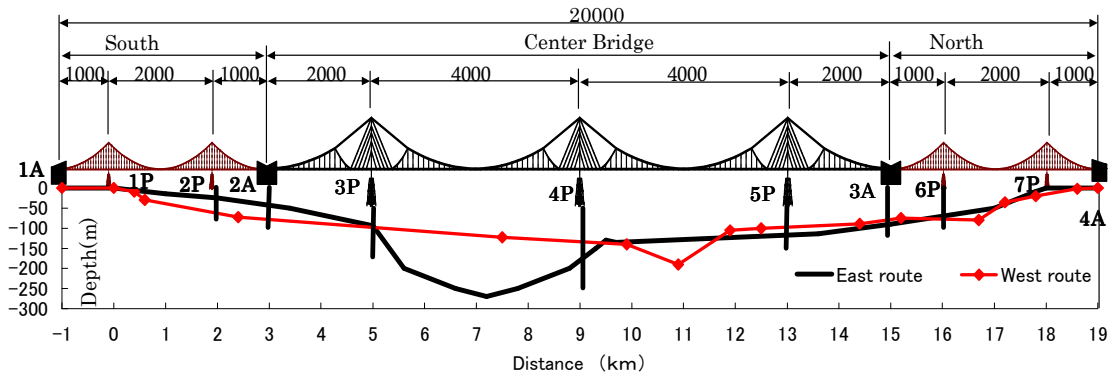


Fig. 1: Tsugaru Strait Bridge and longitudinal profiles of routes

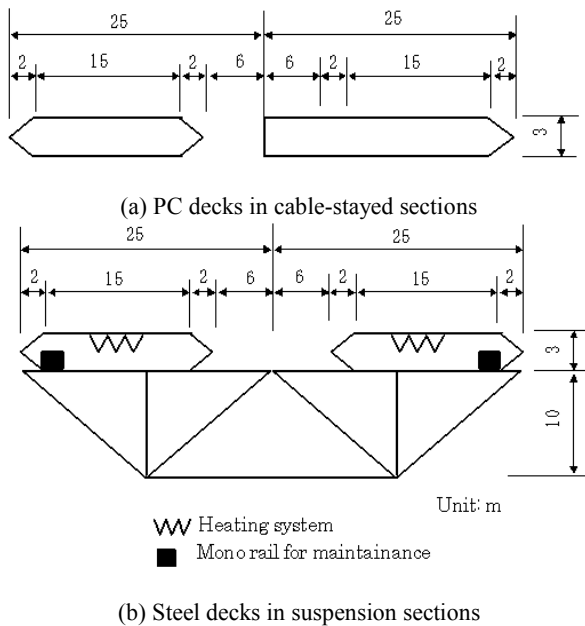


Fig. 2: Warrant truss and steel decks

of Center Bridge with 4000 m span, North Bridge and South Bridge with 2000 m span on both sides (Bounopane and Billington, 1993). Common joint anchorages are proposed among three bridges, which can minimize its dimension by mutual cancellation of main cables tensions. Designs of North and South Bridge are similar to the 1991 m span Akashi Strait Bridge. The Centre Bridge is a compound bridge of 4 spans called 2000 m+4000m+4000 m +2000 m.

In the design of superstructures, in order to decrease the load burden of the main cables, the Center Bridge was designed as a compound bridge of suspension bridge and cable-stayed bridges and three parallel supporting main cables are used to carry all loads on the suspension bridge section. The separation of hangers is 50 m, between suspension portion and cable-stayed portion; sub-cable is designed to adjust their member forces, which should be in state of no compression by any live load (Yang, 1999).

