Dr Hiroshi Isohata

JSCE Vice Chair Conservation of Engineering Heritage, Former Professor Nihon University, Chiba, Japan

Dr. Hiroshi Isohata was working in the Steel Structural Division of NKK Corporation (presently JFE Engineering Co.) from 1971 to 2004 as a bridge engineer and a manager of their engineering division. While he was in London from 1985 to 1987 as a manager of NKK(UK) Ltd., he started his research work on historical aspects of civil engineering. In 2004 he retired from JFE Engineering Co. and became a professor of the Civil Engineering Department, College of Industrial Technology of Nihon University until 2017.

His study of civil engineering history has continued and his papers and articles on the relevant study exceed more than 50. He has published many books including *Civil Engineering Heritage in Japan and Overseas* (2017, Shuwa System Co.,), *Bridges in Japan* (2016, Minerva Shobo Co.,), *A Hundred-year-old Bridges* (2014, JSCE), *Conservation of Historical Engineering Works* (2010, Kajima Publishing. Co.,) and *Manual for repair and strengthening of historic iron and steel bridges* (2006 JSCE).

He is a Fellow and an Executive Professional Civil Engineer of the Japan Society of Civil Engineers (JSCE) and was a chairman of the Committee of Repair and Strengthening of Historical Steel Bridges from 2004 to 2007, a chairman of the Committee of Conservation of Historical Engineering Works from 2007 to 2010, and is now a vice chairman of the Committee of Conservation of Engineering Heritage.

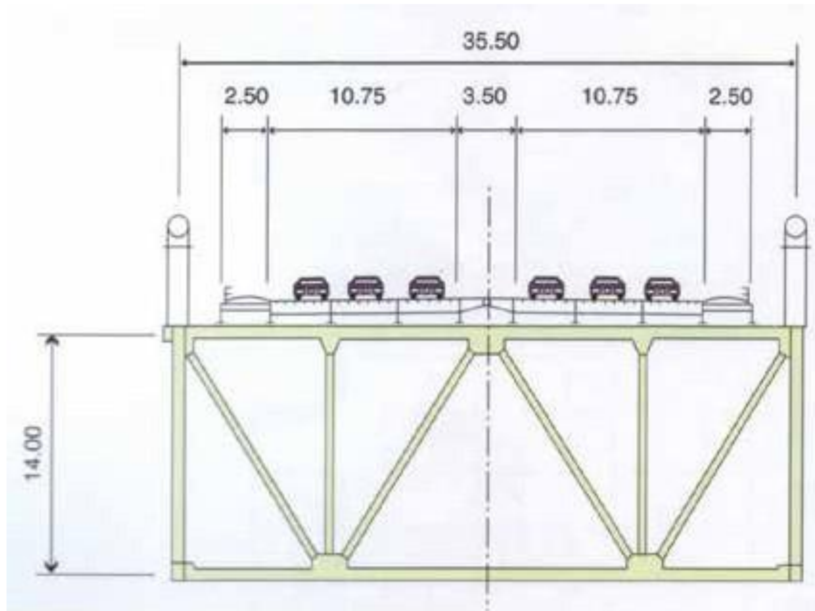
He received his PhD in 1996 from the College of Science & Technology of Nihon University, Japan.

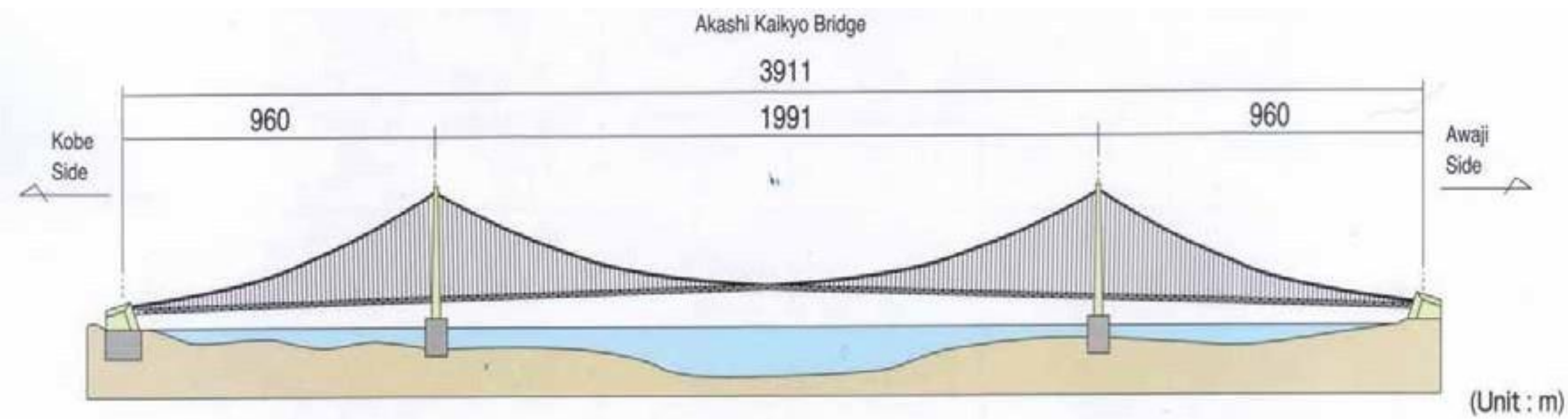
6. The World's longest bridge span today: Akashi Straits Bridge, Japan

