

# Long-span Cable-supported Bridges

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## The Beauty of Bridges

It has been said that "Temples and bridges are the most outstanding exhibits of mankind". On the other hand, never earlier have so many notable (long-span) bridges been built as during the change of the past Millennium. The boom of great bridges concerns long-span suspension bridges, and particularly cable-stayed bridges.

This is a revised abridgement from an earlier article in the magazine *Tierakennusmestari* [1], a quarterly publication of the Finnish Road Administration. The term "span" here means expressly the main span of a bridge which is the centre-to-centre distance between towers/pylons/piers/supports, and definitely not the total length or overall length (= sum of spans) of any multi-span bridge.

At the turn of the Millennium, there exist in the world 17 bridges with a span longer than 1000 m and completed before 2000. These all are suspension bridges (Table 1). Counted by countries: 4 each in the U.S.A. and Japan; 2 each in Britain, Turkey and China; and 1 each in Portugal, Sweden and Denmark. The profiles of these 17 bridges - for technical reasons not in the same scale - were published in [2].

Detailed drafts (longitudinal profiles, cross-sections on deck, front elevations on towers) on those 17 long-span suspension bridges are included in [3].

Hitherto, the suspension bridge is the only bridge type

exceeding the one kilometre span. As appears from Table 1, the record span of suspension bridges is already nearing the 2 km mark. Further to the development of suspension bridges with respect to the growth of the main span, in the original Finnish article [1], the materials of towers are discussed, and the methods of assembling main cables and the increase of tensile strength of the cable-wires are outlined. Also the two main types introduced for deck structures are described, particularly after the collapse of the first Tacoma Bridge (in 1940): strong steel truss stiffening girders (USA) and novel streamlined steel box girders (Europe and Asia). The importance of resistance against earthquakes is pointed out, particularly in view of the survival of the Akashi Bridge in the notorious Kobe Earthquake of 1995.

Among suspension bridges, the No.1 is the mighty Akashi-Kaikyo Bridge, span 1991 m, completed in 1998. It is this Akashi Bridge that is shown on the cover of this issue of *Engineer*. It is situated near Kobe, in Japan, along the Kobe-Naruto Route, between Honshu and Shikoku Islands. The No.2 is the Great Belt East Bridge in Denmark (1624 m; 1998). The next suspension bridge in the world to exceed the 1 km span limit and the first one during the new Millennium will be the Runyang South Bridge in China (1490 m; 2005), of the 3rd longest span ever built. Among suspension bridges for highway/railway traffic, the No.1 is the Tsing Ma Bridge in Hong Kong, China (1377 m; 1997); Table 1.

Cable-stayed bridges are now approaching the 1 km span limit. The No.1 is the Tatara Bridge in Japan (span 890 m, dated 1999), and the No.2 is the Pont de

TABLE 1: The Longest Span Suspension Bridges(completed, or under construction by 2003, span >700 m)

