**Zeitschrift:** IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

**Band:** 11 (1980)

**Artikel:** Network arches

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**DOI:** https://doi.org/10.5169/seals-11363

# NETWORK ARCHES

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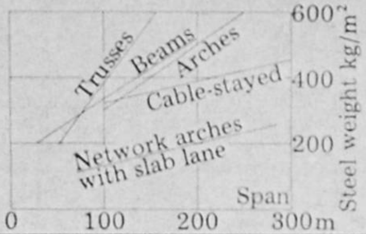
## CENTRAL CLAIMS

A network arch with a simple slab lane usually saves half the steel compared to equal spans.

In the future, the world's most slender arch bridge will most likely remain a network arch.

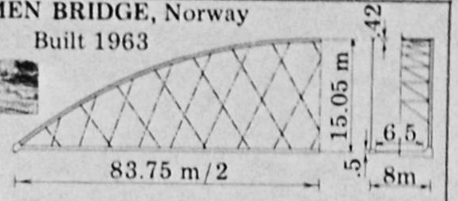
## STEEL WEIGHTS OF ROAD BRIDGES




Weights of network arches from: Per Tveit et al. *Network Arches*, University of Houston, 1978. Weights of other bridges from: Max Herzog: *Stahlgewichte moderner Eisenbahn- und Strassenbrücken*, Der Stahlbau 9/1975.

## BOLSTADSTRAUMEN BRIDGE, Norway

Built 1963




Structural steel 44 t
Prestressed steel 7 t

$$\text{Slenderness} = \frac{\text{Length of span}}{\text{Depth of arch and lane}} = \frac{83.75}{.5 + .42} = 91$$

## FUNDAMENTALS

For trusses and tied arches esthetic reasons

F1

limit the distance between upper and lower chord.

Thus saving of weight can be achieved mainly by reducing bending and by avoiding a high length/depth ratio of compression members.

The most economical diagonals are tension members. When there is live load on part of the span, tension members can relax (dotted

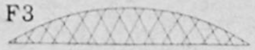
F2

lines) and thus transform part of the truss into part of a bowstring arch with inclined hangers.

When many hangers relax bending moments in the chords are bigger than when the span acts like a truss. The normal forces in the chords, however, are smaller than maximum because the live load is only on part of the span.

To avoid too big bending moments due to relaxation of hangers, hangers must not be too steep. To avoid too great distances between points of support more hangers can

F3



be introduced. This will allow more slenderness in arch and lane. The reduction of chord depth greatly reduces secondary stresses.

## OPTIMAL DESIGN

High-strength materials should be used. Hangers should be placed equidistantly along the arch and along the middle portion of the lane. F5. This gives the best support of the arch and minimum bending moments in the chords. Further all hangers can have the same cross-section, and nearly the same maximum force.

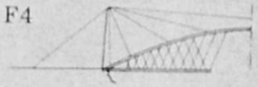
For ease of fabrication the arch should be part of a circle. This also contributes to equally small max. bending moments along the edge beams.

The lane should be a slab spanning between the concrete edge beams, which can be enlarged to act as traffic barriers protecting the hangers. These beams contain the prestressing cables that counteract the tensile force in the lower chord.

## ERECTION

The two network arches in Norway were built on a timber structure resting on wooden piles, see photo. Cable-stayed erection has

F4

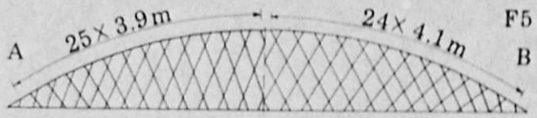


been used many times in Japan.

Better still it seems to utilize the fact that the arch and hangers of the network arch, supplemented by a temporary lower chord, will have enough strength and stiffness to support the lane while it is being cast. This temporary steel structure can be floated into place or lifted into place by big cranes.

In cold climates ice can be used for erecting or moving the temporary structure.

F5




## LATEST RESEARCH

Two bridges, F5, A and B, having the same cross-sections and spanning 200 m, have been designed according to Danish codes to study optimal arrangement of hangers.

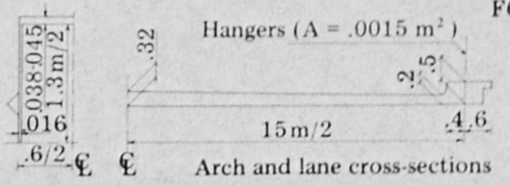
Nonlinear calculation showed that the tension in the lower chord caused a 15-20% reduction of max. bending in the edge beam.