Hiroshi Isohata

Akashi Bridge is the world's longest suspension bridge with a clear span of 1991m, and a total length of 3911m. The bridge was opened in April 1998 at Akashi Straits near Kobe as one of the bridges within the route connecting Honshu and Shikoku in western Japan.

The completion of this suspension bridge at the end of the 20th century is an achievement of the world modern suspension bridge development which started two centuries ago in European countries and North America including the UK where Union Bridge and Menai Bridge had exercised significant influence.





Akashi Bridge - dimensioned cross-section and elevation

View towards Kobe © Dr Miles Oglethorpe

Prelude

Akashi Straits, 4km wide at the narrowest, is located at the east of the Inland Sea of Japan. Bridging over Akashi Straits was just a dream for long time because of severe local conditions such as high tidal velocity up to 4.5m/sec. and deep-sea water from 50m to 110m.

Fundamental surveys had been started in the 1950s, followed by substantial surveys towards construction in 1970 when the Bridge Authority was established. In December 1985 the Government formally decided to commence the bridge project.

The location of the bridge was selected at the narrowest point in the Straits and the type of the structure was a 3-span suspension bridge of truss girder with 1990m centre span and 3910m bridge length. This project was most challenging and ambitious because of the clear centre span of 1990m which was 580m longer than that of Humber Bridge with 1410m centre span as the longest suspension bridge in the world at that time. The commencement ceremony was carried out in April, 1986.

Construction Foundations

The towers stand on foundations based on a 60m deep sandstone sea bed in the Straits. The foundations are cylindrical steel armored concrete islands with a diameter of 80m.

Steel caissons were fabricated in shipyards as a whole and towed floating by tug boats to the locations. They were sunk down on the sea bed excavated in advance, into which mass concrete was poured. Marine construction works were challenging under the conditions of deep-sea water, strong tidal flows and busy sea traffic.

Steel Caisson in floating, Towing 80m diameter "tub" (Source; JBEC)

Construction of Tower, Steel blocks were Steel blocks were "piling up" (Source; JBEC)

Tower

Cables of suspension bridges hang down with parabolic shape from towers to centre. The "Sag Ratio", sag to span is usually between 1/8.5 to 1/11 and is 1/10 in case of Akashi Bridge. To accommodate 1990m span and 100m road elevation from the sea level, almost 300m tower height is required. The towers must be erected vertically with accuracy of 1/10,000 to guarantee safety and durability against 80m/s typhoon wind and 120,000-ton cable load.

Cable Erection, Spinning wires/strands (Source; JBEC)

Cables

Cables are anchored at both sides and supported by towers at the top to transmit the whole bridge loads to the ground. One strand is composed of 127 wires with a diameter of 5.23mm and 290 strands make a cable with a diameter of 112cm. The world record-breaking diameter cable produced a lot of challenging technologies in its erection.

Since cables are the most important part of a suspension bridge, preventing cables from corrosion is a hot issue in maintenance. Conventionally, the cables of suspension bridges are pasted for the first layer and banded by wrapping wires and finally painted against water or moisture. It is known through actual examples that the conventional system is not effective for a long time period. In the case of Akashi Bridge, pressured dried air is injected to keep the inside relative humidity below 60%. This is based on many experiments which show galvanized steel wire corrodes very little in an atmosphere of 60% relative humidity. This dehumidification system was developed and installed in Akashi Bridge 5 years after its completion.

Stiffening Girder Erection Truss advancing outwards from tower (Source; JBEC)

Girders

Stiffening girders suspended by cables carry the carriageway and also, importantly, provide stability against wind. There are two types of stiffening girders: truss girders with high rigidity and enough openings against horizontal wind flows as widely practised in the USA after the Tacoma Narrows Bridge disaster in 1940 and the other, a box girder of streamlined cross-section was developed in the UK for Severn Bridge (1966) and followed in others including Humber Bridge (1983). In the case of Akashi Bridge, a truss girder was adopted as a result of numerous studies.

Great Earthquake

It should be specially mentioned that a great earthquake struck Akashi Bridge while it was under construction. When cable erection was progressing in the final stage, after foundations and tower erection, Akashi Bridge was struck by an earthquake with magnitude of 7.2 on the Richter Scale in the morning of 17 January, 1995. The epicenter was just in the Straits. Damage due to the earthquake in Kobe City was serious. There were 6,434 fatalities and 43,792 injuries. Some 250,000 houses were damaged and the total cost of the damage was ten trillion yen.