| No. | Bridge                | Span      | Location                  | Year |
|-----|-----------------------|-----------|---------------------------|------|
| 1   | Akashi-Kaikyo         | 1991 m    | Kobe-Naruto, Japan        | 1998 |
| 2   | Great Belt East       | 1624 m    | Korsor, Denmark           | 1998 |
| 3   | Runyang South         | 1490 m    | Zhenjiang, China          | 2005 |
| 4   | Humber                | 1410 m    | Kingston-upon-Hull, UK    | 1981 |
| 5   | Jiangyin              | 1385 m    | Jiangsu, China            | 1999 |
| 6   | Tsing Ma              | 1377 m    | Hong Kong, China          | 1997 |
| 7   | Verrazano-Narrows     | 1298 m    | New York, NY, USA         | 1964 |
| 8   | Golden Gate           | 1280 m    | San Francisco, CA, USA    | 1937 |
| 9   | Höga Kusten           | 1210 m    | Kramfors, Sweden          | 1997 |
| 10  | Mackinac              | 1158 m    | Mackinaw City, MI, USA    | 1957 |
| 11  | Minami Bisan-seto     | 1100 m    | Kojima-Sakaide, Japan     | 1988 |
| 12  | Fatih Sultan Mehmet   | 1090 m    | Istanbul, Turkey          | 1988 |
| 13  | Bosporus              | 1074 m    | Istanbul, Turkey          | 1973 |
| 14  | George Washington     | 1067 m    | New York, NY, USA         | 1931 |
| 15  | Kurushima-3           | 1030 m    | Onomichi-Imabari, Japan   | 1999 |
| 16  | Kurushima-2           | 1020 m    | Onomichi-Imabari, Japan   | 1999 |
| 17  | Ponte 25 de Abril     | 1013 m    | Lisbon, Portugal          | 1966 |
| 18  | Forth Road            | 1006 m    | Edinburgh, UK             | 1964 |
| 19  | Kita Bisan-seto       | 990 m     | Kojima-Sakaide, Japan     | 1988 |
| 20  | Severn                | 988 m     | Bristol, UK               | 1966 |
| 21  | Yichang               | 960 m     | Hubei, China              | 2001 |
| 22  | Shimotsui-seto        | 940 m     | Kojima-Sakaide, Japan     | 1988 |
| 23  | Xiling                | 900 m     | Hubei, China              | 1996 |
| 24  | Humen-1               | 888 m     | Guangdong, China          | 1997 |
| 25  | Ohnaruto              | 876 m     | Kobe-Naruto, Japan        | 1985 |
| 26  | Volgograd(1)          | 874 m     | Volga River, Russia       | 1955 |
| 27  | 2nd Tacoma Narrows(2) | 853 m     | Puget Sound, WA, USA      | 1950 |
| 28  | 3rd Tacoma Narrows(3) | 853 m     | Puget Sound, WA, USA      | 2007 |
| 29  | Askoy                 | 850 m     | Bergen, Norway            | 1992 |
| 30  | Innoshima             | 770 m     | Onomichi-Imabari, Japan   | 1983 |
| 31  | Akinada               | 750 m     | Hiroshima, Japan          | 2000 |
| 32  | Semipalatinsk         | 750 m     | Irtys River, Kazakhstan   | 2000 |
| 33  | New Carquinez Strait  | 728 m     | California, USA           | 2003 |
| 34  | Hakucho               | 720 m     | Muroran, Japan            | 1998 |
| 35  | Angostura             | 712 m     | Ciudad Bolivar, Venezuela | 1967 |
| 36  | Kanmon                | 712 m     | Honshu-Kyushu, Japan      | 1973 |
| 37  | Transbay              | 2 x 704 m | San Francisco, CA, USA    | 1936 |
| 38  | Bronx-Whitestone      | 701 m     | New York, NY, USA         | 1939 |
|     | Kirjalansalmi         | 220 m     | Parainen, Finland         | 1963 |
|     | Sääksmäki             | 155       | Valkeakoski, Finland      | 1963 |

Notes:

(1)not standing

(2)first bridge collapsed in 1940

(3)parallel to the 2nd bridge

Normandie in France (856 m; 1995). The projected Stonecutters Bridge in Hong Kong, China, is to be the first cable-stayed bridge in the world to exceed the 1 km mark (1018 m). Among cable-stayed bridges for

Other bridge types than cable-supported bridges may reach spans of 300-500 m. Among other than cable-supported bridges, the longest-span bridge in the world is the Lupu Bridge in China. It is a steel arch bridge (550 m; 2003); Table 3.

Successive span records during the past two Millennia are given in Table 4. To mention some proposed long-span suspension bridges of the future: Qiongzhou [4] in China (span 2000 m to 2500 m); Messina Strait in Italy (3300 m) [5]; Tsugaru Strait in Japan (4000 m) [6]; and Gibraltar Strait between Spain and Morocco (5000 m) [7]. Finally, a gigantic cable-stayed bridge was proposed in the 1980's across the Gibraltar Strait with an enormous main span of 8400 m [8].

#### EPILOGUE

Long-span bridges [9] have interested us always, my wife and me, particularly great suspension bridges and also cable-stayed bridges (Tatara).

Hitherto, we have visited the following long-span cable-supported bridges (in order of main span): Akashi, Great Belt, Humber, Verrazano, Golden Gate, Høga Kusten, Fatih Sultan Mehmet, Bosporus, George Washington, Kurushima-3, Ponte 25 de Abril, Forth, Severn, Transbay (Table 1), and Tatara (Table 2).