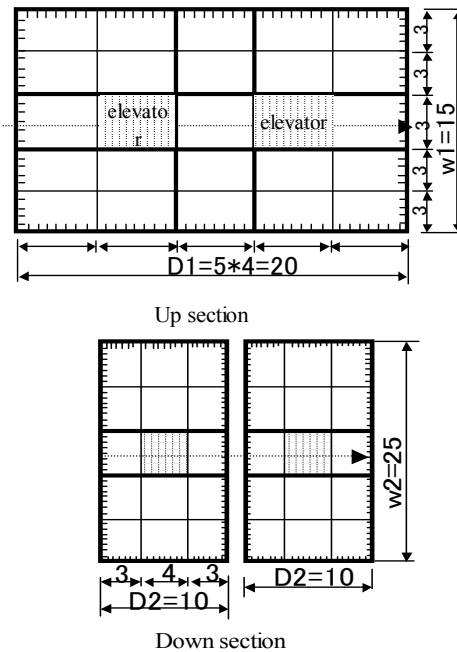


Fig. 3: Section design of main tower

Decks of Centre Bridge: Near to the main towers, cable-stayed bridges are proposed and prestressed concrete decks are designed to endure the great axial compression force (Fig. 2). In the center of span, suspension bridges are proposed (Brown, 1996). Two separated steel box decks stiffened by trusses are proposed and heating system is set inside of steel box decks to against freezing. The stiffening box girder has a width of 15m, allocated to 2 lanes for car and 1 track for a new transportation system. The space between girders is 12m and this will contribute to aero-elastic stability.

Main towers: The towers use steel-concrete composite structures, light concrete is filled in the upper portion to reduce self-weight and general concrete is filled in the lower portion to endure the powerful reaction, as illustrated in Fig. 3 and 4.