The hanger arrangement A gave 8% smaller bending moment in the edge beam, 2% smaller max. stress in the arch, and 9% smaller max. hanger force.

For bridge A live load on half the span with many hangers relaxing, is about equally critical for the arch as max. load on the whole span.

Steel weights are 416t structural steel, 192t prestressing steel, 62t ribbed bars. Complete calculations will be published later.

F6




Arch and lane cross-sections

## NETWORK ARCHES

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### Network Arches Made Exclusively from Concrete

In Vienna several engineers, most of them from Austria, asked why I was using steel in the arch of network arches, when stresses due to axial forces were about 9 times as big as the bending stresses. I answered that I had been using steel because I was afraid of high costs of scaffolding. Since the arch of a network arch is relatively light there is not much money to be saved by replacing the steel by concrete. The arch bridge with inclined hangers is the forerunner of the network arch. In the twenties and thirties concrete arches were used for more than 70 of these bridges.

While listening to the session on »Trends in big bridge engineering» it struck me that network arches with arches made of concrete could be competitive for long bridges like the »Long Key Bridge» and the »Seven Mile Bridge». For each span it would be best to cast the lane slab and traffic barriers in one piece reinforced in two directions by means of pre-tensioned wires. See fig. 1. To cut scaffolding costs it would probably be best to cast elements of arches with pre-tensioned windbracing on the ground. Joints would have to be cast after the arch elements were put in place above the lane.

Preliminary calculations for a 100 m span carrying a 10 m wide lane give .42 $m^3$ concrete ($f'_{ck}$ = 50 $N/mm^2$) and 70 kg steel, mostly wire, per $m^2$ of lane. Such a span would weigh about 1000t, and after installing of hangers they can be lifted from the prestressing bed and rolled sideways to a quay. If sufficiently big floating cranes are not available for placing the spans on the piers, one pontoon at each end of the span could be used. If the lane of the bridge is to be less than 10m above sea level, it seems economical to slide the spans sideways from pontoons to piers, See fig. 2. During this sliding process, pontoon and pier must be fastened to each other, and the buoyancy of the pontoons must be adjusted to compensate for the shifting of the weight of the span. Finally the hydraulic jacks intended for possible changing of permanent bearings, would be used for removing the steel rail and installing the permanent bearings.

For a long bridge the above arrangement would have these advantages: Low weight and a high degree of prefabrication, which would give low labour and materials costs and good control of workmanship.

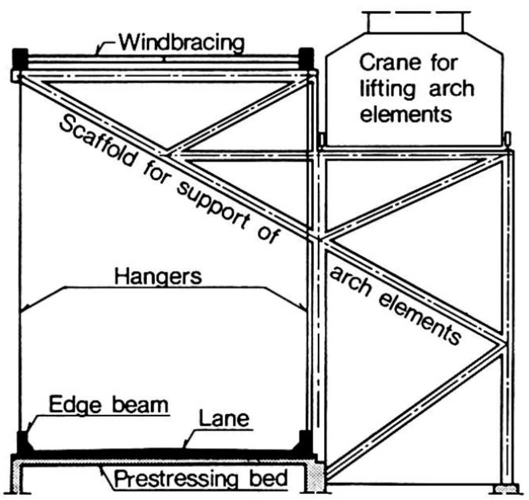


Fig. 1. Cross-sections of rig for casting of the lane, edge beam and joints in arches.

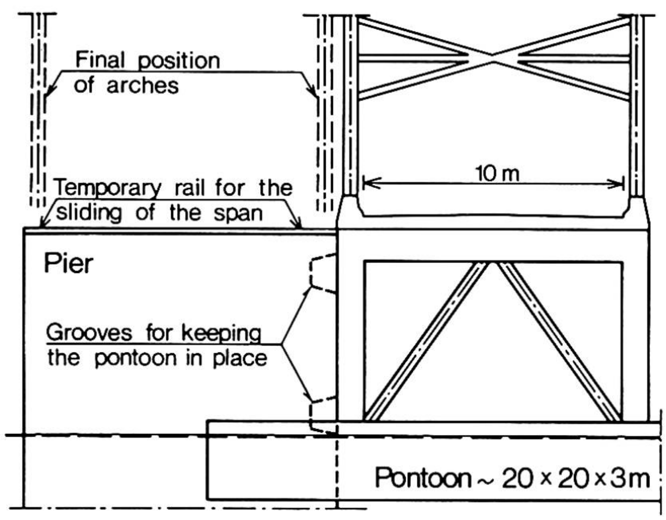


Fig. 2. Pontoon and pier with the span on the pontoon ready for transfer.