Excluding the 2 Istanbul suspension bridges, in other cases we were permitted to enter the top of the towers of the bridges mentioned above. The 3 Kojima-Sakaide suspension bridges (Minami, Kita, Shimotsui) we crossed by train and the Kurushima-2 Bridge on the Onomichi-Imabari Route we passed by ship, so those are not counted (Table 1).

#### REFERENCES

[1] Juhani Virola, "Notable bridges in the world"

highway/railway traffic, the No.1 is the Oresund Bridge between Sweden and Denmark (490 m; 2000). Among 1-tower cable-stayed bridges, the No. 1 is the Surgut Bridge in Russia (408 m; 2000).

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[9] Website of the Helsinki University of Technology (HUT):  
[<http://www.hut.fi/Units/Departments/R/Bridge/longspan.html>].

## Biographical Sketch

**JUHANI VIROLA**, B.S.C.E. Tampere, Eur. Ing. FEANI, born in 1941, married in 1967 and with 1 child, earned his B.Sc. degree in civil engineering from Tampere Institute of Technology, Tampere, Finland in 1967 and is a registered engineer since 1988 with FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs). His main interests are in long-span bridges on which he has written many articles for various technical journals and newspapers worldwide (in 64 countries, in 41 languages). He is a contributor to the Guinness Book

of Records during 1974-2000 and is listed in the Marquis Who's Who in the World, 2001 (p. 2292; see [www.marquiswhoswho.com](http://www.marquiswhoswho.com), and the website of the Helsinki University of Technology: <http://www.hut.fi/Units/Departments/R/Bridge/longspan.html>).

His wife and companion Leena Virola shares his interests and has travelled extensively with him photographing the magnificent structures described in this article. The cover photograph depicts her contribution to this issue.

TABLE 2: The Longest Span Cable-stayed Bridges (completed, or under construction by 2003, span >475 m)

| No. | Bridge            | Span      | Location                | Year |
|-----|-------------------|-----------|-------------------------|------|
| 1   | Tatara            | 890 m     | Onomichi-Imabari, Japan | 1999 |
| 2   | Pont de Normandie | 856 m     | Le Havre, France        | 1995 |
| 3   | Nancha            | 628 m     | Nanjing, China          | 2001 |
| 4   | Baishazhou        | 618 m     | Wuhan, China            | 2000 |
| 5   | Qingzhou          | 605 m     | Fuzhou, China           | 2003 |
| 6   | Yangpu            | 602 m     | Shanghai, China         | 1993 |
| 7   | Xupu              | 590 m     | Shanghai, China         | 1997 |
| 8   | Meiko Central     | 590 m     | Nagoya, Japan           | 1998 |
| 9   | Rion-Antirion     | 3 x 560 m | Patras, Greece          | 2004 |
| 10  | Skarnsundet       | 530 m     | Trondheim Fjord, Norway | 1991 |
| 11  | Queshi            | 518 m     | Shantou, China          | 1999 |
| 12  | Tsurumi Tsubasa   | 510 m     | Yokohama, Japan         | 1994 |
| 13  | Jingzhou          | 500 m     | Hubei, China            | 2002 |
| 14  | Ikuchi            | 490 m     | Onomichi-Imabari, Japan | 1991 |
| 15  | Oresund           | 490 m     | Sweden-Denmark          | 2000 |
| 16  | Higashi-Kobe      | 485 m     | Kobe, Japan             | 1992 |
| 17  | Ehuang            | 480 m     | Ezhou-Huanggang, China  | 2002 |
| 18  | Zhanjiang         | 480 m     | Guangdong, China        | 2002 |
| 19  | Megami            | 480 m     | Nagasaki, Japan         | 2005 |
| 20  | Ting Kau          | 475 m     | Hong Kong, China        | 1998 |
| 21  | Pusan-Geoje       | 475 m     | South Korea             | 2009 |
|     | Raippaluoto       | 250 m     | Vaasa, Finland          | 1997 |
|     | Kärkinen          | 240 m     | Korpilahti, Finland     | 1997 |