The earthquake forced the south side tower foundation and anchorage respectively to move 1m southwards, which required the clear span to be increased from the 1990m of the original design to 1991m. Fortunately there were no structural failures and this occurred because the tops of both towers were supported by the cables. If cable erection had not been finished and the towers had stood independently, the bottom part of the towers would have been damaged. Members of the truss girders under fabrication were quickly changed to conform to “design change order” by nature!

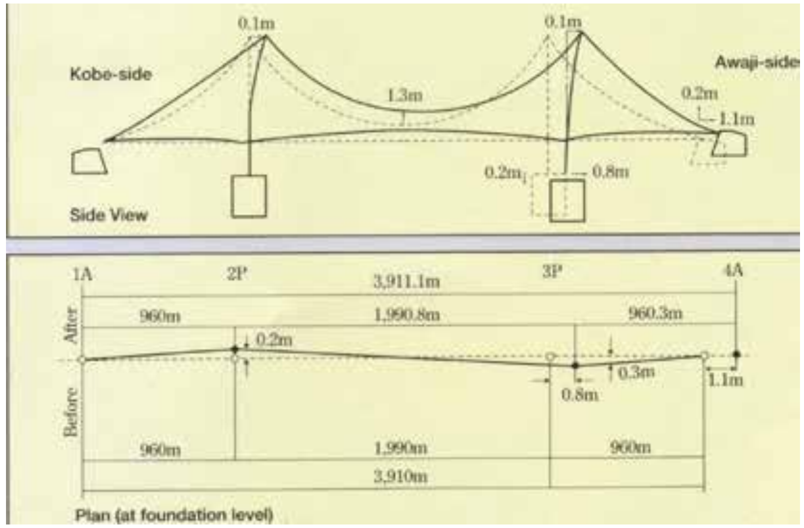
Progressive Development

The first half of the 200-year history of the modern suspension bridge started in Britain, France and North America. Development of the iron industry in these countries supplied malleable iron

Left: Earthquake disaster in Kobe city (source; JSCE)
Right: Akashi Bridge just after the earthquake, 23 Jan. 1995 (Source; JBEC) Tower tops were supported by cables when the earthquake struck

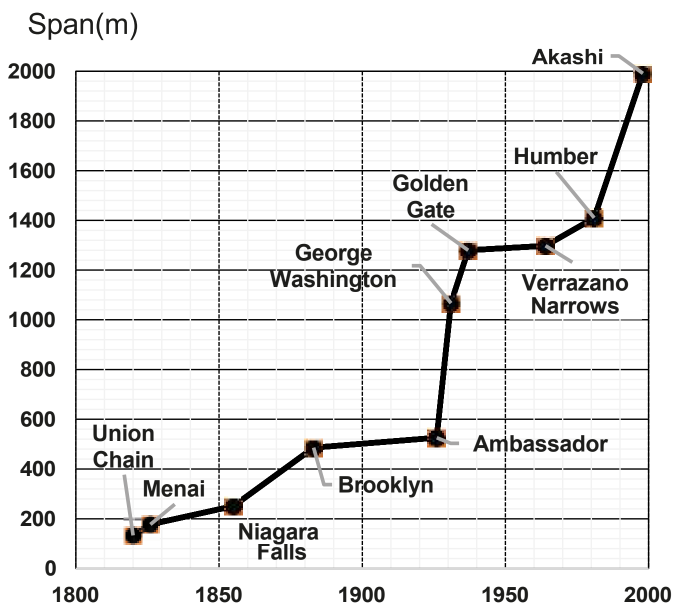
chain and wrought iron wire and enabled the suspension bridge to fulfill its potential as the best solution for the longest spans.

The second half of the history was crowned by Brooklyn Bridge (1883) using steel wire, followed by major development in the USA in the 20th century. Akashi Bridge was completed as an achievement based on the accumulated skills of two centuries stemming from Union Bridge by Brown and Rennie and Brooklyn Bridge by Roebling.



Deformations due to earthquake
Centre span expanded one meter (Source; JBEC)

Year	Span(m)	Name
1820	133	Union Chain
1826	177	Menai
1855	251	Niagara Falls
1883	486	Brooklyn
1926	526	Ambassador
1931	1067	George Washington
1937	1280	Golden Gate
1964	1298	Verrazano Narrows
1981	1410	Humber
1998	1991	Akashi



Development of major suspension bridges from Union Chain Bridge to Akashi Bridge (see Table on Page 15 for more details)

Acknowledgements

This paper is written on behalf of all people who were involved in the Akashi Bridge Project. The author wishes to acknowledge the help received from Mr. Takashi Yamanaka, former director of Akashi Bridge Museum, JBEC who supplied useful information to develop this paper and, finally, to express sincere thanks to Professor Roland Paxton who recommended him to write this paper for the commemoration of the Union Bridge bicentenary.

View towards Awaji © Dr Miles Oglethorpe