

= Nordhordland Bridge =

The Nordhordland Bridge ( Norwegian : Nordhordlandsbrua ) is a combined cable @-@ stayed and pontoon bridge which crosses Salhusfjorden between Klauvaneset and Flatøy in Hordaland , Norway . It is 1 @, @ 614 meters ( 5 @, @ 295 ft ) long , of which the pontoon section is 1 @, @ 246 meters ( 4 @, @ 088 ft ) long . The cable @-@ stayed section consists of a single 99 @-@ meter ( 325 ft ) tall H @-@ pylon which has a length of 368 meters ( 1 @, @ 207 ft ) and a main span of 172 meters ( 564 ft ) . This allows for a clearance of 32 meters ( 105 ft ) .

The floating section is a steel box girder bridge with ten pontoons , which because of the fjord 's depth are not laterally anchored . The roadway sits on an orthotropic deck . The pontoons and the cable @-@ stayed bridge are built in concrete , with the main span being supported with 48 cables . The fjord end of the main span is supported by a 30 @-@ meter ( 98 ft ) deep foundation , where the two bridges meet . From there and for 414 meters ( 1 @, @ 358 ft ) , the roadwall has a 5 @. @ 7 percent gradient on a viaduct anchored to the pontoon bridge .

The bridge carries two lanes of European Route E39 , also called the Coastal Highway , and one pedestrian and bicycle path , and connects the district of Nordhordland to Bergen . Plans for a bridge had existed since the 1960s , and after the decision to construct the bridge was passed by the Parliament of Norway in 1989 , construction started in 1991 . Total costs , including auxiliary roads , was NOK 910 million . Part of the contract payment was subject to a court case which the contractors lost . The bridge opened on 22 September 1994 , and remained a toll road until 31 December 2005 . In 2014 , it had an average daily traffic of 16 @, @ 580 vehicles . There are plans to reinstate a toll on the bridge from 2013 to finance other road projects . The bridge is the second @-@ longest in Norway , and the second pontoon bridge in Norway .

= = Specifications = =

The bridge consists of three sections , a cable @-@ stayed bridge , a pontoon bridge and a viaduct which connects the two . The cable @-@ stayed bridge consists of a 99 @. @ 3 @-@ meter ( 326 ft ) tall H @-@ pylon with a foundation at Klauvaneset on the mainland of Bergen . It supports a 172 @-@ meter ( 564 ft ) main span , with the other end being fixed in a foundation 30 @-@ meter ( 98 ft ) below mean sea level , which is anchored in the ridge Klauvaskallen . The whole cable @-@ stayed bridge is 369 meters ( 1 @, @ 211 ft ) long , with a 190 @-@ meter ( 620 ft ) long viaduct , supported by six pairs of pillars . The cable @-@ stayed bridge allows for a sailing channel which is 32 meters ( 105 ft ) tall and 50 meters ( 160 ft ) wide . The main span is built in lightweight LC55 concrete , while the viaduct and pylon is built with conventional C45 concrete . Inside the pylons is a 1 @. @ 6 by 2 @. @ 0 meters ( 5 ft 3 in by 6 ft 7 in ) hollow area .

The bridge has 48 cables , 12 on each side of the pylon on each side of the roadway . The distance between the cables is 12 @. @ 00 meters ( 39 @. @ 37 ft ) on the main span , and 9 @. @ 33 meters ( 30 @. @ 6 ft ) on the viaduct . Combined , the cables are 4 @, @ 432 meters ( 14 @, @ 541 ft ) long ; each cable consists of 67 to 230 twined cables , each with a 7 @-@ millimeter ( 0 @. @ 28 in ) diameter . The cables have a weight of between 1 @. @ 5 and 14 @. @ 5 tonnes ( 1 @. @ 5 and 14 @. @ 3 long tons ; 1 @. @ 7 and 16 @. @ 0 short tons ) each , and they have a capacity of between 1 @, @ 960 and 7 @, @ 910 kilonewtons ( 440 @, @ 000 and 1 @, @ 780 @, @ 000 lbf ) . They can be tightened at the connection with the roadwall .