TABLE 3: Various Bridge Types in order of Main Span (completed, or under construction by 2003, span >300 m)

| No. | Type: Bridge                                  | Span   | Location                | Year |
|-----|-----------------------------------------------|--------|-------------------------|------|
| 1   | Cable suspension: Akashi-Kaikyo               | 1991 m | Kobe-Naruto, Japan      | 1998 |
| 2   | Cable-stayed: Tatara                          | 890 m  | Onomichi-Imabari, Japan | 1999 |
| 3   | Steel arch: Lupu                              | 550 m  | Shanghai, China         | 2003 |
| 4   | Cantilever steel truss girder: Quebec Railway | 549 m  | Quebec, Canada          | 1917 |
| 5   | Concrete arch: Wanxian                        | 425 m  | Sichuan, China          | 1997 |
| 6   | Continuous steel truss girder: Ikitsuki       | 400 m  | Nagasaki, Japan         | 1991 |
| 7   | Double span swing: El Ferdan                  | 340 m  | Suez Canal, Egypt       | 2001 |
| 8   | Chain suspension: Ponte Hercilio Luz          | 339 m  | Florianopolis, Brazil   | 1926 |
| 9   | Prestressed concrete girder: Stolmasundet     | 301 m  | Austevoll, Norway       | 1998 |
| 10  | Steel box girder: Ponte Costa e Silva         | 300 m  | Rio de Janeiro, Brazil  | 1974 |

Table 4: Successive Main Span Records during the Past Two Millennia

| No. | Name of Bridge and Type or Material        | Span               | Location                  | Year      |
|-----|--------------------------------------------|--------------------|---------------------------|-----------|
| 1   | Martorell (stone arch)                     | 37 m               | Spain                     | B.C. 217  |
| 2   | Trajan's Bridge <sup>1</sup> (timber)      | 52 m               | Danube River, Romania     | A.D. 104  |
| 3   | Trezzo <sup>1</sup> (stone arch)           | 72 m               | Italy                     | A.D. 1377 |
| 4   | Luding (chain suspension)                  | 103 m              | Dadu River, China         | A.D. 1705 |
| 5   | Schaffhausen <sup>1</sup> (timber)         | 119 m <sup>2</sup> | Switzerland               | A.D. 1757 |
| 6   | Schuylkill Falls <sup>1</sup> (suspension) | 124 m              | Philadelphia, PA, USA     | A.D. 1816 |
| 7   | Union/Tweed<br>(chain suspension)          | 137 m              | Berwick, UK               | A.D. 1820 |
| 8   | Menai Straits (chain suspension)           | 177 m              | Anglesey, UK              | A.D. 1826 |
| 9   | Fribourg <sup>1</sup> USA-Canada           | 273 m              | Switzerland               | A.D. 1834 |
| 10  | Wheeling USA-Canada                        | 308 m              | West Virginia, USA        | A.D. 1849 |
| 11  | Lewiston <sup>1</sup> (suspension)         | 318 m <sup>3</sup> | Niagara River, USA-Canada | A.D. 1851 |
| 12  | Cincinnati (suspension)                    | 322 m              | Ohio River, USA           | A.D. 1867 |
| 13  | Clifton <sup>1</sup> (suspension)          | 386 m              | Niagara Falls, USA-Canada | A.D. 1869 |
| 14  | Brooklyn (suspension)                      | 486 m              | New York, NY, USA         | A.D. 1883 |
| 15  | Firth of Forth (cantilever steel truss)    | 2 x 521 m          | Edinburgh, UK             | A.D. 1890 |
| 16  | Quebec (cantilever steel truss)            | 549 m              | Quebec City, Canada       | A.D. 1917 |
| 17  | Ambassador (suspension)                    | 564 m              | Detroit, MI, USA          | A.D. 1929 |
| 18  | George Washington (suspension)             | 1067 m             | New York, NY, USA         | A.D. 1931 |
| 19  | Golden Gate (suspension)                   | 1280 m             | San Francisco, CA, USA    | A.D. 1937 |
| 20  | Verrazano-Narrows (suspension)             | 1298 m             | New York, NY, USA         | A.D. 1964 |
| 21  | Humber Estuary (suspension)                | 1410 m             | Hull, UK                  | A.D. 1981 |
| 22  | Akashi-Kaikyo (suspension)                 | 1991 m             | Kobe-Naruto, Japan        | A.D. 1998 |

Notes:

- (1) Not presently standing
- (2) 119 m actually consisted of 2 spans - middle support was temporarily removed after completion
- (3) Span 318 m c/c of towers - free span 257 m between river banks