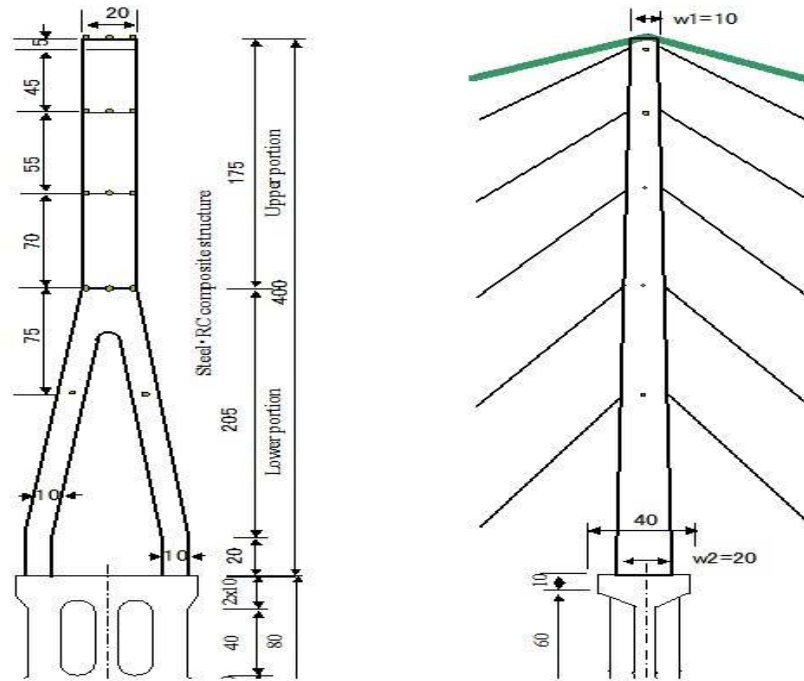


Fig. 4: RC main tower and CFT

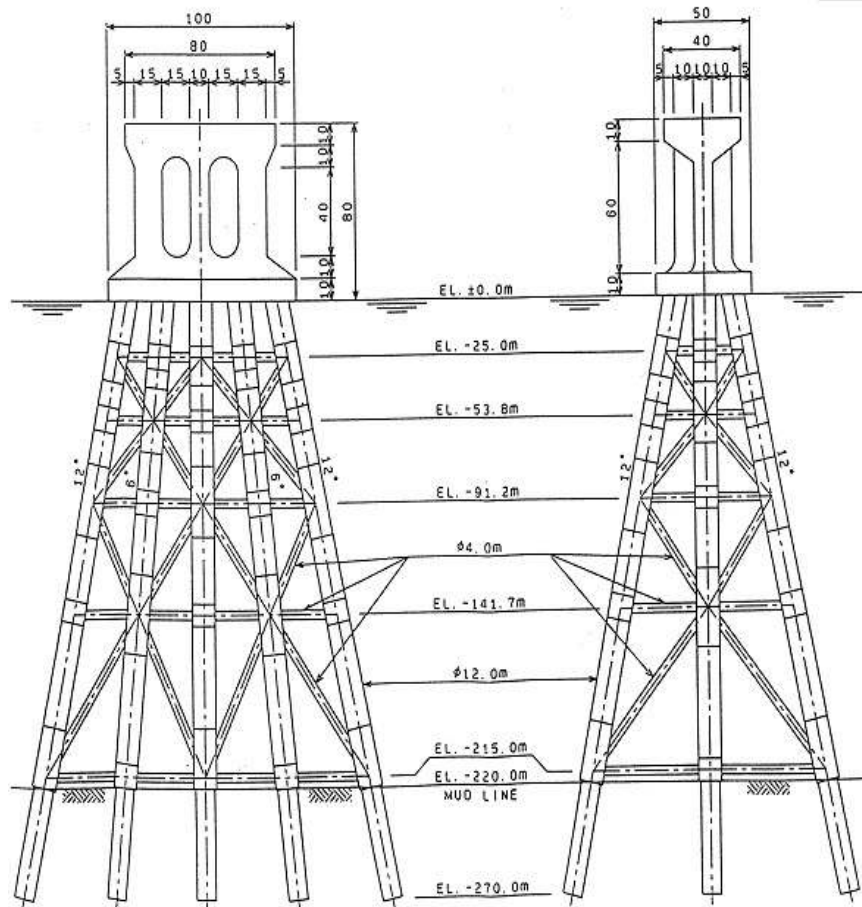


Fig. 5: RC shell pier and CFT jacket foundation

Substructures: In the design of substructures, reinforced concrete shell structure pier and jacket foundation consisted of RCFT (reinforced concrete filled steel pipe) piles have been suggested to keep rigidity and reduce self-weight (Lu and Yang, 2012). It is shown as Fig. 5. The sloping degree of piles is set to 12 and by adjusting the rigidity of piles to balance the horizontal displacement of tower produced by horizontal force and partial loading

DISCUSSION AND SUMMARY

Based on the new proposal, some characteristics can be summarized as follows:

As a compound bridge composed of suspension bridges and cable-stayed bridges, its live-dead load ratio is 0.05 and it is equivalent to the 2500 m-span suspension bridge, this means the proposal is an excellent invention.

Based on previously research result, different kind of decks are adopted in different sections. Prestressed concrete decks at cable-stayed bridges sections can endure the great axial compression force. In the center of span, trusses steel box decks at suspension bridges sections reduce self-weight and enhance its aero-elastic stability.

A new kind of RCFT main tower, RC shell pier and RCFT jacket foundation are proposed, it can enhance rigidity and reduce self-weight.

ACKNOWLEDGMENT

This study was financially supported by Liaoning Provincial Educational Department Fund (L2010412), "Liaoning BaiQianWan Talents

Program" Fund (2011921050), Scientific Research Foundation for the Returned Overseas Chinese Scholars (20086211), Shenyang Science and Technology Plan Fund (F10-205-1-08) and Liaoning Provincial Educational Department Fund (L2010411). The supports are gratefully acknowledged.

REFERENCES

- Agrawal, T.P., 1997. Cable-stayed bridges-parameter Study. *J. Bridge Eng. ASCE*, 2: 61-67.
- Blair, B. and C. Jose, 1997. A Bridge for the 21st Century. *ASCE Civil Eng. Mag.*, 67: 68-71.
- Bounopane, S. and D. Billington, 1993. Theory and history of suspension bridge design from 1823 to 1940. *J. Struct. Eng.*, 119: 954-977.
- Brown, W.C., 1996. Development for the deck for 3300m span Messina crossing. Congress Report IABSE 12th Congress, Copenhagen.
- Japan Tohoku Construction Association, 1997. Foundation Investigation of East Japan. (In Japanese)
- Lu, M.Q. and Q.S. Yang, 2012. Nonlinear finite element analysis on mechanical behavior of concrete filled rectangular steel tubular column. *J. Shenyang Univ., Technol.*, 34(2): 224-230.
- Niels, J.G., 1998. Long span cable supported bridge: Present technology and trends. Proceeding of the Long-Span and High-Rise Structures, IABSE Symposium, Kobe, 79: 103-114.
- Yang, C.W., 1999. Number of cable effects on buckling analysis of cable-stayed bridges. *J. Bridge Eng.*, 4(4): 242-248.