The floating section consists of a steel box girder placed on top of ten floating pontoons . The pontoon section is anchored only at both ends , on the underwater foundation at Kauvaskallen and on Flatøy . It is fastened using flexible plate connections fastened by bolts and cables under tension . These are flexible around the horizontal axis at right angles towards the axis of the bridge , allowing for deformation caused by the tide . The fastening on Flatøy consists of a massive concrete block 22 by 20 meters ( 72 by 66 ft ) long and 14 @. @ 5 meters ( 48 ft ) tall which was poured into a blast @-@ out foundation pit in bedrock . Vertical pretension rock anchors have also been installed , with 12 at Klauvaskallen and 14 at Flatøy , giving 42 and 44 meganewtons ( 9 @, @ 400 @, @ 000 and 9 @, @ 900 @, @ 000 lbf ) of support , although they were only built to increase the safety factor

There are ten lightweight concrete pontoons , with 113 @. @ 25 @-@ meter ( 371 @. @ 6 ft ) spans between them . The pontoons are between 7 @. @ 0 and 8 @. @ 6 meters ( 23 @. @ 0 and 28 @. @ 2 ft ) in height . The draught varies between 4 @. @ 3 to 5 @. @ 6 meters ( 14 to 18 ft ) . Each pontoon consists of nine watertight cells which are partially filled with ballast for trim . The cells are dimensioned so two adjacent cells can fill with water without endangering the bridge .

The roadway lies on top of an orthotropic deck on a steel box girder , which is 15 @. @ 9 meters ( 52 ft ) wide , 5 @. @ 50 meters ( 18 @. @ 0 ft ) tall and 1 @, @ 246 meters ( 4 @, @ 088 ft ) long . The steel box girder weighs 14 @, @ 150 tonnes ( 13 @, @ 930 long tons ; 15 @, @ 600 short tons ) , of which 3 @, @ 000 tonnes ( 3 @, @ 000 long tons ; 3 @, @ 300 short tons ) is high @-@ strength low @-@ alloy steel . The girder has an octagonal shape and is made with 14 @-@ to @-@ 20 @-@ millimeter ( 0 @. @ 55 to 0 @. @ 79 in ) thick steel plates . They are longitudinally stiffened by trapezoidal stiffeners supported by cross frames at most every 4 @. @ 5 meters ( 15 ft ) . Two full bulkheads have been used for every pontoon pilaster , made from welded steel plates 8 to 50 millimeters ( 0 @. @ 31 to 1 @. @ 97 in ) thick . External brackets built into the bulkheads transfer the support forces to the pontoons . The girder was built in sections of 21 , 36 , and 42 meters ( 69 , 118 , and 138 ft ) , which were subsequently welded together into 11 modules with a skew angle of 1 @. @ 2 to 1 @. @ 3 degrees . The girder has a constant cross @-@ section throughout the length , except at the anchoring points to the pontoons . The section from the land anchoring to the first pontoon is subject to the most stress , and is made with steel with a higher yield point . The inside of the girder has two dehumidifiers which ensure that it does not rust . The clearance under the girder is 5 @. @ 5 meters ( 18 ft ) .

The two bridges are connected with a 414 @. @ 5 @-@ meter ( 1 @, @ 360 ft ) long steel viaduct , which runs on top of the floating bridge , bringing the road from 11 @. @ 0 to 34 @. @ 4 meters ( 36 @. @ 1 to 112 @. @ 9 ft ) above mean sea level . The viaduct weighs 1 @, @ 600 tonnes ( 1 @, @ 600 long tons ; 1 @, @ 800 short tons ) and has a gradient of 5 @. @ 7 degrees . It consists of spans between 18 and 33 meters ( 59 and 108 ft ) , with the roadway also built as an orthotropic deck with 12 @-@ millimeter ( 0 @. @ 47 in ) thick plates . Overall , the construction of the bridge used 24 @, @ 000 tonnes ( 24 @, @ 000 long tons ; 26 @, @ 000 short tons ) of concrete , of which 10 @, @ 000 tonnes ( 9 @, @ 800 long tons ; 11 @, @ 000 short tons ) in the pontoons . The bridge was coated with 40 @, @ 000 litres ( 8 @, @ 800 imp gal ; 11 @, @ 000 US gal ) of paint .

The bridge is monitored by 132 sensors , including sensors on hatches to the pontoons , on doors to the steel box girder , for corrosion , strain gauges on the girder and on flexible elements , and weather information . On the cable @-@ stayed section , the bridge is marked with navigation lights , as well as the center of the sailing area having a racon . The bridge is the second @-@ longest bridge in Norway , behind the Drammen Bridge .

= = History = =

= = = Planning = = =

Ship services in Nordhordland started in 1866 , and in 1923 the first car was purchased . A car ferry service between Isdalstø in Lindås and Steinestø in Åsane on the mainland was established on 7 July 1936 . A plan was launched whereby all traffic from Nordhordland would be collected in one place and transported across Salhusfjorden to Åsane . By moving the ferry quay from Isdalstø to Knarvik , the length of the ferry service could be reduced . However , the fares would be kept the same and the extra revenue used to finance a bridge from Flatøy to Lindås . This allowed the Alversund Bridge to open in 1958 , and the ferry service from Flatøy and Meland to move to Knarvik . The proposal to cross Salhusfjorden was launched during the planning of the Alversund Bridge . Cost estimates were made based on the Golden Gate Bridge in the United States , but it proved too expensive for a suspension bridge crossing between Frekhaug and Salhus .

In 1962 , the issue was brought up again , this time as a pontoon bridge . The depth and steepness

of the fjord would make it impossible to fasten the bridge to the sea bottom . However , a method without lateral anchorage had been developed for the Hobart Bridge in Australia . Another alternative was launched in 1963 , involving a submerged floating tunnel through the fjord . It was estimated to cost between NOK 19 @. @ 5 and 26 million . Norwegian expatriate Leif J. Sverdrup , co @-@ founder of Sverdrup & Parcel of the United States , inspected the fjord in 1965 and was later hired to plan the bridge in cooperation with Oslo @-@ based civil engineering consultants Prosjektering . Municipal engineers started measuring currents in 1966 . Prosjektering and Sverdrup & Parcel recommended a pontoon bridge with a movable section to allow passage of ship traffic . In 1967 , a new proposal was launched , in which a seaway tunnel would be blasted out in the rock on the Bergen side .

The Alversund Bridge was a toll bridge which was paying for the debt accumulated in its construction . By 1968 , the debt would be paid off , but the Norwegian Public Roads Administration launched a plan whereby the tolls would continue to be collected and used to finance a bridge across Salhusfjorden . This was opposed by a group of locals , who brought the issue to the courts , claiming it to be illegal , as a bridge would never be built . Both Oslo District Court and Eidsivating Court of Appeal concluded that the tolls were legal , and the issue was rejected by the Supreme Court . Protests were also raised against the use of a pontoon bridge , as it would limit the vessel size and thus the commercial development in the inner parts of the fjord .

In the 1970s , National Road 1 ( today part of E39 ) was established through Knarvik towards Sognefjorden , resulting in upgrades to the roads in Nordhordland , and making the crossing one of the main routes from the north . At the same time , it was decided to establish a refinery at Mongstad in Lindås . In 1971 , details about the suspension bridge were again discussed , with three different proposals with the main span of between 1 @, @ 090 and 1 @, @ 210 meters ( 3 @, @ 580 and 3 @, @ 970 ft ) with 160 @-@ meter ( 520 ft ) tall pylons . There were protests from the Salhus area , as the suspension bridge would have resulted in the demolishing of part of the residential area .

In 1972 , discussion started with the plans to connect Meland , Flatøy and Lindøy with bridges . This was passed by the Parliament of Norway in May 1975 , and consisted of the Krossnessundet Bridge between Flatøy and Meland , which opened in November 1978 . The Hagelsund Bridge opened on 1 April 1982 and connected Flatøy to Lindås and Knarvik , thus also connecting Meland and Lindås . Both bridges were partially financed with tolls . The plans for a pontoon bridge were presented to the Standing Committee on Transport and Communications on 31 March 1981 . They supported the choice of a pontoon bridge . The decision to construct the bridge was taken by parliament on 9 December 1987 , but they demanded that a larger ship channel be constructed .

Detailed planning started in March 1990 , and at first two technical methods for constructing the pontoon bridge were considered : a continuous concrete floating caisson between the abutments , and a steel version incorporating a truss bridge carrying concrete pontoons . However , they were both rejected in favor of a concrete or steel box section borne on concrete pontoons .

= = = Construction = = =

Design of the bridge was awarded to Aas @-@ Jakobsen and Det Norske Veritas , the former who also performed dynamic analysis and structural engineering . Architects were Hindhammer ? Sundt ? Thomassen , Lund & Løvseth , and Lund & Slaatto . An H pylon was chosen instead of an A pylon both because it was more functional , and would be more aesthetic in conjunction with the other bridges in the area , particularly three suspension bridges .

The technology for the bridge was based on recent technology for pontoon bridges combined with Norwegian offshore technology . Among the technologies initially considered , but later ruled out , was that used in the Homer M. Hadley Memorial Bridge and the Hood Canal Bridge in the United States . Instead , an orthotropic deck was chosen , such as the Bergsøysund Bridge had used . The choice of a box girder bridge and the orthotropic deck were chosen because it gave the lower material use . Conventional pontoon bridges have lateral anchorage systems which fasten the bridge to the seabed . The technique had previously been used down to 140 meters ( 460 ft ) , but

Salhusfjorden is 500 meters ( 1 @, @ 600 ft ) deep , making the method prohibitively expensive . The choice of a cable @-@ stayed section allowed reduced traffic hazards in storms , a reduction in corrosion on the bridge deck , and improved passage of water beneath the bridge in support of wildlife .

The contract for construction of the pontoon bridge was awarded in August 1991 to a consortium , Arbeidsfellesskapet Salhus Bru , which consisted of Norwegian Contractors , Aker Entreprenør , Veidekke and Kværner Eureka . The components were built in Moss and Fredrikstad and then shipped to Lonevågen , a branch of Osterfjorden which was suitable to connect the parts . There were problems welding the high @-@ strength low @-@ alloy steel , which resulted in the work being halted for several days before an agreement was reached between the contractor and the Public Roads Administration . On 26 January 1994 , the steel frame which would be used to fasten the pontoon bridge to the cable @-@ stayed bridge , came adrift during transport in Skagerrak , and was severely damaged , causing a delay in the project . As the bridge had the longest laterally unsupported span in the world , the construction was watched by many international delegations .

The construction of the tunnel also involved other investments in road infrastructure . This included 5 @. @ 7 kilometers ( 3 @. @ 5 mi ) of new highways , 4 @. @ 2 kilometers ( 2 @. @ 6 mi ) of local roads , and the 785 @-@ meter ( 2 @, @ 575 ft ) long Hordvik Tunnel just south of the bridge . A grade @-@ separated crossing was built on both sides of the bridge . The intersection on Flatøy was also built as a bus interchange , and became the terminus of many bus routes in Nordhordland . Express buses would from there run directly to the city center of Bergen .

The bridge project cost NOK 910 million , of which NOK 513 was for the pontoon bridge , NOK 81 million was for the cable @-@ stayed bridge , NOK 25 million was used for the waterway , NOK 115 million was used on planning , and NOK 176 million was used on auxiliary roads and the tunnel . The bridge was financed with NOK 41 million in state grants , NOK 139 million from tolls paid in advance , and NOK 730 million in debt which would be repaid by the tolls . Interest during construction cost NOK 138 million . The construction involved 1 @, @ 150 @, @ 000 man @-@ hours .

= = = Aftermath = = =

The use of high @-@ strength steel caused problems as it was necessary to heat the steel to 150 ° C ( 302 ° F ) before and after welding , and Kværner had problems finding an adequate process during late 1992 . In January 1993 , an appropriate process had been found , although experimentation with various methods continued for another six months . Kværner felt that the Public Roads Administration should bear the extra costs , demanding NOK 108 million in compensation , but the administration denied this , resulting in a lawsuit . On 26 January 1996 , Nordhordland District Court supported the administration , but gave the plaintiff partial support , claiming the administration should take part of the costs through improper choice of material . The Public Roads Administration was sentenced to pay NOK 34 million to Kværner . Both sides appealed to Gulating Court of Appeal , which on 18 February 1998 refuted all of Kværner 's claim regarding the steel boxes , and sentenced the administration to pay NOK 7 @. @ 5 million . In addition , Kværner had to pay the administration NOK 19 @. @ 5 million in penalties for overrunning the contract date . However , the court 's decision was not unanimous . The plaintiff appealed to case to the Supreme Court , who unanimously confirmed the ruling of Gulating Court of Appeal . In addition , the plaintiff was sentenced to pay the defendants legal costs of NOK 910 @, @ 000 .

The bridge was officially opened by King Harald V on 22 September 1994 . It was the second pontoon bridge in Norway , after the Bergsøysund Bridge which opened in 1992 . The last tolls were collected on 31 December 2005 . In 2008 , there were 19 @, @ 700 travelers on the bridge each day , 14 percent of which used public transport . In 2009 , the bridge had an average daily traffic ( ADT ) of 14 @, @ 698 vehicles , up from 7975 in 2000 . Following the removal of the tolls , the ADT increased from 9912 in 2005 to 12249 in 2006 . In 2010 , the bridge was one of twelve finalists in Teknisk Ukeblad 's competition for the most beautiful bridge in Norway . In December 2010 , Bergen City Council approved the Nordhordland Package , which would result in NOK 3 @. @ 8 billion being

used on road investments in Åsane and Nordhordland . Two @-@ thirds of the financing is to come from tolls , which will involve reinstalling a toll plaza on the bridge . The tolls will first be set to NOK 20 for five years , and then after the completion of the first stage , the toll will be NOK 40 for fifteen years . The toll plaza is scheduled to reopen in 2013 . Among the projects is a new four @-@ lane Nyborg Tunnel which will shorten the distance of E39 from the bridge with the motorway at Nyborg in Bergen .